NASA/TP-2001-209979

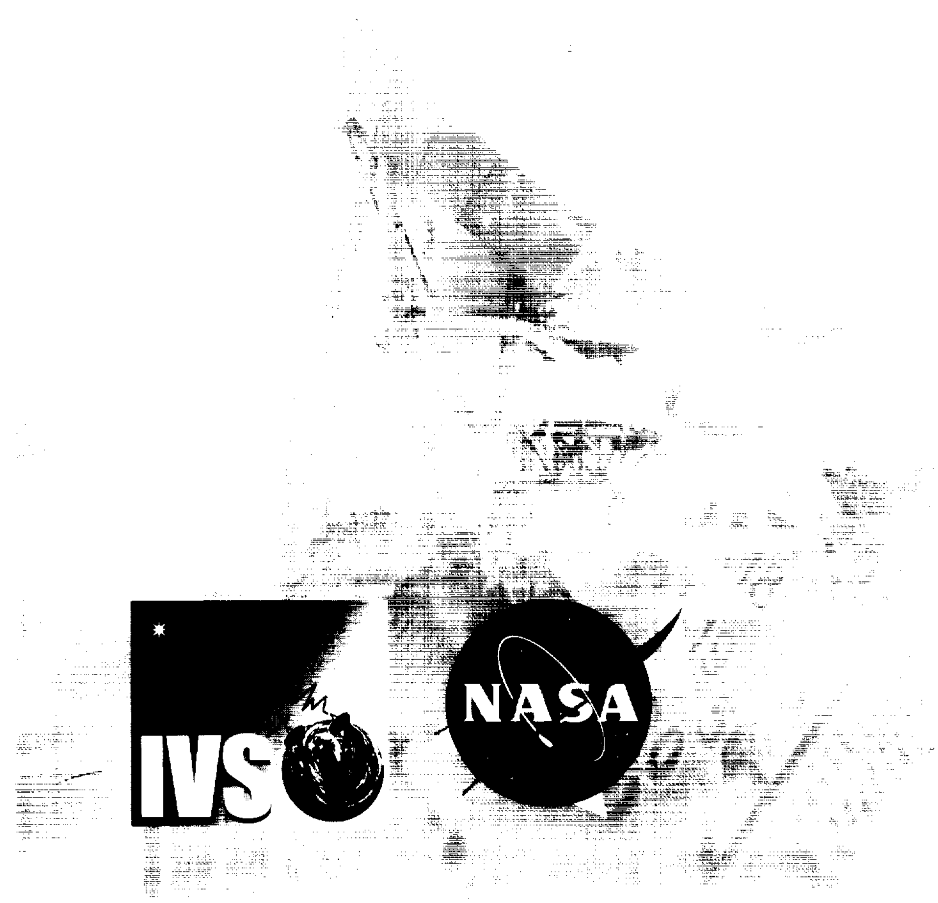
International VLBI Service for Geodesy and Astrometry

2000 ANNUAL REPORT

Edited by

N.R. Vandenberg
and K.D. Baver

IVS Coordinating Center
February 2001



On the cover: The cover layout includes a photograph of the 32-m VLBI antenna at Tsukuba, Japan, operated by the Geographical Survey Institute

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Preface

This volume of reports is the 2000 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 2000 Annual Report documents the work of the IVS components for the period March 1, 1999 (the official inauguration date of IVS) through December 31, 2000. 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/ar2000`

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 report of the IVS Chair.
- The second section of Special Reports contains a status report of the IVS Working Group on GPS phase center mapping, a reproduction of the resolution making IVS a Service of the International Astronomical Union (IAU), and a reprint of the VLBI Standard Interface (VSI).
- The next seven sections hold the component reports from the Coordinators, Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers.
- The last section includes reference information about IVS: the Terms of Reference, the lists of Member and Affiliated organizations, the IVS Associate Member list, a complete list of IVS components, the list of institutions contributing to this report, and a list of acronyms.

The 2000 Annual Report demonstrates the vitality of the IVS and the outstanding progress we have made during our first 22 months.

Table of Contents

ABOUT IVS

OBJECTIVES

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

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

The IVS

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

REALIZATION AND STATUS OF IVS

IVS consists of

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

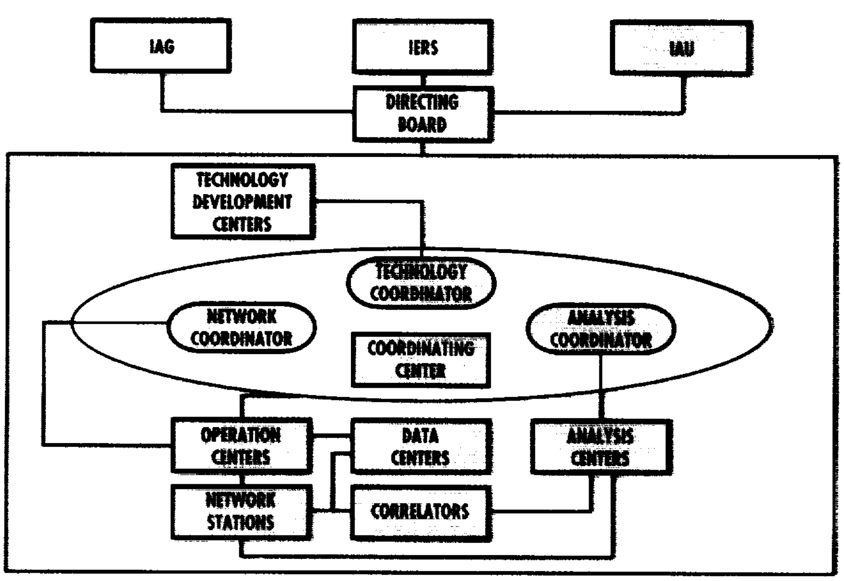
Altogether

- 74 Permanent Components, representing 31 institutions in 15 countries,
- 250 Associate Members.

In addition the IVS has:

- Directing Board, determining policies, standards and goals; the board is composed of 14 members (elected and ex officio), including
- Coordinators for the network, analysis and technology.

IVS STRUCTURE



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.

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
Chinese Academy of Sciences	China
Observatoire de Paris	France
Observatoire de Bordeaux	France
Deutsches Geodätisches Forschungsinstitut	Germany
Bundesamt für Kartographie und Geodäsie	Germany
Geodetic Institute of the University of Bonn	Germany
Istituto di Radioastronomia CNR	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
Communications Research Laboratory	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Institute of Applied Astronomy	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Institut d'Estudis Espacials de Catalunya	Spain
Instituto Geografico Nacional	Spain
Chalmers University of Technology	Sweden
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.

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

PRODUCTS

The VLBI technique contributes uniquely to

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

Further significant products are

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

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

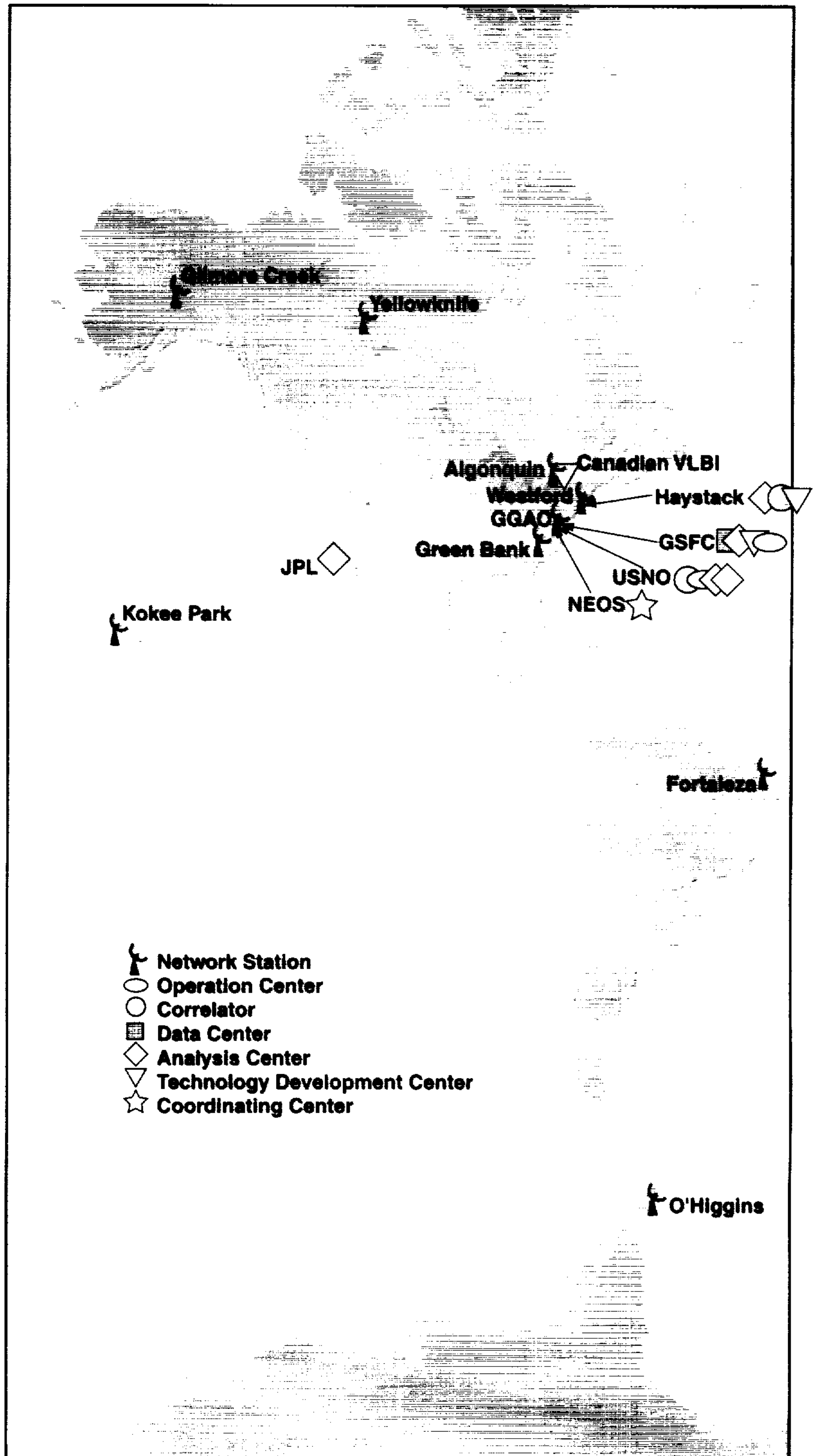
http://ivscc.gsfc.nasa.gov

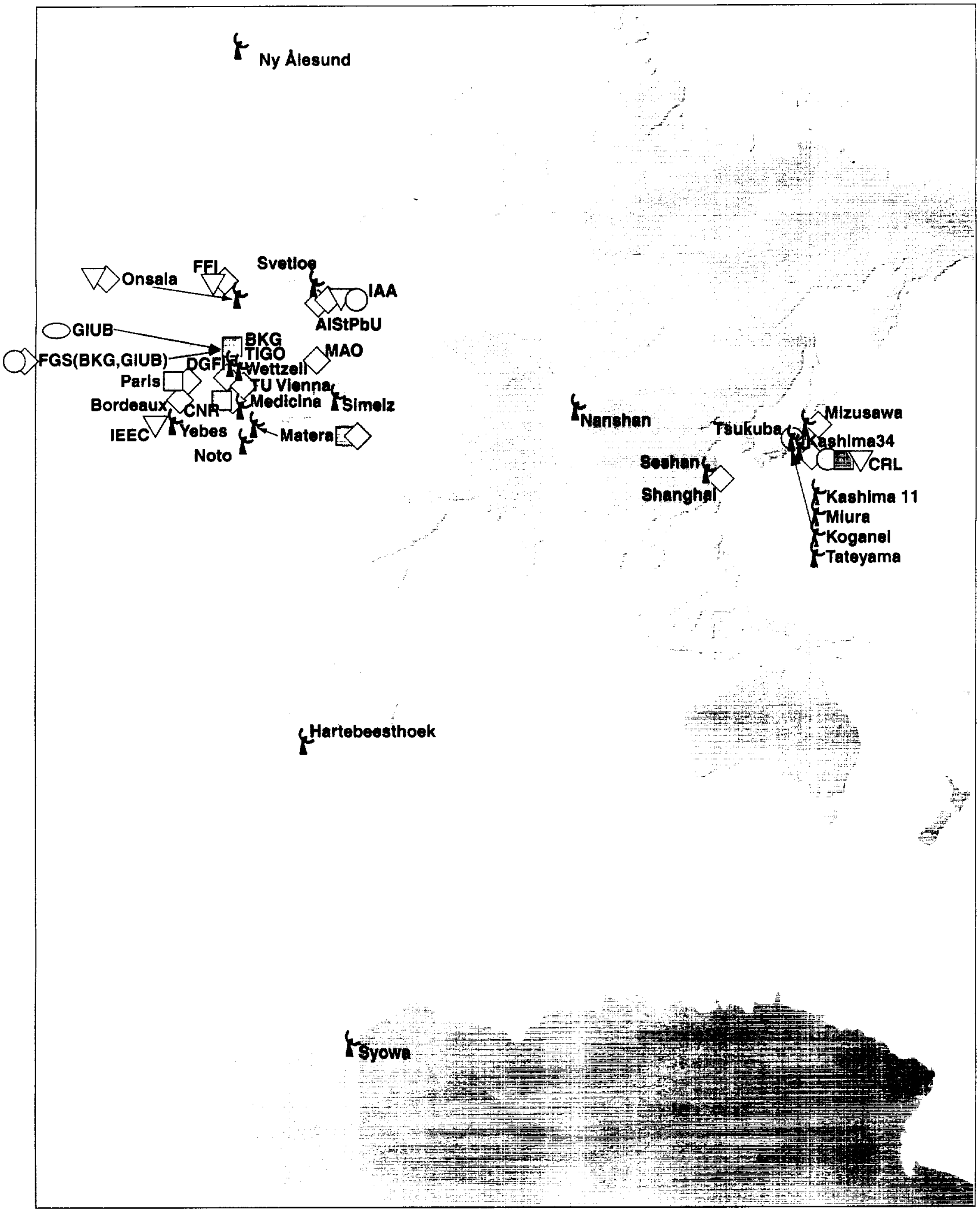
IVS COMPONENT MAP

IVS COMPONENTS BY COUNTRY

Austria	1
Brazil	1
Canada	3
China	3
France	3
Germany	8
Italy	7
Japan	14
Norway	3
Russia	5
South Africa	1
Spain	2
Sweden	3
Ukraine	2
USA	18
Total	74

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




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

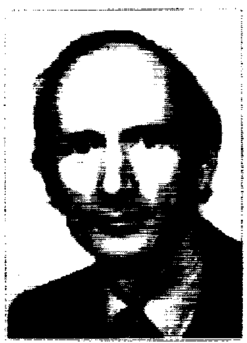
IVS DIRECTING BOARD

NAME: Wolfgang Schlüter

AFFILIATION: Bundesamt für Kartographie und Geodäsie, Germany

POSITION: Chair and Networks Representative

TERM: Feb 1999 to Feb 2003

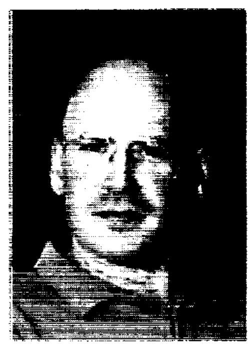


NAME: James Campbell

AFFILIATION: University of Bonn, Germany

POSITION: IAG Representative

TERM: ex officio



NAME: Ed Himwich

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

POSITION: Network Coordinator

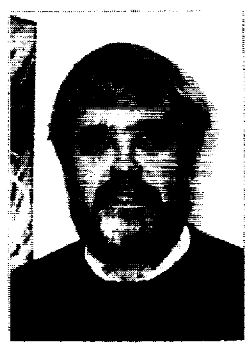
TERM: permanent

NAME: Wayne Cannon

AFFILIATION: Space Geodetic Laboratory, Canada

POSITION: At Large Member

TERM: Feb 1999 to Feb 2001

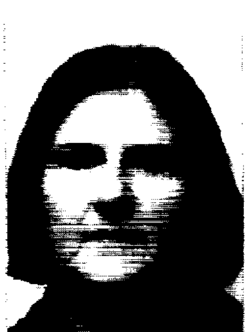


NAME: Kerry Kingham

AFFILIATION: U.S. Naval Observatory, USA

POSITION: Correlators and Operation Centers Representative

TERM: Sep 2000 to Feb 2003



NAME: Nicole Capitaine

AFFILIATION: Paris Observatory, France

POSITION: IAU Representative

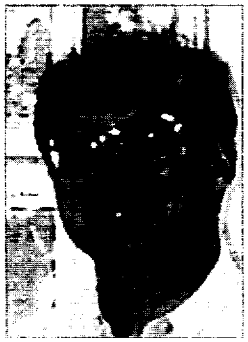
TERM: ex officio

NAME: Tetsuro Kondo

AFFILIATION: Communications Research Laboratory, Japan

POSITION: Technology Development Centers Representative

TERM: Feb 1999 to Feb 2001

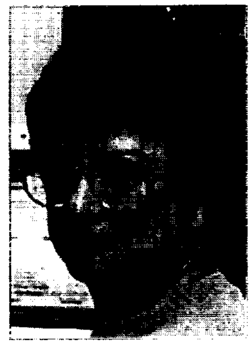


NAME: Chopo Ma

AFFILIATION: NASA Goddard Space Flight Center, USA

POSITION: IERS Representative and Analysis and Data Centers Representative

TERM: ex officio



NAME: Nancy Vandenberg

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

POSITION: Coordinating Center Director

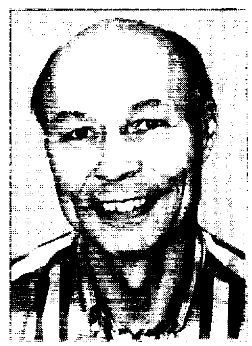
TERM: ex officio

NAME: Shigeru Matsuzaka

AFFILIATION: Geographical Survey Institute, Japan

POSITION: Networks Representative

TERM: Feb 1999 to Feb 2003



NAME: Alan Whitney

AFFILIATION: Haystack Observatory, USA

POSITION: Technology Coordinator

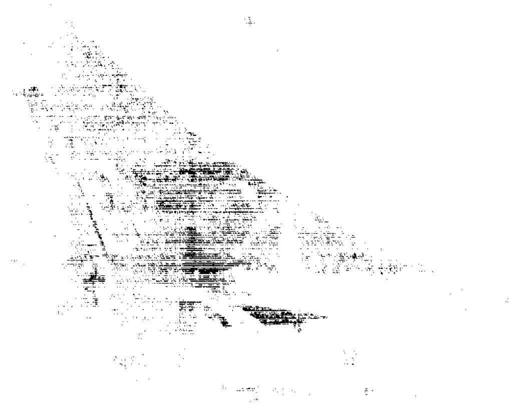
TERM: permanent

NAME: Axel Nothnagel

AFFILIATION: University of Bonn, Germany

POSITION: Analysis Coordinator

TERM: permanent



NAME: Paolo Tomasi

AFFILIATION: CNR Bologna, Italy

POSITION: At Large Member

TERM: Feb 1999 to Feb 2003

IVS CHAIR'S REPORT

Wolfgang Schlüter
Bundesamt für Kartographie und Geodäsie

INTRODUCTION

This is the second issue of the Annual Report of the International VLBI Service for Geodesy and Astrometry. It is a very good documentation of our activities. The Annual Report demonstrates the vitality of the IVS. With the 1999 Annual Report – released before the end of 1999 – emphasis was placed on documenting the status of the individual components. The 2000 Annual Report documents changes, activities and progress of the Service. I'm personally proud about the progress and the results and also about the reliability of the IVS Associate Members, that we can issue the Annual Report 2000 in such a timely manner. Let me express my thanks to all who have contributed.

EVENTS DURING 2000

The first IVS General Meeting was held February 21 to 24, 2000, with more than 120 participants, representing mostly all components of the IVS. The purpose of the IVS 2000 General Meeting was to share information and to plan future activities. One of the goals was to strengthen our cooperation and to build bridges between the various components for a better understanding. These goals were considered by the program committee. Tutorials were held in order to introduce the session topic to those who work in different areas. I thank the members of the program committee: Marshall Eubanks/USNO, Hayo Hase/BKG, Ed Himwich/NVI, Inc./GSFC, Yasuhiro Koyama/CRL, Chopo Ma/NASA GSFC, Arthur Niell/MIT Haystack, Axel Nothnagel/GIUB, Hans Peter Plag/SK, Rich Strand/GCGO, Nancy Vandenberg/NVI, Inc./GSFC, and Alan Whitney/MIT Haystack.

The Proceedings of the IVS 2000 General Meeting were released by the editors Nancy Vandenberg and Karen Baver in August. The papers are electronically available as well as in book form. The publication with the tutorials is a valuable contribution not only to VLBI experts and participants, but also to people who have an interest in learning about VLBI.

During the IVS 2000 General Meeting, a first meeting was held of the IVS Working Group on "GPS phase center mapping", which is a joint Working Group with the International GPS Service (IGS) and International Laser Ranging Service (ILRS). The objectives were "to study the feasibility of equipment, time required, and if it could be done with accuracy sufficient to make it worthwhile". The members of the WG are Brian Corey/MIT Haystack and Ed Himwich/NVI, Inc./GSFC for the IVS, Tom Herring/MIT Boston and Tim Springer/AIUB for the IGS, and Graham Appleby/UK and Richard Biancale/CNES for the ILRS. I thank the members for their contribution. The activity and the status of the work can be seen on the IVS home page http://ivscc.gsfc.nasa.gov. A status report is given in this Annual Report.

On the last day of the 2000 General Meeting, February 24, the first IVS Analysis Workshop was held. The Analysis Coordinator Axel Nothnagel, who became the Analysis Coordinator on October 1, 1999, organized and chaired the meeting. Standards, analysis models, and contributions of the various Analysis Centers were discussed. Five working groups were established in order to share the workload. Access to all the information is made available also via http://ivscc.gsfc.nasa.gov and the home page of the Analysis Coordinator, which is linked from the IVS home page.

In September 2000 the hardware VLBI Standard Interface (VSI-H) specification was released. The complete specification is reprinted in this Annual Report. The VSI-H specification was developed by an international committee of experts in VLBI instrumentation, led by Alan Whitney/MIT Haystack, the IVS Technology Coordinator, in a concerted effort to standardize interfaces to/from VLBI data recording and playback systems. Adherence to the VSI-H specification will allow data collected on heterogeneous VLBI data systems to be processed directly on VLBI correlators. A standardized software interface, VSI-S, is expected to follow within the next year. I would like to express my thanks to the committee especially Alan Whitney/MIT Haystack-USA as the chair, Wayne Cannon and Richard Worsfold/CRESTech-Canada, Ralph Spencer/Jodrell Bank Observatory-UK, Richard Ferris/CSIRO Telescope National Facility-Australia, John Romney, George Peck/NRAO-USA, Brent Carlson/Herzberg Institut of Astrophysics NRCC-Canada, Tetsuro Kondo, Junichi Nakajima, Yasuhiro Koyama, Mamorou Sekido and Hitoshi Kiuchi/CRL-Japan and Mickael Popov/Astro Space Center of Lebedev Physical Institute Moscow-Russia.

NEW IVS MEMBERS

During 2000 IVS received proposals from two institutions applying to become IVS components. In January 2000 the Directing Board accepted the proposal from the U.S.

Naval Observatory to contribute with the "USNO Analysis Center for Source Structure" and in December 2000 the Directing Board accepted the proposal from the Institut für Geodäsie und Geophysik of the Technical University Vienna to contribute with an Associate Analysis Center based on OCCAM with special emphasis on modeling the tropospheric refraction. I thank both agencies for their willingness to cooperate with the IVS. Their important contributions are appreciated very much.

The Directing Board changed the Terms of References in order to extend the IVS membership to affiliated organizations. The affiliated organizations do not necessarily support an IVS component but expressed their willingness to cooperate with IVS on issues of common interest. The Directing Board accepted proposals from the following: Geodynamics Group, Research School of Earth Science, Canberra/Australia; Westerbork Observatory, Dwingeloo/ Netherlands; FÖMI Satellite Geodetic Observatory, Budapest/Hungary; Department of Geodesy and Geomatics Engineering of the University New Brunswick/ Canada; National Radio Astronomy Observatory (NRAO), Socorro/USA; Max Planck Institute für Radioastronomie, Bonn/Germany.

The Joint Institute for VLBI in Europe, Dwingeloo/Netherlands changed their membership category to that of an Affiliated Member. I thank the Affiliated Member organisations for their interest and for their willingness to cooperate with IVS.

DIRECTING BOARD

The IVS Directing Board held its 3rd and 4th meetings in 2000. The 3rd Meeting was held in Wettzell on February 20, 2000, the day before the IVS 2000 General Meeting. The 4th meeting was held in Paris/France on September 17, 2000. Detailed information about the meetings was mailed to the Associate Members through the ivsmail, and it is also available at http://ivscc.gsfc.nasa.gov.

We have had some personnel changes in 2000. Marshall Eubanks has withdrawn from the IVS Directing Board due to personal reasons. His successor as the representative for the Correlators and Operation Centers is Kerry Kingham, USNO. On behalf of the IVS I would like to thank Marshall for all he has done for the IVS and for the entire VLBI community especially in the field of data analysis and investigations in Earth orientation. We wish him success for his new business.

The terms of the representatives of the Analysis Centers and of the Technology Development Centers were two years, ending with the board meeting in February 2001. The election, conducted by the election committee, which included Shigeru Matsuzaka/Japan as chair, Paolo Tomasi/Italy and Nancy Vandenberg/USA, resulted in the election of Harald Schuh, TU-Vienna/Austria as the representative for the Analysis Centers and of Arthur Niell from Haystack Observatory/USA as the representative of the Technology Development Centers. Also one of the At Large positions ends after two years. The Directing Board elected Yasuhiro Koyama from CRL/ Japan. Congratulations to all new elected board members. I take the opportunity to thank Tetsuro Kondo and Wayne Cannon for their contributions and their fruitful discussions during the first two years term. I'm sure both will continue to support the IVS.

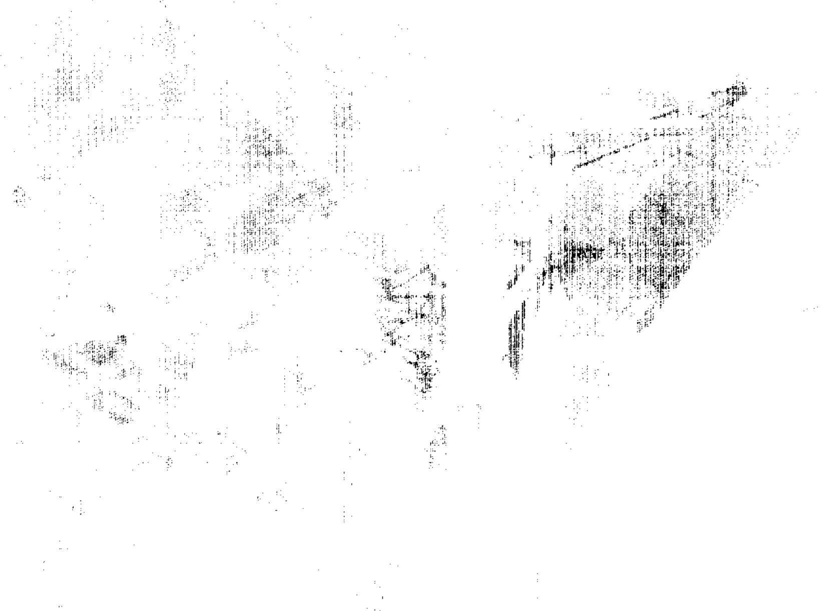
IVS IS A SERVICE OF THE IAU

IVS has been recognized as a Service of the International Association of Geodesy (IAG) since July 1999 when the General Assembly was held in Birmingham/ England. Since the XXIVth General Assembly of the International Astronomical Union IAU held in Manchester/England, August 2000 the IVS is also recognized as a Service of the IAU. The fact of being an IAU Service will open up more cooperation with radio astronomy groups. You can find the IAU resolution reprinted in this Annual Report.

ACKNOWLEDGEMENTS

The year 2000 has been a busy year for all of us. The activities summarized above indicate the vitality of our service. There is still a lot to do within the next years. We have to establish our products in order to realize what is expected from us as a service, we have to improve our observing programs and the analysis steps to provide and guarantee timeliness and highly reliable products. The discussion on these issues has started.

I would like to express my gratitude to the IVS Coordinators Ed Himwich, Axel Nothnagel and Alan Whitney, who have to carry a heavy workload and responsibility. I thank Nancy Vandenberg for all the work she has done for the IVS as Coordinating Center Director such as organizing meetings, publishing proceedings, caring for the IVS homepage and much much more. I'm aware that every Associate Member supports IVS, so I will express my appreciation to all of you. Let's continue our good work.



SPECIAL REPORTS

IVS/IGS/ILRS Working Group on GPS Phase Center Mapping

Brian Corey

Abstract

A joint working group composed of representatives from the IVS, IGS, and ILRS is investigating the feasibility of using VLBI observations of GPS satellites to measure the phase center locations of the satellite transmitter antennas. This report describes the motivation behind the investigation, the organization of the working group, and some key points from the initial discussions.

1. Motivation for establishing working group

Accurate knowledge of the location of the phase center of each GPS satellite transmitter antenna is essential in high-accuracy GPS geodesy. Estimates of the scale of the terrestrial reference frame (TRF) and of station zenith tropospheric delays are particularly sensitive to the phase center z-component, along the direction from the satellite toward the geocenter. A change of 1 meter in the assumed z-component for all satellites causes a change in the terrestrial scale of $\sim$8 ppb (50 mm in station height) and a change in zenith delay of $\sim$5 mm.

Several related pieces of evidence point to significant errors in the phase center locations assumed in most GPS geodetic analyses. The instantaneous location of each satellite is normally set equal to the vector sum of (1) the instantaneous position of the satellite center of mass, which is believed to be known to < 10 cm in all three dimensions from GPS orbital solutions and from SLR rangings on selected satellites, and (2) the nominal offset between the phase center and the center of mass. When global GPS data sets are analyzed with these phase center locations and with absolute phase patterns for the GPS receiving antennas, the scale of the GPS TRF is found to differ from the scale of the VLBI and SLR TRF's by $\sim$15 ppb, or 10 cm in station height [1, 2]. An adjustment of the z-component of the phase center offsets by 2 m brings the scale of the GPS TRF into agreement with VLBI and SLR. Furthermore, if the phase center z-component offsets are estimated from the GPS data, differences from the nominal offsets of 1–2 m are found [1, 2].

The immediate impetus for the formation of the IVS/IGS/ILRS joint working group (WG) on GPS phase center mapping was a series of discussions at the IGS Analysis Center Workshop at the Scripps Institution of Oceanography in 1999 regarding the uncertainty in the location of the phase centers of the GPS satellite transmitters. It was suggested at the workshop that VLBI observations of the satellites could provide independent information on the phase center locations, including perhaps the relative locations for the 12 individual radiating elements in the phased array transmitters. An informal request was made to the IVS to lead an investigation of the feasibility of such observations.

2. Establishment and organization of working group

At the second IVS Directing Board meeting in July 1999, the board decided to establish a working group on this matter and to invite the IVS, IGS, and ILRS chairs to nominate representatives to serve on it. The charge to the working group was to study the feasibility of the proposed VLBI observations, the equipment and time required, and the expected accuracy of the phase center location estimates.

Following the nomination of members from the three services, the WG was officially established under the rules of the IVS at the third IVS Directing Board meeting on 20 Feburary 2000. The members of the WG are:

Graham Appleby	ILRS-nominated representative
Richard Biancale	ILRS-nominated representative
Brian Corey	IVS-nominated representative and WG chair
Tom Herring	IGS-nominated representative
Ed Himwich	IVS-nominated representative
Axel Nothnagel	IVS analysis coordinator, *ex officio*
Wolfgang Schlüter	IVS chair, *ex officio*
Tim Springer	IGS-nominated representative
Nancy Vandenberg	IVS coordinating center director, *ex officio*

The initial meeting of the WG was held on 23 February 2000 in Kötzting, Germany, during the first IVS General Meeting. The purpose of the meeting was primarily organizational, but some technical issues regarding the phase center estimates from GPS observations and the proposed VLBI measurements were also discussed.

3. Initial working group activities

A WG web site was set up in March 2000 at

`http://ivscc.gsfc.nasa.gov/WG/wg1`

Background information on the phase center problem, general information on the WG, and a WG email archive are available on the web site.

Following official notification of the IGS and ILRS chairs by the IVS chair that the WG had been established, a general email announcement was distributed to the IGS, ILRS, and IVS communities to inform them of the existence and purpose of the WG. The announcement included an invitation for interested individuals with expertise in relevant fields to participate in the WG studies. In response to this invitation, the following IVS members have joined in the WG discussions: Wayne Cannon, Hayo Hase, Maria Rioja, David Shaffer, and Vincenza Tornatore.

4. Summary of technical discussions in 2000

There are two related goals to the proposed VLBI observations:

A. Measure the mean phase center location of the full, 12-element phased array on each satellite.

B. Measure the relative signal phase and drive level of the 12 individual radiating elements in each array.

The results of A could be compared directly against the GPS estimates, while the results of B might provide clues to help understand the GPS and VLBI mean phase center results. The key questions to be answered regarding both types of measurements are what the potential accuracy is and what the technical roadblocks are to observing the satellites with a VLBI network, correlating the VLBI data, and analyzing the results. The investigations to date have concentrated on assessing the limitations on accuracy.

4.1. Measuring the mean phase center location

VLBI phase center measurements will likely employ an observing strategy similar to narrow-field VLBI astrometry, in which the VLBI antennas alternately observe a target source (in this case, a GPS satellite) and one or more extragalactic reference sources of accurately known position that lie near the line of sight to the target. The small angular separation between target and reference is intended to minimize errors from propagation media effects and from uncertainties in various global parameters such as station locations. The nature of the GPS orbits sets two different types of limits on how small the target-reference separation can be made:

- With an orbital period of 12 hours, a satellite moves 1° every 2 minutes. A reference source that lies right on the path of a satellite will remain within 5° of the satellite for only 20 minutes, or a few antenna nodding cycles between satellite and reference.
- For a 5000-km baseline transverse to the satellite nadir direction, the parallax on the satellite between the two ends of the baseline is 14°. If a reference source is coincident in direction with a satellite at one station, it will be 14° from the satellite at the other station.

In order to measure the phase center z-component to 20 cm accuracy (5σ over 1 m), say, the differential range from satellite to ground between nadir and Earth limb (which is 14° away from nadir) must be measured to an accuracy of (20 cm) $\times$ ($\cos 0^\circ - \cos 14^\circ$) = 6 mm, or 11° phase at the GPS L1 frequency of 1575 MHz. All error sources that affect the VLBI phase or delay must be accounted for, to this level of accuracy. These error sources, which are currently under investigation, include:

- Reference source positions — The L-band positions of the reference sources in the global celestial reference frame must be known to ~0.2 mas to achieve the accuracy goal. Global S/X-band astrometry on compact sources can achieve such small uncertainties, but reaching this level at L-band may be difficult.
- Ionosphere — The typical differential L-band ionospheric delay between two directions 5° apart is 1–2 orders of magnitude larger than the error budget, so the ionospheric delay between satellite and reference sources must be either measured or modeled. Ionospheric total electron content models derived from global GPS data appear to be too inaccurate [3]. The best approach may be to use the VLBI observations on the satellite and reference sources to estimate the differential ionospheric delay directly from the fringe phase difference between the GPS frequencies L1 and L2, in a manner similar to a technique developed for L-band pulsar astrometry [4].
- Troposphere — The tropospheric delay can be estimated from GPS measurements with colocated geodetic GPS receivers. Systematic errors in the estimates of the differential tropospheric delay across 5° should be ~3 mm.
- Instrumentation — When pointing at a GPS satellite, the antenna temperature for a 20-m antenna is of order 20,000 K over 20 MHz. Such high levels may cause problems with saturation and distortion in the electronics, particularly in the VLBI baseband converters.

4.2. Mapping the satellite phased array

The second goal of the VLBI observations, which is equivalent to measuring the aperture field distribution of the phased array, will almost certainly be more difficult to achieve than the first.

The applicable technique is microwave holography, in which the far-field amplitude and phase pattern of the test antenna (the GPS transmitter, in this case) is measured over a grid of points spaced wavelength/(aperture size) radians apart; the Fourier transform of the pattern gives the aperture distribution. For the GPS phased array, the grid spacing is 13°, so Earth-bound observers can measure the far-field pattern at only a few grid points, and the resolution on the aperture field map will be very poor – only slightly better (*i.e.*, smaller) than the overall size of the array itself. Super-resolution techniques can sometimes be employed to improve the resolution, but they typically require very accurate phase and/or amplitude measurements, which the error sources noted above may well preclude.

References

[1] Rothacher, M., "Comparison of absolute and relative antenna phase center variations," GPS Solutions, **4**(4), 2001 (in press).

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[3] Walker, C., and Chatterjee, S., "Ionospheric corrections using GPS based models," VLBA Scientific Memo 23, 1999.

[4] Brisken, W.F., *et al.*, "Measurement of the parallax of PSR B0950+08 using the VLBA," Astrophys. J., **541**, pp. 959-962, 2000.

IVS is a Service of the IAU

IVS was recognized as a Service of the International Association of Geodesy (IAG) effective July 1999 when the General Assembly was held in Birmingham/England. Since the XXIVth General Assembly of the International Astronomical Union IAU held in Manchester/England, August 2000 the IVS is also recognized as a Service of the IAU. Here is the IAU resolution:

IAU Resolutions B1.1 Maintenance and Establishment of Reference Frames and Systems

The International Astronomical Union

Noting

1. that Resolution B2 of the XXIIIrd General Assembly (1997) specifies that "the fundamental reference frame shall be the International Celestial Reference Frame (ICRF) constructed by the IAU Working Group on Reference Frames",
2. that Resolution B2 of the XXIIIrd General Assembly (1997) specifies "That the Hipparcos Catalogue shall be the primary realisation of the International Celestial Reference System (ICRS) at optical wavelengths", and
3. the need for accurate definition of reference systems brought about by unprecedented precision, and

Recognising

1. the importance of continuing operational observations made with Very Long Baseline Interferometry (VLBI) to maintain the ICRF,
2. the importance of VLBI observations to the operational determination of the parameters needed to specify the time- variable transformation between the International Celestial and Terrestrial Reference Frames,
3. the progressive shift between the Hipparcos frame and the ICRF, and
4. the need to maintain the optical realisation as close as is possible to the ICRF

Recommends

1. that IAU Division I maintain the Working Group on Celestial Reference Systems formed from Division I members to consult with the International Earth Rotation Service (IERS) regarding the maintenance of the ICRS,
2. that the IAU recognise the International VLBI Service (IVS) for Geodesy and Astrometry as an IAU Service Organization,
3. that an official representative of the IVS be invited to participate in the IAU Working Group on Celestial Reference Systems,
4. that the IAU continue to provide an official representative to the IVS Directing Board,
5. that the astrometric and geodetic VLBI observing programs consider the requirements for maintenance of the ICRF and linking to the Hipparcos optical frame in the selection of sources to be observed (with emphasis on the Southern Hemisphere), design of observing networks, and the distribution of data, and
6. that the scientific community continue with high priority ground- and spacebased observations (a) for the maintenance of the optical Hipparcos frames and frames at other wavelengths and (b) for links of the frames to the ICRF.

VLBI Standard Interface Specification

Alan Whitney

International agreement and finalization of a VLBI Standard Interface (VSI-H) specification has now been accomplished. The final specification was released in August 2000 after 18 months of hard work by the dozen members of the VSI Technology Coordination Group.

This specification promises to help ease the long-standing incompatibility between various VLBI data systems. The VSI-H specification is designed to allow heterogeneous VLBI digital-data systems to be interchangeably connected to both data acquisition and data processing (correlator) systems in a "plug-compatile" fashion, something that is not currently possible. Furthermore, looking to the future, the VSI-H specification is designed to be compatible not only with traditional recording/playback systems, such as magnetic tape, but also with magnetic or optical discs, optical fibers, network data-transmission, or whatever future data transmission technology may be available.

The fledgling VSI concept leading to the current specification was first proposed at the time of the GEMSTONE meeting in Tokyo in January 1999 and was discussed by a small interested group at that meeting. With the support of IVS, as well as the astronomy-VLBI community, a VSI Technology Coordination Group was appointed, composed of experts representing all of the major world institutions involved in the development of VLBI equipment. The members of the VSI-TCG are Wayne Cannon (York University/Crestech, Canada), Brent Carlson (DRAO, Canada), Dick Ferris (ATNF, Australia), Dave Graham (MPI, Germany), Tetsuro Kondo (CRL, Japan), Nori Kawaguchi (NAO, Japan), Misha Popov (ASC, Russia), Sergei Pogrebenko (JIVE, Netherlands), Jon Romney (NRAO, U.S.), Ralph Spencer (Jodrell, England), Alan Whitney (Haystack, U.S., Chairman) and Rick Wietfeldt (JPL, U.S.). The VSI- H specification was shaped by intensive e-mail discussions, plus three (multi-hour!) international telephone conferences and a two-day international VSI meeting held at Haystack Observatory in February 2000.

The current VSI-H specification is intended as a starting point from which to progress, and will be extended and amended as needed. It is heartening that already at least three groups are known to be developing or adapting VLBI data systems to meet the VSI-H standard. The full VSI-H specification is reprinted in this article, and is available on-line at http://dopey.haystack.edu/vsi/index.html.

The next job of the VSI TCG is the definition of a companion VSI software standard, to be called VSI-S, which we hope to have in place by the end of 2001.

VLBI Standard Hardware Interface Specification – VSI-H

Revision 1.0
7 August 2000

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0. Prologue

The incompatibility of various VLBI data systems has long been recognized as posing a serious obstacle to the realization of the full potential of VLBI observations. Sporadic efforts have developed over the years to define a common interface standard which would allow observations recorded on different VLBI data systems to be processed at a common correlator, but these efforts have foundered for various reasons.

The establishment of the Global VLBI Working Group (GVWG) in the early 1990's, growing primarily from the space-VLBI community but serving the broader interests of astronomy, and the International VLBI Service (IVS) in 1998, serving primarily the geodetic VLBI community, provided an organizational framework for which efforts at standardization could proceed in a more organized and sanctioned fashion. It was from these roots that the present effort was initiated.

The fledgling VSI concept leading to the current specification was first proposed at the time of the GEMSTONE meeting in Tokyo in January 1999 and was discussed by a small interested group at that meeting. Support was then sought and received from IVS and GVWG to create a VSI Technology Coordination Group (VSI-TCG) comprised of experts representing all of the major world institutions involved in the development of VLBI equipment. The members of this committee are Wayne Cannon (York University/Crestech, Canada), Brent Carlson (DRAO, Canada), Dick Ferris (ATNF, Australia), Dave Graham (MPI, Germany), Tetsuro Kondo (CRL, Japan), Nori Kawaguchi (NAO, Japan), Misha Popov (ASC, Russia), Sergei Pogrebenko (JIVE, Netherlands), Jon Romney (NRAO, U.S.), Ralph Spencer (Jodrell, England), Alan Whitney (Haystack, U.S., Chairman) and Rick Wietfeldt (JPL, U.S.).

Early in the discussions it was decided to separate the hardware and software VSI, concentrating first on hardware, hence this VSI-H specification, to be followed by a companion software specification, VSI-S. The VSI-H specification was shaped by intensive e-mail discussions, plus three (multi-hour!) international telephone conferences and a two-day international VSI meeting held at Haystack Observatory in February 2000.

The current VSI-H specification is intended as a starting point from which to progress, and will be extended and amended as requirements and technology demand. It is heartening that already at this writing at least three groups are known to be developing or adapting VLBI data systems to meet the VSI-H standard.

The VSI-H specification represents the work of many individuals at many institutions, even well beyond those named in the formal VSI-TCG. The chairman would like to particularly acknowledge the important contributions of Dick Ferris, Jon Romney, Rick Wietfeldt, the entire Japanese group, and the Crestech group in this effort.

Alan Whitney
MIT Haystack Observatory
25 July 2000

1. Introduction

This document defines a VLBI Hardware Standard Interface (VSI-H) to and from a VLBI 'Data Transmission System' (DTS) that allows heterogeneous DTS's to be interfaced to both data-acquisition system (DAS) and data-processing system (DPS) with a minimum of effort. The interface is defined to be compatible with traditional recording/playback systems, network data transmission and even direct-connect systems. It is designed to completely hide the detailed characteristics of the DTS and allow the data to be transferred from DAS to DPS in a transparent manner.

The VSI-H specification defines the notion of a 'channel quantum', which is the maximum data rate that can be carried on a single standard VSI-H data connector. The basic VSI-H specification specifies a 'channel quantum' of 1.024 Gbps on a single 80-pin connector, with extensions to 2.048 and 4.096 Gbps. Higher data rates may be realized simply by parallel use of two or more 'channel quanta'.

A VLBI Standard *Software* Standard Interface (VSI-S) to accompany VSI-H is proposed but does not yet exist.

2. Intent of the VSI-H Specification

The intent of the VSI-H specification is to define a standard electrical and timing interface, along with a control *philosophy*. In this sense, VSI-H is not intended to be completely 'plug and play', and will require at least some software customization in each case; the future adoption of a VSI-S specification will hopefully minimize the software customization as well. Nevertheless, the adoption of a standardized interface at the hardware level should help to relieve many of the existing incompatibilities that now exist between various VLBI data systems.

The VSI-H specification is primarily aimed at normal data-taking and data-correlation tasks commonplace to VLBI. However, note will also be made of other related activities such as translation of tape media (i.e. tape copying) and parallel operation of multiple DTS's.

3. Structure of the VSI-H Specification

The VSI-H specification is structured as a *base* specification plus a set of *optional extensions*. Adherence to the optional extensions is desirable but not mandatory.

4. Levels of Compliance

Full compliance with the VSI-H specification is expected for all *future* systems designed by parties agreeing to the VSI-H specification. Existing systems are expected to be modified to comply on a *best-effort* basis only. For the purpose of indicating the degree of compliance to the VSI-H standard, two levels of compliance are established:

Level A – Fully compliant with the base VSI-H specification

Level B – Compliant with the VSI-H base specification *except* for one or more of the following:

1. Support for fewer than 32 bit streams (Section 7)
2. Incomplete signal-switching or active-signal-selection capability (Section 9)
3. Incomplete support of full range of f_{CLOCK} (Section 10)
4. Incomplete delay-offset support (Section 8.4)

5. Lack of support for PDATA/QDATA and/or PVALID/QVALID signals (Sections 10 and 11)
6. Incomplete test-vector capability (Section 13)
7. Data-replacement format (Section 14)

Non-support of the optional extensions to 64 and 128 MHz does not affect VSI-H compliance.

5. Assumptions on which VSI-H Specification is Based

The VSI-H specification is based on the following set of assumptions:

- The DTS is fundamentally a receiver and transmitter of parallel *bit streams* between a Data-Acquisition System and a Data Processing System.
- The *meaning* of individual bit streams is not specified; normally, a bit-stream is a stream of sign or magnitude bits associated with particular samples, but the actual meaning is to be mutually agreed upon between the DAS and DPS.
- The received and transmitted bit-stream clock rates may be different (e.g. the playback rate into the DPS may be speeded-up or slowed-down), however all received bit-stream information rates on acquisition are the same, and all bit-stream clock rates on transmit are the same.
- A single time-tag applies to all parallel bit streams. The DAS time-tag of every bit in every bit-stream must be fully recoverable at the output of the DTS.

Note that, under these assumptions, no restrictions or specifications are placed on the type or format of the medium used to transport the data through the DTS; magnetic tape, disk, optical fiber, Internet or any other type of transmission medium is allowed.

6. Data Transmission System (DTS) Structure

For the purposes of the VSI-H specification, the DTS is divided into two logical modules, as indicated in Figure 1:

1. The 'Data Input Module' (DIM) is responsible for accepting multiple parallel bit streams, accompanied by a common clock and common 1-second tick, applying a common time-tag ('observe time'), and sending them to a *transmission medium* (tape, disc, fiber-optic, etc.).
2. The 'Data Output Module' (DOM) accepts data from the *transmission medium*, decodes the accompanying 'observe-time' information, and recreates the data-streams in accordance with an external clock and '1-second' tick.

The entire DTS (DIM plus DOM) may reside either in a single physical module or in separate physical DIM and DOM modules.

7. Data Input Module (DIM)

A simplified model of one 'channel quantum' of the Data Input Module is shown in Figure 1.

7.1 *DIM Interface*

7.1.1 Input signals from the DAS to the DIM–

1. BS_0 through BS_{31} – 32 parallel bit-streams, all sampled by the DIM at the same rate, which may be selected to be 2, 4, 8, 16 or 32 MHz,

corresponding to the 'bit-stream information rate' (f_{BSI}). The maximum aggregate DIM input data rate is 1.024 Gbps for one 'channel quantum'.

Any 1, 2, 4, 8, 16 or all 32 input channels may be selected and marked as 'active'. Only 'active' bit-streams are sampled and made available at the DOM output.

Optional extension of f_{CLOCK} to 64 and 128 MHz provides maximum aggregate rates of 2.048 and 4.096 Gbps, respectively.

2. CLOCK – a clock accompanying the bit-streams, also providing a reference frequency for the DIM, at 2, 4, 8, 16 or 32 MHz with optional extension to 64 or 128MHz. Note $f_{CLOCK} \geq f_{BSI}$.
3. 1PPS – a 1pps tick which defines the corresponding parallel data bits which are to be time-tagged on the integer second. The 1PPS signal is timed to coincide with the data bit taken on the second tick (the 'TOST' bit).
4. PVALID – signal that specifies the 'validity' of the BS_n bit streams. The content and use of the PVALID signal is not defined by the VSI-H specification.
5. A standard 8-bit ASCII asynchronous serial data stream, PDATA, which may send a burst of up to 2048 bytes of information between each 1PPS tick. The content and use of this information is not specified by the VSI-H specification.

7.1.2 DIM Control Interface

The DIM control interface is a 2-way communications interface, implemented in both RS-232 and Ethernet, and normally connected to a computer. The control interface both controls and monitors the operation of the DIM. The DIM controller must be aware of 1PPS ticks to the extent that certain critical messages can be reliably sent to the DIM between specific 1PPS pulses, and that certain messages can be reliably transmitted from the DIM between specific adjacent 1PPS pulses.

If the DIM and DOM reside in the same physical unit, they may share a single set of control interfaces.

7.1.3 Other Signals

1. ALT1PPS – an external (possibly asynchronous) signal which may be selected as a substitute for 1PPS, as indicated in Figure 1. An example of ALT1PPS might be the 1pps tick from a station atomic clock.
2. DOTMON – a monitor signal from the DIM which allows confirmation of the epoch of the DOT-clock second tick (see Section 7.2).

7.2 *The Data-Observe-Time (DOT) Clock*

As shown in Figure 1, the DIM maintains an internal Data-Observe-Time (DOT) clock which has the following properties:

1. The DOT clock is the master clock within the DIM, and is used to unambiguously mark each incoming data bit with its current reading to the full resolution of CLOCK.
2. The DOT clock may be set to a specified second of time (presumably UTC) on a given 1PPS or ALT1PPS tick.

3. Once set, the DOT clock keeps time solely by counting CLOCK cycles (i.e. subsequent 1PPS/ALT1PPS ticks are ignored by the DOT clock unless the DOT clock is expressly commanded to be reset).

7.3 *Example of DIM Operation*

The following is an example of a typical sequence of operations of a DIM in a normal observing situation:

1. Through the Control Interface, the DIM is configured to accept any particular subset of 1, 2, 4, 8, 16 or 32 of the incoming bit-streams, all at a specified bit-rate. Only these specified bit streams will be sampled by the DIM and relayed to the DOM.
2. Through the Control Interface, the DOT clock is commanded to be set to a specified integer second of time on the *next* 1PPS (or ALT1PPS) tick [see Note 6 below]. Once set, the DOT clock keeps time by counting cycles of CLOCK, ignoring subsequent 1PPS/ALT1PPS signals. The DOTMON monitor signal allows confirmation of the DOT epoch setting.
3. Through the Control Interface, the DIM is commanded to begin transmitting the selected input bit streams to the *transmission medium.* Each bit in each data stream must be transmitted with its accompanying time tag, either explicitly or implicitly.
4. At the end of the observing period, the DIM is commanded (through the Control Interface) to cease transmitting data.

Notes:

1. The method the DIM uses to record/transmit data or to time-tag data is irrelevant to the VSI-H specification.
2. Each type of DIM may have various control and configuration requirements which are outside the VSI-H specification.
3. It is the responsibility of the DAS to implement any multiplexing or de-multiplexing that may be necessary to transform sampled data into bit streams presented to the DIM. It is explicitly noted, however, that the DTS designer is free to implement any DTS-internal multiplexing scheme so long as the DOM output bit-streams are faithful reproductions of the DIM input bit-streams.
4. Some DIM systems may have the ability to transmit additional low-data-rate information, such as bit-stream identification and high-level global validity (i.e. 'antenna on-source'), in addition to the bit-streams themselves. Such information may be transmitted to the DIM via the Control Interface or, in some cases, via the PDATA and/or PVALID data streams. The VSI-H specification neither requires nor prohibits any such capability.
5. With the exception of ALT1PPS, DOTMON and the Control Interface, all DIM interface signals are contained in a single 80-pin connector (see Section 12).
6. The Control Interface must be designed so that the controlling computer can, on request, be notified in a timely way of the occurrence of a 1PPS/ALT1PPS tick so that the control computer can unambiguously command the DIM to set the DOT clock to a specified integer second of time on the *next* 1PPS/ALT1PPS tick. The subsequent relationship between 1PPS/ALT1PPS and DOTMON can then be monitored either internally within the DIM [preferred] or externally to verify the 1PPS/ALT1PPS vs DOTMON relationship. In addition, the control computer should be able to verify the

DOT epoch by requesting that the DIM report the DOT setting at the occurrence of the *next* DOTMON tick.

8. Data Output Module (DOM)

A simplified model of the Data Output Module is shown in Figure 1.

8.1 *DOM Interface*

8.1.1 Input timing signals from the DPS –

1. A clock, DPSCLOCK, from the DPS which acts as a reference frequency for the DOM.
2. A '1-pps tick', DPS1PPS, which is used to set an internal DOM clock called the 'Requested Observe Time' (ROT) clock to an integer-second epoch in a manner similar to the way 1PPS sets the DOT clock in the DIM.

8.1.2 Output signals from the DOM to the DPS –

1. Reconstructed bit-streams, RBS_0 through RBS_{31} - accurate reproductions of the active sampled bit-streams transferred from the DIM except in so far as (i) they may be collectively speeded up or slowed down with respect to f_{BSI} at the input to the DIM, and (ii) switching within the DOM allows an arbitrary mapping of bit-streams to output signals $RBS_0..RBS_{31}$. The reconstructed bit streams are at a common rate called the 'reconstructed bit-stream information rate' (f_{RBSI}).
2. RCLOCK – clock accompanying the reconstructed bit streams.
3. R1PPS – reconstructed 1PPS accompanying the bit streams, subject to the same speed-up or slow-down as RBS_n, but may be delayed by a specified amount with respected to ROT1PPS. The R1PPS tick *always* marks the data bit(s) corresponding to the 'TOST bit' at the DIM input.
4. ROT1PPS - 1pps tick from ROT clock, subject to the same speed-up or slow-down as the reconstructed bit streams.
5. QVALID – a 1-bit global signal indicating that the reconstructed data are judged by the DOM to be correct (i.e. tape is reproducing properly). May optionally be extended to include more sophisticated validity indications, such as pulsar gating, or as a pass-through of PVALID from the input to the DIM.
6. QDATA – A standard 8-bit ASCII serial data stream which may send a burst of up to 2048 bytes of information framed between each R1PPS or ROT1PPS tick (user can select to frame QDATA between either; see Section 14.2). The content and use of this information is not specified by the VSI-H specification.
7. Control Interface --The DOM control interface is a 2-way communications interface, encompassing *both* RS-232 and Ethernet, which both controls and monitors the operation of the DOM. The DOM controller must be aware of DPS1PPS to the extent that certain messages can be reliably sent to/from the DOM between specific adjacent DPS1PPS pulses. May be shared with DIM control interface.

8.1.3 Other Signals

ROTMON – a monitor signal from the DOM which allows confirmation of the epoch of the ROT-clock second tick (see Section 8.2).

8.2 *The Requested Observe Time (ROT) Clock*

The DOM maintains an internal Requested-Observe-Time (ROT) clock which maintains the reference time to which the re-constructed data are to be synchronized. The ROT clock has the following properties:

1. The ROT clock is set to a specified second of time on a given DPS1PPS tick.
2. Once set, the ROT clock keeps time solely by counting DPSCLOCK cycles (i.e. subsequent DPS1PPS ticks are ignored unless the ROT is expressly commanded to be reset). The monitor signal ROTMON allows confirmation of the ROT epoch setting.

8.3 *Speed-up/Slow-down Data Reproduction*

Some systems may also allow the DOM output bit rate (f_{RBSI}) to be speeded-up or slowed-down by compared to the DIM input rate (f_{BSI}). In such cases, the ROT-clock-increment per DPSCLOCK-cycle must be commanded to change correspondingly. The rates of RCLOCK, ROT1PPS, R1PPS and RBS_n will all change correspondingly.

The VSI-H specification does not mandate any speed-up or slow-down capability, nor does it constrain the implementation of such capability.

8.4 *Delay Offset*

In a *storage-based* DPS system, where the data are actually captured to a transportable storage medium and then replayed at a later time, a delay-offset capability in the DOM allows control of data alignment into the DPS. In these storage-based systems, VSI-H specifies that the DOM include the capability to offset the delay of the reconstructed bit-streams with respect to the ROT clock, as indicated in Figure 1. The delay is specified as a *bit offset.* This allows adjustment of the data delay into the DPS for processing. When the delay offset is set to a non-zero value, the RBS_n bit streams, R1PPS and QVALID[1] signals are delayed with respect to the ROT1PPS tick by the amount specified. When the delay offset is zero, ROT1PPS and R1PPS are coincident. QVALID indicates that valid data with the proper delay is being output from the DOM.

The range of the available delay offset in a *storage-based* DPS system shall be sufficient to cover at least ± 0.5*ROT1PPS. This allows an arbitrarily large offset (with respect to some DPS master clock) to be specified with a combination of ROT setting and bit offset.[2]

The design of the DOM should be such that the ROT clock and the delay offset can be set independently without disturbing the other.

In a *direct-transmission* DPS system, where the data are transmitted directly from DIM to DOM and not stored in a transportable medium, the required delay offsets are primarily a

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[1] That is to say that QVALID remains synchronized to the RBS_n bit streams to which it pertains.

[2] It has been pointed out that implementing a specified delay in the DIM between 1PPS and the DOT-generated 1pps may also provide some useful features, such as test-vector verification in some cases, or in compensating for a known epoch error in 1PPS or ALT1PPS. The implementation of such a delay capability in the DIM is optional and not part of the VSI-H specification.

function of the geographic extent of the VLBI data-collection network. In this case, the DPS is assumed to implement the necessary data-delay requirements and VSI-H mandates no delay capability.

8.5 *Example of DOM Operation*

The following is an example of a typical sequence of operations of a DOM in a common data-playback situation:

1. Through the Control Interface, the DOM is configured to reproduce any desired subset of the 'active' bit streams sent to it by the DIM.
2. Through the Control interface, the ROT clock is commanded to be set to a specified UTC integer second of time on the *next* DPS1PPS tick; a delay offset may also be specified (see Section 8.4). Once set, the ROT clock keeps time by counting cycles of DPSCLOCK, ignoring subsequent DPS1PPS signals.
3. Through the Control Interface, the DOM is commanded to begin transmitting the selected input bit streams *synchronized to the ROT clock or specified bit offset from the ROT clock.* For tape-playback systems, this means the DOM must use a combination of mechanical tape positioning and electronic buffering to synchronize the recorded data to the ROT clock. When the output data are properly synchronized (with a delay offset, if any) and valid, the QVALID signal is asserted logical 'true'.
4. At the end of the data-period of interest, the DOM is commanded (through the Control Interface) to cease transmitting data.

Notes:

1. Note that the reconstructed data streams from the DOM are, except possibly for the data-stream clock rate and for playback errors or intentionally replaced data (see Section 14.1), identical to the data sampled by the DIM.
2. It is the responsibility of the DPS to do any manipulations necessary to transform the reconstructed bit streams into usable data (such as multiplexing or demultiplexing).
3. Some DOM's may have the ability to reproduce additional low-data-rate information transmitted from the DIM, such as bit-stream identification, etc. in addition to the bit-streams themselves. Such information may be accessed in the DOM via the Control Interface or, in some cases, transmitted via the QDATA serial-data stream. When performing a tape-copying operation, for example, QDATA may be used in conjunction with its DIM counterpart, PDATA, to transfer time-tag data to execute simple tape copying operations. The VSI-H specification does not mandate content or usage of QDATA.
4. Since the DPS is presumed to have some internal buffering, ROT1PPS and RCLOCK need not be precisely aligned with DPS1PPS and DPSCLOCK.
5. With the exception of DPS1PPS, DPSCLOCK, ROTMON and the Control Interface, all DOM interface signals are contained in a single 80-pin connector (see Section 12.1).
6. The procedure for setting and monitoring of the ROT clock is similar to that for the DOT clock in the DIM.

9. Signal Selection and Switching

9.1 *DIM*

As implied in the discussions above, the DIM must include the capability to select as 'active' any subset of 1, 2, 4, 8 or 16 of the 32 potential BS_n input data streams. Only the selected set of bit-streams is required to be transmitted to the DOM. This enables the DTS to more efficiently use the transmission medium in cases of reduced aggregate data rates.[3]

9.2 *DOM*

The DOM is required to reconstruct only the 'active' set of bit-streams transmitted to it by the DIM. However, the DOM must include the capability to connect *any* of the reconstructed bit-streams to any DOM RBS_n output bit-stream. Figure 1 shows a 32x32 crossbar switch as a functional illustration of this capability, but the designer is free to implement this specification in any satisfactory manner, including a separate external module (presumably containing its own control interface).

10. Signal Descriptions

10.1 *DIM Input Signals*

Signal	Frequency/Period	Voltage	Comments
CLOCK	f_{CLOCK} = 2, 4, 8, 16, 32 MHz with optional extensions to 64 and 128 MHz (see Table 2); dynamic variability up to ±100 ppm	LVDS(see Section 12.1)	f_{CLOCK} sets maximum BS_n sample rate; variability to allow for high-velocity spacecraft applications
1PPS	1 per f_{CLOCK} cycles of CLOCK (e.g. 1 per 32×10^6 CLOCK cycles for 32 MHz CLOCK	LVDS	Rising edge should be synchronous with rising edge of data bit to be tagged as 'taken on the second tick' (the 'TOST' bit); see Figure 2
ALT1PPS	Alternate 1PPS signal	LVDS	May be asynchronous with CLOCK
BS_n n=0 to 31	Sampled by DIM at 'bit-stream information rate' (f_{BSI}); $f_{BSI} \leq f_{CLOCK}$	LVDS	For all clock rates, TOST bit (see Section 11.1) must be coincident with 1PPS; one data bit accepted every 2^k CLOCK cycles thereafter
PDATA	115 kbaud 8-bit serial data; one stop bit, no parity	LVDS	Up to 2048 bytes to be received *between* each 1PPS tick

Table 1: DIM Input Signals

f_{CLOCK} [f_{RCLOCK}] (MHz)	f_{BSI} [f_{RBSI}] (Mbps)						
	2	**4**	**8**	**16**	**32**	**64**	**128**
2	Y						
4	Y	Y					
8	Y	Y	Y				
16	Y	Y	Y	Y			
32	Y	Y	Y	Y	Y		
64 (opt)	Z	Z	Z	Z	Z	Z	
128 (opt)	Z	Z	Z	Z	Z	Z	Z

Table 2: Required combinations of clock frequencies and internal bit-stream data rates

Table 2 notes:

1. 'opt' indicates optional
2. 'Y' indicates required. 'Z' indicates required if that optional clock frequency (or a higher one) is implemented.

[3] A signal-switching capability at the DIM input may be useful to order the bit-streams so that the default DOM output bit-stream ordering is more directly compatible with a target DPS, but this capability is not required. See also footnote in Section 13.4

3. Clock frequencies of 64 and 128 MHz are optional extensions to the VSI-H standard.

Notes:

1. Use of ALT1PPS is intended for systems where the station 1PPS is provided by an independent external source such as a hydrogen maser. In such a case, the ALT1PPS cannot be guaranteed to be synchronous with CLOCK, which may result in a ±1 CLOCK cycle ambiguity in the setting of the DOT clock. This will normally be of little consequence so long as the DOT clock is not subsequently reset, which could cause a timing discontinuity.
2. Strictly speaking, the ALT1PPS signal need only be a single pulse to set the DOT clock, but is typically a repetitive signal at a 1-pps rate. Following the setting of the DOT clock, the DOTMON monitor signal generated by the DOT clock is a useful indicator of proper DOT-clock synchronization.
3. Each input bit-stream, BS_n, is sampled by the DIM only once every 2^k, k=0,1,2,... periods of CLOCK, where k is determined by the relevant cell value in Table 2. This sample rate is known as the 'bit-stream information rate' (f_{BSI}). This allows, for example, the DAS samplers to always run at f_{CLOCK}, even though f_{BSI} is lower than the DAS sample rate.
4. The inclusion of PDATA is primarily for future use, particularly for tape copying, where the output of a DOM can be connected directly to the input of a DIM. In such a case, the QDATA output from the DOM can dynamically transmit data time to the DIM to automatically update the DOT clock. Other uses of PDATA are also possible (see Section 14.2).
5. Any discontinuity or frequency change of CLOCK, other than the allowed dynamic variability of ±100 ppm, will normally require the DIM, including the DOT clock, to be reset.

10.2 *DIM Output Signals*

Signal	Frequency/Period	Voltage	Comments
DOTMON	Same as 1PPS	TTL	For monitor purposes only

Table 3: DIM Output Signals

Notes:

1. The DOTMON signal provides a useful monitor that indicates the DOT is properly synchronized to 1PPS/ALT1PPS.
2. The inclusion in the DIM of other useful monitor signals is encouraged.

10.3 *DOM Input Signals*

Signal	Frequency/Period	Voltage	Comments
DPSCLOCK	Allowed frequency is dependent on f_{RCLOCK}, as given in Table 5; dynamic variability up to ±100 ppm	LVDS	Sets max f_{RBSI}; variability to allow for high-velocity spacecraft applications
DPS1PPS	1 per $f_{DPSCLOCK}$ cycles of DPSCLOCK (e.g. 1 per $32x10^6$ DPSCLOCK cycles for $f_{DPSCLOCK}$=32 MHz	LVDS	Sets epoch of ROT clock second tick

Table 4: DOM Input Signals

Notes:

1. The DPS1PPS signal is used only once to set the ROT clock epoch upon command, presumably at the beginning of a scan or tape.
2. Any discontinuity or frequency change in of DPSCLOCK, other than the allowed variability of ±100 ppm, will normally require the DOM, including the ROT clock, to be reset.

$f_{DPSCLOCK}$ (MHz)	f_{RCLOCK} (MHz)						
	2	4	8	16	32	64	128
2	Y						
4	Y	Y					
8	Y	Y	Y				
16	Y	Y	Y	Y			
32	Y	Y	Y	Y	Y		
64 (opt)	Z	Z	Z	Z	Z	Z	
128 (opt)	Z	Z	Z	Z	Z	Z	Z

Table 5: Required frequency combinations of DPSCLOCK and RCLOCK

Table 5 notes:
1. 'opt' indicates optional.
2. 'Y' indicates required. 'Z' indicates required if that optional clock frequency (or a higher one) is implemented.
3. CLOCK frequencies of 64 and 128 MHz are extensions to the VSI-H standard.

10.4 *DOM Output Signals*

Signal	Frequency/Period	Voltage	Comments
RCLOCK	f_{RCLOCK} is dependent on $f_{DPSCLOCK}$, according to Table 5	LVDS	Sets max output reconstructed bit-stream information rate (f_{RBSI})
R1PPS	1 pulse per second of ROT clock time	LVDS	Ratio of R1PPS to DPS1PPS pulse frequencies depends on DOM speed-up factor (see Notes)
ROT1PPS	Same as R1PPS	LVDS	Coincident with R1PPS if delay=0 or delay option not implemented
RBS_n n=0 to 31	$f_{RBSI}=f_{RCLOCK}/2^k$, k=0,1,2,... in accordance with Table 2	LVDS	May be arbitrarily re-mapped
QVALID	Global logical indication that data is sync'ed and valid; no period	LVDS	
QDATA	115 kbaud 8-bit serial data; one stop bit, no parity	LVDS	Up to 2048 bytes transmitted *between* successive R1PPS or ROT1PPS ticks (selectable)
ROTMON	Same as ROT1PPS	TTL	For monitor purpose only

Table 6: DOM Output Signals

Notes:
1. Speed-up/slowdown on DOM playback is optional and may not be possible with all systems.
2. If the DOM can operate with a speed-up/slowdown, the ROT increment per DPSCLK must be specified to the DOM.

11. Signal Timing Relationships

11.1 *General*

Figure 2 shows the timing relationships between 1PPS, CLOCK and BS_n; timing relationships between R1PPS, RCLOCK and RBS_n are similar. The sample points for three different bit-stream information rates (f_{BSI}'s) are shown to illustrate that the epoch of the first sample taken after the rising edge of the 1PPS tick (the so-called 'TOST' sample) must maintain a constant timing relationship with respect to 1PPS regardless of the f_{CLOCK} or f_{BSI}. This guarantees that the epoch of the sampled data stream will not change with f_{CLOCK} or f_{BSI}. After the TOST sample, subsequent samples are taken every 2^k CLOCK cycles, depending on the ratio of f_{CLOCK} to f_{BSI}.

11.2 *Timing Ticks*

Table 7 specifies the minimum and maximum durations of various periodic ticks:

Signal	Type	Min duration	Max duration
1PPS	LVDS	1 cycle of CLOCK	500 ns (inverse 2 MHz)
ALT1PPS	LVDS	1 cycle of CLOCK	No specification
DPS1PPS	LVDS	1 cycle of DPSCLOCK	500 ns
R1PPS	LVDS	1 cycle of RCLOCK	500 ns
ROT1PPS	LVDS	1 cycle of RCLOCK	500 ns
DOTMON	TTL	Stretched for easy viewing	~10 ms
ROTMON	TTL	Stretched for easy viewing	~10 ms

Table 7: Timing-Tick Min/Max Durations

12. Interconnect Hardware Specifications

12.1 *LVDS Interfaces*

Three physical LVDS interfaces are present in the DTS:

1. DAS-to-DIM 'data interface' on an 80-pin MDR connector with 4-40 jackscrews; pinout specified in Table 8.
2. DOM-to-DPS 'data interface' on an 80-pin MDR connector with 4-40 jackscrews; pinout specified in Table 8. This pinout is compatible with the DAS-to-DIM connector to allow easy DOM-to-DIM connections.
3. 'Timing interface' on a 14-pin MDR connector with spring latch; pinout as specified in Table 9. If the DIM and DOM are separate physical units, each will have a 14-pin MDR connector.

The interfaces all conform to the LVDS differential format as defined by the ANSI/EIA/TIA-644 standard. All connectors are Mini D Ribbon (MDR) with sockets on both the transmitting and receiving equipment.

DAS-DIM	DOM-DPS	Pin(+)	Pin(-)	Comments
BS0	RBS0	1	2	
BS1	RBS1	3	4	
"	"	"	"	
"	"	"	"	
BS14	RBS14	29	30	
BS15	RBS15	31	32	
BS16	RBS16	42	41	
BS17	RBS17	44	43	

"	"	"	"	
"	"	"	"	
BS30	RBS30	70	69	
BS31	RBS31	72	71	
1PPS	R1PPS	33	34	
Unused	ROT1PPS	35	36	See 12.1.6 Notes
PVALID	QVALID	37	38	
CLOCK	RCLOCK	39	40	
PCTRL	QCTRL	74	73	Reverse-channel control: '1' (default) – forward only '0' – reverse permitted
PDATA	QDATA	76	75	
PSPARE1	QSPARE1	78	77	Spare signal 1
PSPARE2	QSPARE2	80	79	Spare signal 2

Table 8: MDR-80 Pin Allocations (Data Interface)

Signal	**Pin(+)**	**Pin(-)**
ALT1PPS	1	2
DPS1PPS	3	4
DPSCLOCK	5	6
Undefined (see 12.1.6 Notes)	7..14	

Table 9: MDR-14 Pin Allocations (Timing Interface)

12.1.1 Reverse Channel Control

Due to requirements of some system designers, the base VSI-H specification requires the use of only uni-directional signals in each of the two MDR connectors. In order to accommodate the *option* that some reverse-channel functions be allowed, three signal pairs (P/QCTRL, P/QSPARE1, P/QSPARE2) have been defined in the MDR-80 Data-Interface connector in Table 8:

P/QCTRL – a control signal asserted received by the DAS (as PCTRL) or transmitted by the DOM (as QCTRL) which specifies whether the two spare signal lines P/QSPARE1 and P/QSPARE2 are in the 'forward' or are allowed to communicate in the 'reverse' direction, as follows:

- P/QCTRL=1 (default state): no change, i.e. all signal channels transmit in the normal direction.
- P/QCTRL=0: Ports *optionally* fitted with transceivers for channels P/QSPARE1 and P/QSPARE2 will operate in the reverse direction, i.e. DPS to DOM or DIM to DAS. Thus static two signal 'back channel' or conventional half-duplex operation becomes possible.

Notes:

1. Equipment not installing the optional transceivers fix P/QCTRL in the default state and may continue to use P/QSPARE1/2 in the normal direction for any other "spare" purpose as desired.
2. Any combination of equipment with and without the optional transceivers may be connected without complication. Any combination with less than both optioned up, will by default operate in the normal (forward only) mode.

3. The reverse channels may only become active when explicitly commanded by the DAS or DOM. A disconnected cable automatically forces transceivers to the receive state.

4. LVDM (Multipoint) standard transceiver chips (e.g. SN65LVDM050/051) allow terminations at both ends of the line by driving double the normal current into it. Net waveform and timing specifications are indistinguishable from normal single-terminated LVDS.

5. No specific purpose is defined for the reverse channels, but see suggested usage below.

12.1.2 Suggested Reverse-Channel Usage

If the optional reverse channel capability described above is implemented, the PSPARE1/2 lines can carry the clocking signals normally assigned to the Timing Cable, integrating all 'reverse-channel' timing signals into the Data Cable and eliminating the need for the Timing Cable (though the MDR-14 connector must be present as well). Table 10 shows suggested signal assignments when P/QCTRL="0":

Signal	New Assignment	Direction	Comments
PSPARE1	TVGCTRL	From DIM	See Notes
PSPARE2	DOT1PPS	From DIM	See Notes
QSPARE1	DPSCLOCKX	To DOM	Substitute for DPSCLOCK
QSPARE2	DPS1PPSX	To DOM	Substitute for DPS1PPS

Table 10: Suggested Reverse-Channel Signal Assignments

Notes:

1. The use of QSPARE1/2 here are simply direct replacements for the signals DPSCLOCK and DPS1PPS.
2. The purpose of DOT1PPS is to allow a DAS otherwise without a 1-pps signal to receive DOT1PPS from the DIM via the Data Cable. This then enables the use of a TVG in the DAS (pseudo-random noise functions only) without requiring either a 1-pps input or a control port on the DAS. It also enables the periodic PDATA function which requires a 1-pps synchronizing signal.

12.1.3 Waveform Specifications

Figures 3 through 5, along with Table 11, specify the timing characteristics of the LVDS waveforms.

Parameter	Spec.	32MHz	64MHz	128MHz
T	$1/f_{CLOCK}$	31.3	15.6	7.8
t1	0.3T	9.4	4.7	2.3
t2	0.35T	10.9	5.5	2.7
t3	T-t1	21.9	10.9	5.5
t4	0.15T	4.7	2.3	1.2
t5	0.2T	6.3	3.1	1.6
t6	T-t4	26.6	13.3	6.6
t7,t8	≥ 0.25	0.25	0.25	0.25
t7,t8	$\leq 0.2T$	6.3	3.1	1.6

Table 11: LVDS Timing Specifications and Values (ns) at Rated Frequencies

12.1.4 Transmitter Specifications

1. The transmitter will produce waveforms satisfying the transmitter output eye pattern and transitions in Figures 3 and 5 when driving a standard LVDS receiver.
2. The default state of inactive signals is "1".
3. Pair to pair cross-talk : $\leq$-40dB

12.1.5 Receiver Specifications

1. Line termination (pair) : 100Ω ±5%.
2. Line receivers will fail-safe to a logical '1' state when disconnected.
3. The receiver will respond correctly to incident waveforms satisfying the receiver input eye pattern in Figure 4.

12.1.6 Cable Specifications

When driven by any transmitter conforming to the transmitter output eye pattern in Figure 3 the cable assembly will deliver waveforms satisfying the receiver input eye pattern in Figure 4, into a properly terminated receiver.

This formal specification is difficult to verify on such a wide interface so the following indirect specifications are offered as a guide:

1. Differential (odd-mode) characteristic impedance (pair) : 100Ω ±10%
2. Pair to pair skew : $\leq$ 0.1T
3. Rise time degradation : $\leq$ 0.1T
4. Attenuation : $\leq$ 9dB at $f = 1/T$
5. Pair to pair cross-talk : $\leq$ -40dB over $0.5/T < f < 5.5/T$
6. Aggregate cross-talk : $\leq$ -30dB over $0.5/T < f < 5.5/T$
7. Rated frequencies : 32MHz, 64MHz & 128MHz

Standard cable lengths are 5m, 10m and 20m.

Notes:

1. Cable assemblies comprise n-pair screened or 2n-line multi-coax cables, terminated by metal shrouded plugs which continue full screening through to the connection plane. Corresponding shrouds on the equipment connectors directly ground the shield to their respective chasses.
2. All input lines should be terminated normally even if a circuit is not implemented. This provides proper loads for all drivers and avoids problems due to resonances in floating wires in the cable.
3. MDR-80 only: 'Unused' signal on DIM connector pins 35-36 should be terminated normally as it will be driven by ROT1PPS when a DOM output is connected to a DIM input.
4. MDR-14 only: Ground undefined pins on receptacles. Connectivity within the cable not required. Grounding the spare pins reduces stray coupling on the board and within the connector. It also provides convenient returns for the drain wires from pair shields in some cable types. The enveloping cable shield is of course continuous with and returned to chassis, by the metal connector shrouds.

12.2 *TTL Interfaces*

The two monitor signals, DOTMON and ROTMON are the only TTL signals defined in the VSI-H specification. They are to 'back terminated' 50Ω ports, implemented by placing a ~50Ω resistor in series with the driver chip.[4] The rising edge of these signals is the active transition. Duration is to be stretched to be conveniently observed on an oscilloscope. The nominal time offset from 1PPS/ALT1PPS to DOTMON and from DPS1PPS to ROTMON should be provided to the user and is, ideally, independent of f_{CLOCK} (in the case of DOTMON) or $f_{DSPCLOCK}$ (in the case of ROTMON).

The DOTMON and ROTMON signals are to be carried on 50Ω BNC connectors.

12.3. *Control Interfaces*

The DIM and the DOM shall have *both* an Ethernet *and* an RS-232 control interface. Both may be simultaneously active, though this is not required. Some of the control and monitor functions, as discussed above, are quasi-real-time, in that control/monitor data must be reliably communicated between 1PPS pulses (in the DIM) or DPS1PPS pulses (in the DOM) in order to properly set and monitor the DOT and ROT clocks.

If the DIM and DOM are in the same physical unit, they may share the Ethernet and RS-232 control interfaces.

The details of the communications messages and protocols are to be specified in the VSI-S document.

Control Interface:

RS-232: DB-9 configured as DCE (pinout in Table 12)
Ethernet: RJ-45 jack (10Base-T or 10/100 Base-T)

Signal	Description	Direction	Pin	Comments
CD	Carrier Detect	From DTS	1	optional
RD	Received Data	From DTS	2	required
TD	Transmitted Data	To DTS	3	required
DTR	Data Terminal Ready	To DTS	4	optional
SG	Signal Ground	--	5	required
-	-	-	6	not used
RTS	Request to Send	To DTS	7	optional
CTS	Clear to Send	From DTS	8	optional
RI	Ring Indicator	From DTS	9	optional

Table 12: DB-9 Pin Allocations (EIA/TIA-574)

[4] This raises the output impedance of the driver chip to ~50Ω Given a 50Ω signal path all the way to the monitoring device (scope, for example), the forward wave is completely reflected by the high impedance of the monitoring device and absorbed back in the source.

The specifications of the control interfaces are:

1. RS-232: operating at least to 9600 baud, preferably higher (to 115 kbaud); 8-bit, 1 stop bit, no parity; software handshaking to be specified in VSI-S specification.
2. Ethernet: 10Base-T or 10/100Base-T

13. Test Vectors

Test-vector generators (TVG) and receivers (TVR) are used to validate the physical layer connections between the Data Acquisition System (DAS), Data Input Module (DIM), Data Output Module (DOM), and Data Processing System (DPS) components of the VLBI Data Transfer System (DTS).

The VSI-H specification imposes no requirements on testing the interface through the transmission medium from the DIM to the DOM, though designers are urged to implement testing procedures suitable to the characteristics of the DTS.

13.1 *General Characteristics*

The philosophy of the TV specification is to fully test the connection of user equipment to the DIM and DOM data interfaces. To this end, the TV system should have the following characteristics (see Figure 1):

1. The DIM includes a TVR to validate data transmission from equipment connected to the DIM data interface.
2. The DOM includes a TVG to validate data transmission from the DOM to external equipment.
3. Each TVG is capable of generating 32 unique pseudo-random noise (PRN) bit streams, denoted as TV_0-TV_{31}, each of a fixed period of 2^{15}-1 (32767) bits.
4. All PRN bit-streams are re-synchronized at each 1PPS/R1PPS epoch.
5. The TV bit-stream data rate is always at the rate of the data which it replaces. This implies that TV rates must be consistent with Table 2.

Though the VSI-H specification does not directly extend to the DAS or DTS, a complete TV system would also include a TVG in the DAS[5] and a TVR in the DTS.

13.2 *Test Vector Generator*

Figure 6 shows an example gate-level design of the TVG (based on Crestech design) to be used in VSI-H compliant DTS's. Each of the 32 output PNS bit-streams is re-initialized at each 1PPS/R1PPS tick. Table 13 tabulates the first 20-bits of each of the 32 TV bit-streams. Each bit stream has an approximate balance of the number of 'ones' and 'zeroes', corresponding to a 'DC-bias' of ~50%. Note that, for illustration purposes, the CLOCK signal in Figure 6 is shown to have the same frequency as the data-bit-stream sample rate.

In addition, each TVG must be capable of producing an "all 0's" or "all 1's" signal on all 32 bit-stream outputs. In this mode, it is useful to verify that the TVR's reports an error rate of ~50%.

[5] Including a TVG in the DAS probably only makes sense when the DIM receives and uses 1PPS from the DAS. The use of an asynchronous ALT1PPS makes the use of a DAS-TVG difficult.

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}	t_{15}	t_{16}	t_{17}	t_{18}	t_{19}	t_{20}
TV_0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0
TV_1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0
TV_2	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0	0	0
TV_3	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0
TV_4	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	0	0	0	1
TV_5	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	0	0	0	0	1
TV_6	0	0	0	0	1	0	1	1	1	0	0	1	0	1	1	0	0	0	1	1
TV_7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
TV_8	0	0	0	1	0	1	1	0	0	0	1	0	1	1	1	0	0	1	1	1
TV_9	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1
TV_{10}	0	0	1	1	1	0	0	0	0	1	1	1	0	1	1	0	1	0	0	1
TV_{11}	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0
TV_{12}	0	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	0	1	0	0
TV_{13}	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0	0	0
TV_{14}	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0
TV_{15}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
TV_{16}	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1
TV_{17}	1	1	1	1	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	1
TV_{18}	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1
TV_{19}	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	1	1	1
TV_{20}	1	1	1	1	1	0	0	0	1	0	0	1	0	0	0	1	1	1	1	0
TV_{21}	1	1	1	1	1	0	1	0	1	0	1	1	0	1	0	1	1	1	1	0
TV_{22}	1	1	1	1	0	1	0	0	0	1	1	0	1	0	0	1	1	1	0	0
TV_{23}	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1
TV_{24}	1	1	1	0	1	0	0	1	1	1	0	1	0	0	0	1	1	0	0	0
TV_{25}	1	1	1	0	1	0	1	1	1	1	0	1	0	1	0	1	1	0	0	0
TV_{26}	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	1	0	1	1	0
TV_{27}	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0	1
TV_{28}	1	0	0	1	1	1	1	1	0	0	1	1	0	0	0	0	1	0	1	1
TV_{29}	1	0	1	1	1	1	1	1	0	1	1	1	0	1	0	0	0	1	1	1
TV_{30}	0	1	1	1	1	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1
TV_{31}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1

Table 13: TVG data outputs for first 20 data bits following 1PPS/R1PPS

13.3 *Test Vector Timing Relationships*

As indicated in Figure 7, the TVG is initialized at every 1PPS/R1PPS tick in such a way that the 'TOST bit' at t_0 is undefined. From that point forward, the TVG increments every sample clock period and has the same timing relationship to CLOCK as normal user data. The TVG continuously cycles through the 32767-bit TVG sequence until the next 1PPS/R1PPS tick, at which point the TVG is again re-initialized.

13.4 *Test Vector Receiver*

On command, the DIM-TVR will measure and report the bit-error rate (BER) and "DC-bias" on each of the 32 input test bit-streams, either sequentially or simultaneously. In order to untangle possible bit-stream 'mix-ups' (i.e. bit streams being directed to the wrong place), a useful, but not required, capability of the TVR is to examine each possible bit stream for each of the 32 possible TV sequences.[6]

The TVR reporting period may be selected to correspond to any integer number of 1PPS/R1PPS periods, up to a reasonable number (say ~64).

14. Other Notes and Comments:

14.1 *Data-Replacement Format*

Some systems may periodically replace small portions of data sampled by the DIM with timing and synchronization information. The use of a 'data-replacement' format under the VSI-H standard is allowed under Level B compliance. The QVALID signal must accurately flag any replacement data as 'invalid' as it emerges from the DOM. In addition, the use of standard VSI-H test-vector testing with the DAS and DPS may be difficult or impossible with a data-replacement format.

14.2 *Media Translation (Tape Copying)*

With the use of the VSI-H interfaces, data may be easily copied from one medium to another in a straightforward manner. The output of a DOM may be directly connected to the DIM input. For this purpose, the DOM must have the capability of 'standalone playback' without the connection of DPSCLK or DPS1PPS signals. In such case, the ROT clock will be commanded to simply track the playback time on the tape.

Time-tag transfer between DOM and DIM can be accomplished by two different methods. By using the DOM facility to transmit the ROT setting immediately following a R1PPS tick, a control computer can read the ROT and appropriately set the DOT clock in the DIM. Once ROT and DOT clocks are appropriately set, copying will take place with no further intervention until a time discontinuity (tape stop and restart, for example) when the DOT and ROT clocks must again be reset. Alternatively, time-tag transfer from DOM to DIM can be done through the QDATA/PDATA serial data lines (as discussed below).

14.3 *Usage of PDATA/QDATA*

The usage and content of the PDATA/QDATA asynchronous serial-ASCII signals is not specified under the VSI-H specification. A few possible uses of these signals are:

14.3.1 Media translation

During media-translation (i.e. tape copying) operations, where the DOM output is connected to the DIM input, QDATA may be used to transmit the high-level time (e.g. date and time to the unit-second level) to the PDATA input of the DIM between each R1PPS tick. In this case, it is probably most useful if the QDATA time tag corresponds to the epoch of the *next* R1PPS tick. This allows the DIM to dynamically set the DOT clock to the proper time at the next 1PPS (R1PPS) tick in much the same way the DOT clock is set in normal operation. Other auxiliary information may, of course, be transmitted between the DIM and DOM in the same way.

[6] It has been pointed out that placing a 32x32 crossbar switch in the DIM may aid in implementing this capability. In addition, the ability to route one selected data stream to a front-panel monitor connector could be of significant benefit in debugging difficult situations.

14.3.2 Auxiliary information from DAS

If the DAS is capable of supplying PDATA information to the DIM, this information may be used as the DIM sees fit. Possible information might include time, data-collection parameters, antenna pointing, system temperature, etc. If the system is capable, some or all of this information may be used to control the DIM, or perhaps transmitted to the DOM for output to QDATA.

14.3.3 Model parameters to DPS: An attractive possible use of QDATA is to periodically transmit station-model information to the DPS. This capability is particularly attractive if the DOM includes the capability to delay the data according to a dynamic model supplied to it by the host computer. If, for example, the ROT clocks of all DOM's are set to represent a center-of-earth clock and each DOM dynamically delays its output data according to a center-of-earth model, the DOM output data may be immediately available for correlation processing with only a small amount of FIFO re-synchronizing (using ROT1PPS tick) necessary in the DPS. The QDATA model parameters, transmitted between each ROT1PPS tick, would need only to carry such information as fractional bit delay, rate, plus a phase model for each channel, in order to provide the DPS with all necessary information to do proper processing.

14.4 *Usage of PVALID/QVALID*

The VSI-H specifies the use of the QVALID signal only to the extent that it indicates the global validity status of the DOM output data streams. If available to the DIM, the PVALID signal may be used to indicate that the DAS output data are 'valid'. This information can be used by the DIM as it sees fit, including transmitting it to the DOM for inclusion as a factor in controlling the QVALID output. If the DOM is sufficiently capable, the QVALID signal may also be used, for example, as a pulsar-gating mechanism to the DPS.

14.5 *Multiple Parallel DTS's*

In the event that a single DTS is not able to handle the required aggregate data rate, multiple DTS's may be employed in parallel. In the case of the DIM, the DAS must be able to support multiple DIM's in parallel, each being supported as if it were standalone. Multiple parallel DOM's can be handled in the same way.

14.6 *Multi-Port DTS*

A DTS may support multiple channel quanta simply by the inclusion of multiple MDR-80 data connectors on the DIM and DOM. Only a single MDR-14 connector for other timing signals is required. VSI-H imposes no requirements on signal connectivity between channel quanta within a multi-port DTS.

14.7 *Validity per Bit Stream*

Some DTS systems may benefit by having the capability to specify per-bit validity at the DOM output for each bit-stream individually. Currently the VSI-H specification says nothing about such a capability, but two possible options for such a capability have been discussed:

1. A parallel MDR-80 connector from the DOM can carry validity-per-bit-stream information. Depending on the resolution of the validity information, it may be necessary to also carry parallel timing information in the validity connector (RCLOCK, etc.). The pin-out of the validity connector would parallel that of the data connector.

2. Validity per bit stream can also be implemented without the addition of another connector by employing a 'bi-phase' code on each of the RBS_n output bit-streams. This works by using the second half of each RBS bit cell to indicate the validity state of that bit, so that the negative-going transition of RCLOCK samples the validity state of each bit cell of every RBS_n; this means that the effective RBS data rate is doubled. Coding is chosen so that a *change* of level in the second half of the bit cell signifies invalidation; this coding means that a bit stream without per-bit-validation is identical to a fully-valid bit stream with per-bit-validation. A DPS may choose to use this information or not. The 'bi-phase' scheme effectively doubles the information rate on the data connector, and as such may not be suitable for systems with clocking at 64 MHz or 128 MHz.

   The bi-phase coding scheme is common in commercial applications. Note that only *DOM-generated* signals are affected; these validity states are *not* transmitted from the DIM to DOM.

In either of these cases, the conditions used to control the per-bit-stream validation signals may presumably be specified by the user and are dependent on the details of the DTS system.

14.8 *Higher Clock Rates*

The possibility to move to bit-stream clock rates even higher than 128 MHz, particularly 256 MHz, is moving rapidly towards reality, particularly with introduction of extremely low-skew cable assemblies and higher-performance LVDS components. Though not currently a part of the VSI-H specification, this issue may well be ripe for re-examination in the future, and designers should keep the possibility in mind. At the appropriate time, it will be necessary to write the detailed specifications necessary to support these higher rates. Depending on high-speed-data technology developments over the next few years, it may also be advantageous to consider extending the VSI-H specification to include other well accepted data interfaces, such as high-speed serial links.

15. Glossary

15.1 *General*

BER	Bit Error Rate
'Channel Quantum'	The data carried on a single 80-pin LVDS signal connector; the base VSI-H specification defines a 'channel quantum' at a data rate of 1.024 Gbps.
DAS	Data Acquisition System; provides parallel bit-stream data to DIM
DIM	Data Input Module
DOM	Data Output Module
DOT	Data Observe Time; maintained in DIM
DPS	Data Processing System (most commonly a correlator)
DTS	Data Transmission System; includes DIM and DOM
f_{CLOCK}	Frequency of CLOCK signal

$f_{DPSCLOCK}$	Frequency of DPSCLOCK signal
f_{BSI}	Bit Stream Information Rate at input to DIM (i.e. DIM sample rate)
f_{RBSI}	Reconstructed bit-stream information rate at DOM output
LVDS	Low-Voltage Differential Signaling
ROT	Requested Observe Time; maintained in DOM
TOST bit	Data bit 'Taken On the Second Tick'; the TOST bit maintains a constant relationship to 1PPS and is always transmitted regardless of the bit-stream sample rate.
TV	Test Vector
TVG	Test Vector Generator
TVR	Test Vector Receiver
UTC	Universal Coordinated Time
VSI	VLBI Standard Interface
VSI-H	VSI Hardware Specification
VSI-S	VSI Software Specification

15.2 *Signals*

Name	Function	Format	Description
1PPS	DIM input	LVDS	One-second tick
ALT1PPS	DIM input	LVDS	Alternate one-second tick
BS_n	DIM input	LVDS	Bit-stream n
CLOCK	DIM input	LVDS	Data clock
DOT1PPS	DIM output	LVDS	Optional reverse-channel 1-pps from DOT clock (suggested use of PSPARE2)
DOTMON	DIM output	TTL	DOT clock 1-pps epoch monitor
DPS1PPS	DOM input	LVDS	DPS one-second tick to DOM
DPS1PPSX	DOM input	LVDS	Optional reverse-channel substitute for DPS1PPS (suggested use of QSPARE2)
DPSCLOCK	DOM input	LVDS	DPS clock to DOM
DPSCLOCKX	DOM input	LVDS	Optional reverse-channel substitute for DPSCLOCK (suggested use of QSPARE1)
PCTRL	DIM input	LVDS	Reverse-channel enable/disable
PDATA	DIM input	LVDS	115 kbaud asynchronous 8-bit data; up to 2048 bytes per 1PPS 'tick'; content unspecified by VSI-H
PSPARE1	DIM input/output	LVDS	Spare; optional use as reverse channel
PSPARE2	DIM input/output	LVDS	Spare; optional use as reverse channel
PVALID	DIM input	LVDS	Global 'data-valid'
QCTRL	DOM output	LVDS	Reverse-channel enable/disable
QDATA	DOM output	LVDS	115 kbaud asynchronous 8-bit data; up to 2048 bytes transmitted between 1PPS or ROT1PPS 'ticks'
QSPARE1	DOM input/output	LVDS	Spare; optional use as reverse channel
QSPARE2	DOM input/output	LVDS	Spare; optional use as reverse channel
QVALID	DOM output	LVDS	Global 'data valid'
R1PPS	DOM output	LVDS	'Reconstructed' 1PPS

RBSn	DOM output	LVDS	'Reconstructed' bit-stream n
RCLOCK	DOM output	LVDS	'Reconstructed' data clock
ROT1PPS	DOM output	LVDS	ROT clock 1-pps
ROTMON	DOM output	TTL	ROT clock monitor
TVGCTRL	DIM output	LVDS	Optional reverse-channel TVG control (suggested use of PSPARE1)

16. References

3M Connectors:
http://www.mmm.com/Interconnects/prod_con_0531.html

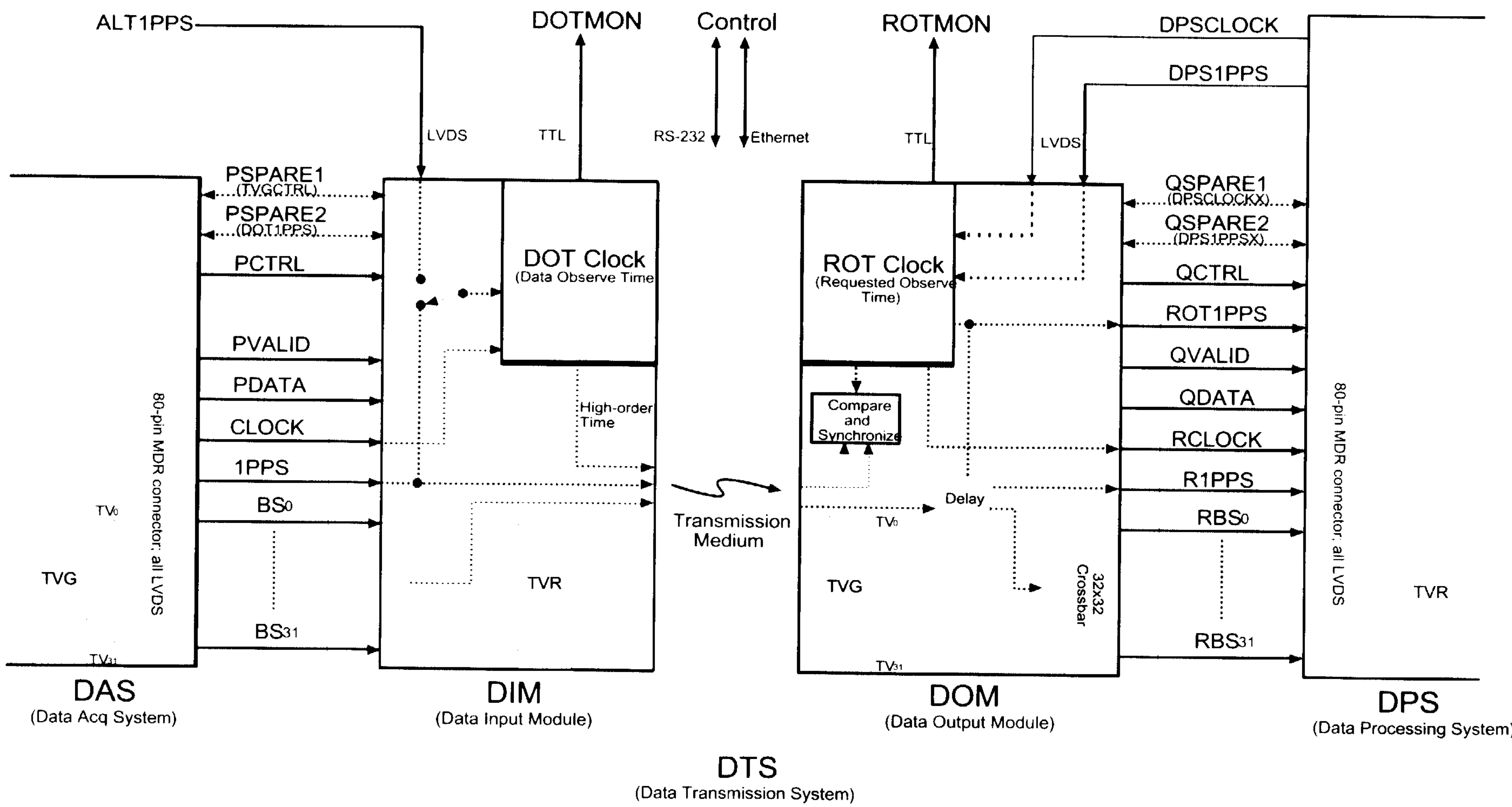
3M Pleated Foil Cable Assemblies:
http://www.mmm.com/Interconnects/Prod_cas_0804.html

Gore Max-Band Cable Assemblies:
http://www.gore.com/electronics/pages/cable/highdata/maxband.htm

TI LVDS Devices:
http://www.ti.com/sc/docs/schome.html
(At this site, perform "SC Parameter Search" for 'LVDS')

National Semiconductor LVDS Information
http://www.national.com/appinfo/lvds
(At this site, you can find the application notes by number or by category.)

Useful discussions of VSI interconnect issues:
VSI Interconnect Hardware Specifications, Dick Ferris, 15 March 2000
Derivation of Hardware Specs, Dick Ferris, 15 March 2000



Notes:
1. Shaded items are for illustrative purposes only.
2. PVALID is optionally transmitted from DIM to DOM.
3. PDATA is optionally transmitted from DIM to DOM.
4. Data delay in DOM is required only for storage-based systems.
5. See text for discussion of use of optional use of P/QSPARE1/2 signals.
6. If DIM/DOM in single box, ALT1PPS/DPSCLOCK/DPS1PPS share single MDR-14 connector.
7. This diagram does not show all functions and options -- see VSI-H specification for details.

FIG1.DRW
ARW 21 Jun 2000

Figure 1: VSI-H Functional Block Diagram

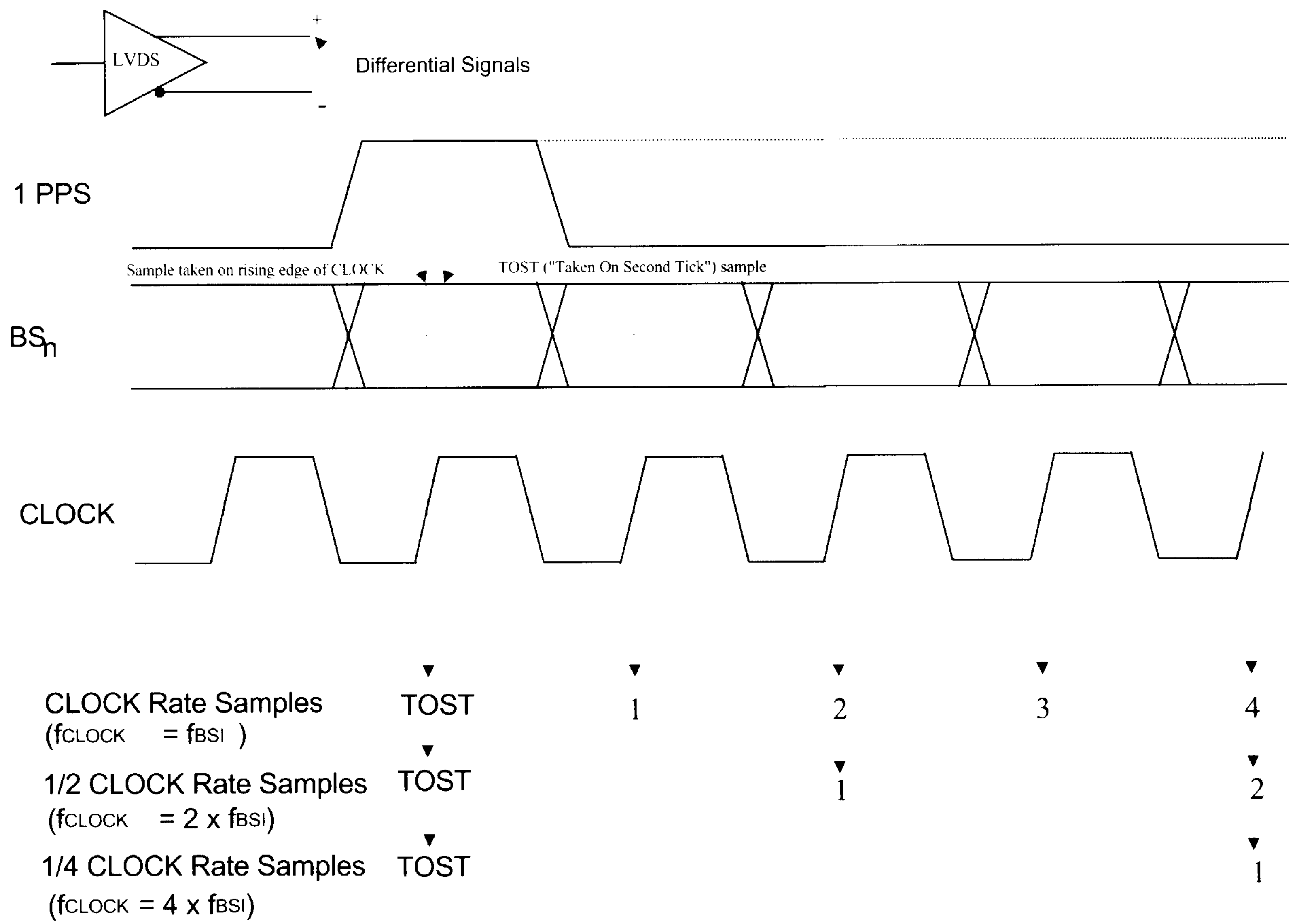


Figure 2: LVDS Timing Relationships

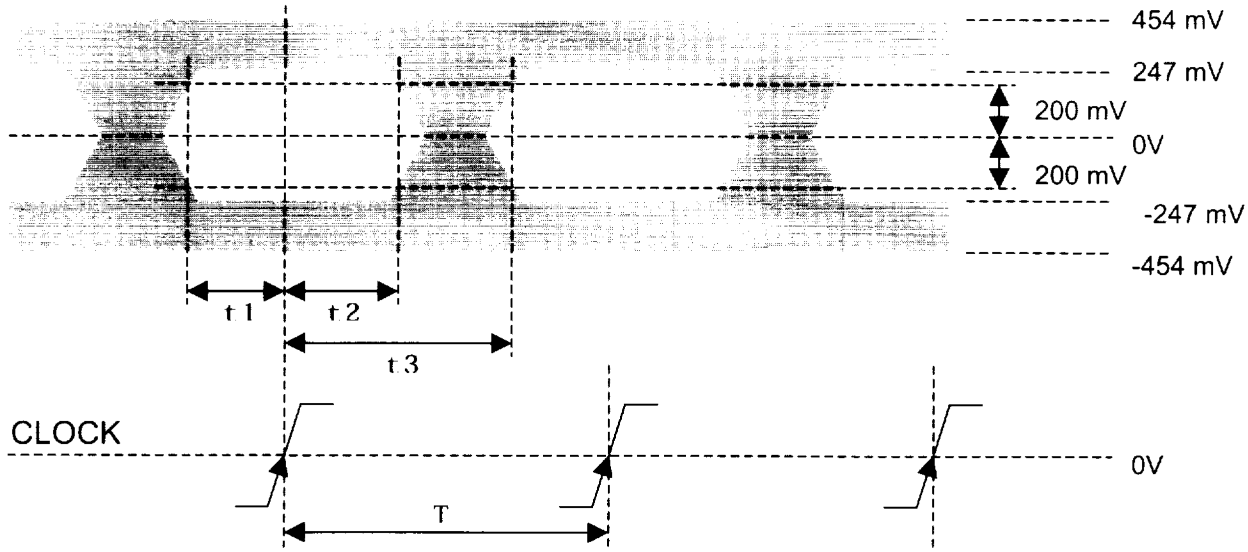


Figure 3: LVDS Transmitter Output Eye Pattern

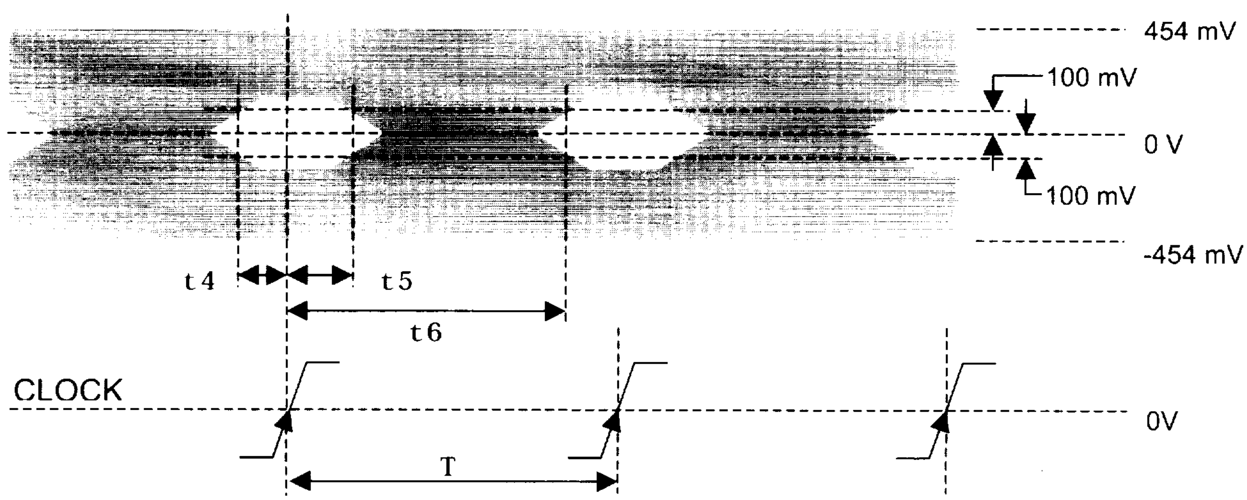


Figure 4: LVDS Receiver Input Eye Pattern

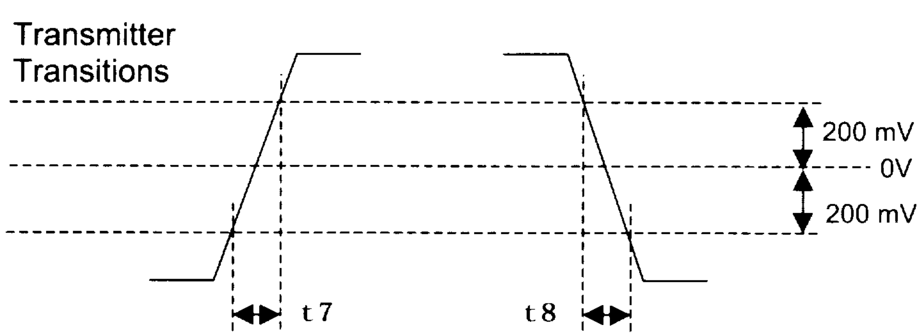


Figure 5: LVDS Waveform Transition Definitions

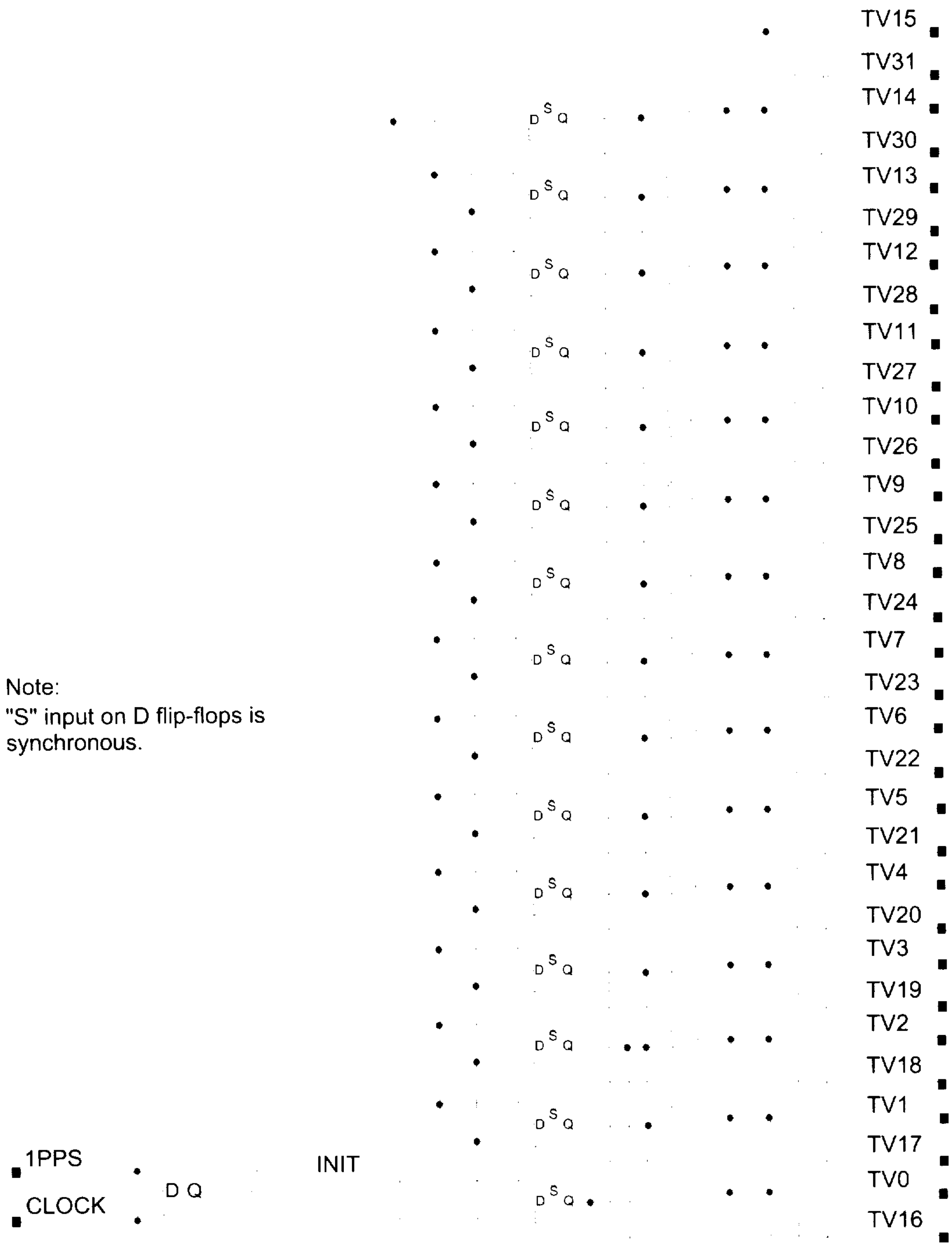
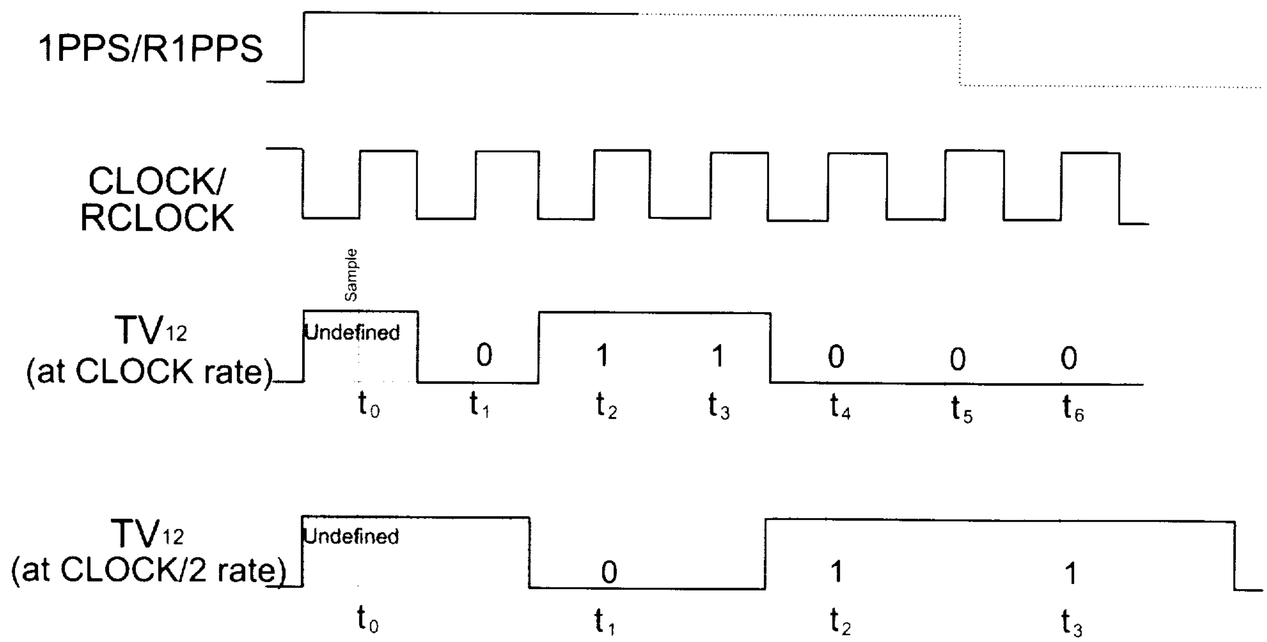


Figure 6: Test-Vector Generator Schematic

TVGEN.DRW
000422



Notes:

1. TV12 bit stream is shown for illustration.
2. The TV data streams have exactly the same timing relationship to CLOCK/RCLOC and 1PPS/R1PPS as actual data streams.
3. The TVG is initialized on every 1PPS/R1PPS tick. The TV value at t0 is undefined
4. Starting with t1, the TVG continuously cycles through the 32767-bit TVG sequenc(until the next 1 PPS/R1PPS tick, at which point the TVG is again re-initialized.

Figure 7: TVG Timing Relationships

Appendix A: Revision History

Revision 1.0, 7 August 2000

First issue

IVS COORDINATION

Coordinating Center Report

Nancy R. Vandenberg

Abstract

This report summarizes the activities of the IVS Coordinating Center from the establishment of IVS to the end of 2000, and forecasts activities planned for the year 2001.

1. Coordinating Center Operation

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

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

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

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

The IVS web site's home page is organized into three main sections: Service, Communications and Information, and Coordination. Within each main section there are three subsections, each of which contains links to tables, files, or other pages. The design of the home page is a "portal" style, which has many links on the top level and minimizes the number of clicks required to reach information.

2. Initial Activities

During the period beginning with the official inauguration of IVS and ending in December 2000, the Coordinating Center supported the following IVS activities:

- Directing Board support: Coordinated four IVS Directing Board meetings, in Birmingham (UK), Wettzell (Germany), Paris Observatory (France), and at Goddard Space Flight Center (USA). Notes from each meeting were published on the IVS web site.
- Communications support: Maintained the IVS web site, e-mail lists, and web-based mail archive files. The e-mail system and the web site are the primary means of providing communication and information services to the IVS community.
- Publications: Published the first Annual Report in summer, 1999; proceedings of the first IVS General Meeting in spring, 2000. Published the IVS flyer in fall, 2000. All publications are available electronically as well as in print form.
- Master schedules: Generated master observing schedules for 2000 and 2001. Set up master schedules for all prior years of VLBI sessions, for use by analysts and coordinators. Coordinated VLBI resources for observing time, Mark III/IV correlator usage, and tapes.
- Meetings: Coordinated, with Local Committees, support for the first IVS General Meeting held in Kötzting, Germany in February 2000 and the second Analysis Workshop held in Greenbelt, MD in February 2001.

- IVS Logo: Worked with the Directing Board and graphic artist to develop the official IVS logo, which may be seen on the cover of this publication.

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	Allocation
Nancy Vandenberg	Director	Web and data base design and content, Directing Board support, meeting support, session web pages, publications	75%
Cynthia Thomas	Operation Manager	Master schedule, resource management, meetings support, special sessions support	50%
Frank Gomez	Web Manager	Web server administration, mail system maintenance, discussion system maintenance, data center support, session processing scripts, mirror site liaison	50%
Karen Baver	Publication Support Programmer and Editor	Publication processing programs, Latex support and editorial assistance	10%

4. Plans

During the year 2001 the Coordinating Center plans include the following:

- Publish the 2000 Annual Report (this volume).
- Coordinate the first Technical Operations Workshop (TOW), to be held at Haystack Observatory in March, 2001.
- Coordinate the second General Meeting and the third Analysis Workshop, to be held in Tsukuba, Japan in February 2002.
- Support Directing Board meetings in Greenbelt, MD (February) and Barcelona, Spain (September).
- Work with the Analysis Coordinator to improve the access by IVS Analysis Centers to data and products via the IVS web site.
- Work with the Network Coordinator to improve the reporting of station performance data via the IVS web site.
- Coordinate the 2001 master observing schedule and IVS resources, and coordinate the initial version of the 2002 master schedule.

Analysis Coordinator Report

A. Nothnagel, C. Steinforth

1. Introduction

The first 15 months of working as the IVS Analysis Coordinator have shown significant progress towards making IVS a successful service. Many small tasks have been completed, eventually leading to a number of steps forward worth reporting.

Some of the ground work of the IVS Analysis Coordinator had already been laid by the IVS Acting Analysis Coordinators prior to October 1, 1999 (EUBANKS, MA, VANDENBERG, 1999). In the meantime 19 centers have been accepted either as IVS Analysis Centers or as IVS Associate Analysis Centers. The distinction between these two groups has been streamlined in the current IVS Terms of Reference (ToR) reducing the number of classes included in the initial version of the ToR.

Although the ToR calls for regular submissions of a full list of IVS products, so far only EOP results from 24 hour VLBI sessions and of Intensive UT1 observing sessions are available. By now four IVS Analysis Centers

- Bundesamt für Kartographie und Geodäsie (BKG) Leipzig, Germany
- Institute for Applied Astronomy (IAA), St. Petersburg, Russia
- Astronomical Institute of St. Petersburg University (SPU), St. Petersburg, Russia
- NASA Goddard Space Flight Center (GSFC), Greenbelt MD, USA

regularly submit their EOP results from 24 hour sessions to the IVS Data Centers for use by many scientists around the world. Up to now the four IVS Analysis Centers and the

- US Naval Observatory (USNO), Washington D.C., USA

have regularly submitted UT1 results from quasi-daily Intensive observations. Unfortunately, USNO teminated its VLBI analysis activities in October 2000.

Currently all submissions are formatted according to the IERS submission format using one data line per epoch with correlation coefficients only between EOP parameters of the same epoch. No information on the terrestrial reference frames (TRF) underlying the EOP solutions are submitted as yet. Under a different directory of the IVS data structure the results of a single TRF solution are available which are the basis of the current GSFC EOP solution.

The Analysis Centers have taken great efforts to organize their resources for regular analysis activities and submissions of the results. The regular delivery is of particular importance for the long term maintenance of consistent series. Currently, all Analysis Centers use a TRF of their choice either by fixing the corresponding values in the least squares adjustment or by transferring the TRF covariance information using pre-reduced normal equations.

Starting on October 1, 2000 the individual session EOP results are processed further in a combination procedure at the Analysis Coordinator's office in order to generate a combined IVS EOP product (see section 2). Before the comparison and combination activities of the EOP results could be started a number of obstacles had to be removed in a concerted effort. The data format and auxiliary information, although specified as standards, had to be corrected in some of the submissions. File names and directory structures were reorganized, and Analysis Centers had to be summoned to speed up their submissions. As of today the delay between observations and result dissemination is on the order of 14 days.

The combination of the results of different solutions to one combined product serves several purposes. In the combination process the individual solutions complement and control each other leading to a higher accuracy and a higher reliability. Considering the facts that the constellation of analysis centers may change for various reasons or that errors in data and product submissions occur, the redundancy of analyses is of general importance: the more Analysis Centers contribute the smaller the effect of taking out or adding a contributor. This improves not only the individual results but stabilizes long-standing series in general. Any differences can be analysed for the detection of outliers and their causes can be investigated. Another aspect of combination is that more objective error bounds can be established which is of particular importance where formal errors are not representative.

Although one of the fundamental rules of statistics is to never use an observation more than once, it is still appropriate to produce combined results from submissions of different Analysis Centers. They are using different software packages and/or different analysis strategies by e.g. rejecting different data points, using different weighting schemes, or using different reference frames for station coordinates or radio source positions. All this leads to independent analyses as well as to independent and slightly different results.

An important aspect of carrying out the combinations is, of course, the correct relative weighting of the Analysis Centers. For this the use of the scatter in the nutation offset results of each center relative to a combined average is currently deemed to be the most appropriate approach which is unique for combinations of space geodetic results.

2. IVS Combination Procedure

On December 22, 2000, the availability of the combined IVS EOP products was officially announced by the IVS Analysis Coordinator. This section provides a description of the combination strategy being used. In addition, some topics are listed which will need further investigation to refine this strategy or to mitigate known problems of the combination.

The combination strategy can be divided into two steps. In the first step, a comparison of the results is carried out to derive relative weights for the Analysis Centers and to determine biases to maintain consistency with a reference series. In the second step the results of the individual Analysis Centers are combined into one solution by applying the weighting factors and the biases.

In the following formulae the total number of Analysis Centers contributing to the combination is denoted by n, the index i designates the respective Analysis Center (AC). The total number of epochs is m, the epochs are labelled by j.

In the current combination **the full variance/covariance matrix is used**, whereas in the following formulae the correlations between the parameters are omitted for more clarity.

2.1. Data Preparation

2.1.1. Weighting Factors

For the comparisons the question arises of how to establish relative weights for the individual analysis centers since weighted averages have to be computed as a first reference. It is quite clear that these cannot only depend on the formal errors assigned by the Analysis Centers alone. For this purpose the scatter of the nutation angels $d\psi$ and $d\epsilon$ appears to be a suitable indicator. The celestial reference frame as such is very stable at the sub-milliarcsecond level and deficiencies of individual sources average out in the large number of sources used in geodetic VLBI series. Therefore, most of the scatter to be found in the individual nutation offset series can be attributed to the way the analysis is carried out, e.g. which software and parameterization is used (analyst's noise).

Initial mean values are computed for each epoch where the input data is only weighted according to the formal errors assigned by the Analysis Centers.

$$\overline{d\psi}_j \sin\epsilon_0 = \frac{\sum\limits_{i=1}^{n} p_{d\psi_{ij}} d\psi_{ij} \sin\epsilon_0}{\sum\limits_{i=1}^{n} p_{d\psi_{ij}}} \tag{1}$$

and

$$\overline{d\epsilon}_j = \frac{\sum\limits_{i=1}^{n} p_{d\epsilon_{ij}} d\epsilon_{ij}}{\sum\limits_{i=1}^{n} p_{d\epsilon_{ij}}} \tag{2}$$

with $p_{d\psi_{ij}}$ and $p_{d\epsilon_{ij}}$ being the respective weights

$$p_{d\psi_{ij}} = \frac{1}{\sigma^2_{d\psi_{ij}}} \tag{3}$$

and

$$p_{d\epsilon_{ij}} = \frac{1}{\sigma^2_{d\epsilon_{ij}}} \tag{4}$$

In the next step biases for each nutation offset and analysis center are computed from the residuals:

$$v_{d\psi_{ij} \sin\epsilon_0} = d\psi_{ij} \sin\epsilon_0 - \overline{d\psi}_j \sin\epsilon_0 \tag{5}$$

and

$$v_{d\epsilon_{ij}} = d\epsilon_{ij} - \overline{d\epsilon}_j \tag{6}$$

$$bias_{i,d\psi \sin\epsilon_0} = \frac{\sum\limits_{j=1}^{m} p'_{d\psi_{ij}} v_{d\psi_{ij} \sin\epsilon_0}}{\sum\limits_{j=1}^{m} p'_{d\psi_{ij}}} \tag{7}$$

and

$$bias_{i,d\epsilon} = \frac{\sum\limits_{j=1}^{m} p'_{d\epsilon_{ij}} v_{d\epsilon_{ij}}}{\sum\limits_{j=1}^{m} p'_{d\epsilon_{ij}}} \tag{8}$$

where $p'_{d\psi_{ij}}$ and $p'_{d\epsilon_{ij}}$ are the weights of the respective residuals, computed from

$$p'_{d\psi_{ij}} = \frac{1}{\sigma'^2_{d\psi_{ij}}} \tag{9}$$

and

$$p'_{d\epsilon_{ij}} = \frac{1}{\sigma'^2_{d\epsilon_{ij}}} \tag{10}$$

with

$$\sigma'^2_{d\psi_{ij}} = \chi^2_{d\psi_j}(\sigma^2_{d\psi_{ij}} - \frac{1}{\sum\limits_{i=1}^{n} p_{d\psi_{ij}}}) \tag{11}$$

and

$$\sigma'^2_{d\epsilon_{ij}} = \chi^2_{d\epsilon_j}(\sigma^2_{d\epsilon_{ij}} - \frac{1}{\sum\limits_{i=1}^{n} p_{d\epsilon_{ij}}}) \tag{12}$$

with the respective χ^2 per degree of freedom

$$\chi^2_{d\psi_j} = \frac{\sum\limits_{i=1}^{n} p_{d\psi_{ij}} v^2_{d\psi_{ij}\sin\epsilon_0}}{n-1} \tag{13}$$

and

$$\chi^2_{d\epsilon_j} = \frac{\sum\limits_{i=1}^{n} p_{d\epsilon_{ij}} v^2_{d\epsilon_{ij}}}{n-1} \tag{14}$$

The quantity χ^2 is also called variance of unit weight (Koch 1988). From the bias-free series a weighted root mean squared error (wrms) is computed for each analysis center combining both nutation components in a root sum squared (rss) sense:

$$wrms_{i,nut} = \sqrt{wrms^2_{i,d\psi\sin\epsilon_0} + wrms^2_{i,d\epsilon}} \tag{15}$$

with

$$wrms_{i,d\psi\sin\epsilon_0} = \sqrt{\frac{\sum\limits_{j=1}^{m} p'_{d\psi_{ij}\sin\epsilon_0}(v_{d\psi_{ij}} - bias_{i,d\psi\sin\epsilon_0})^2}{\sum\limits_{j=1}^{m} p'_{d\psi_{ij}}}} \tag{16}$$

and

$$wrms_{i,d\epsilon} = \sqrt{\frac{\sum\limits_{j=1}^{m} p'_{d\epsilon_{ij}}(v_{d\epsilon_{ij}} - bias_{i,d\epsilon})^2}{\sum\limits_{j=1}^{m} p'_{d\epsilon_{ij}}}} \tag{17}$$

The combined wrms of the nutation offsets are then used to derive new weighting factors for each of the analysis centers:

$$f_i = \frac{wrms_{i,nut}}{\overline{wrms}_{nut}} \tag{18}$$

where

$$\overline{wrms}_{nut} = \frac{1}{n}\sum_{i=1}^{n} wrms_{i,nut} \tag{19}$$

Finally new weights $p^{(new)}_{d\psi_{ij}}$ and $p^{(new)}_{d\epsilon_{ij}}$ for the input data are calculated:

$$p^{(new)}_{d\psi_{ij}} = f_i p^{(old)}_{d\psi_{ij}} \quad (20)$$

and

$$p^{(new)}_{d\epsilon_{ij}} = f_i p^{(old)}_{d\epsilon_{ij}} \quad (21)$$

For fine tuning, the process is then repeated by applying the new weights to the input data (Fig. 1). Table 1 gives an impression of the current level of agreement of the weighting factors.

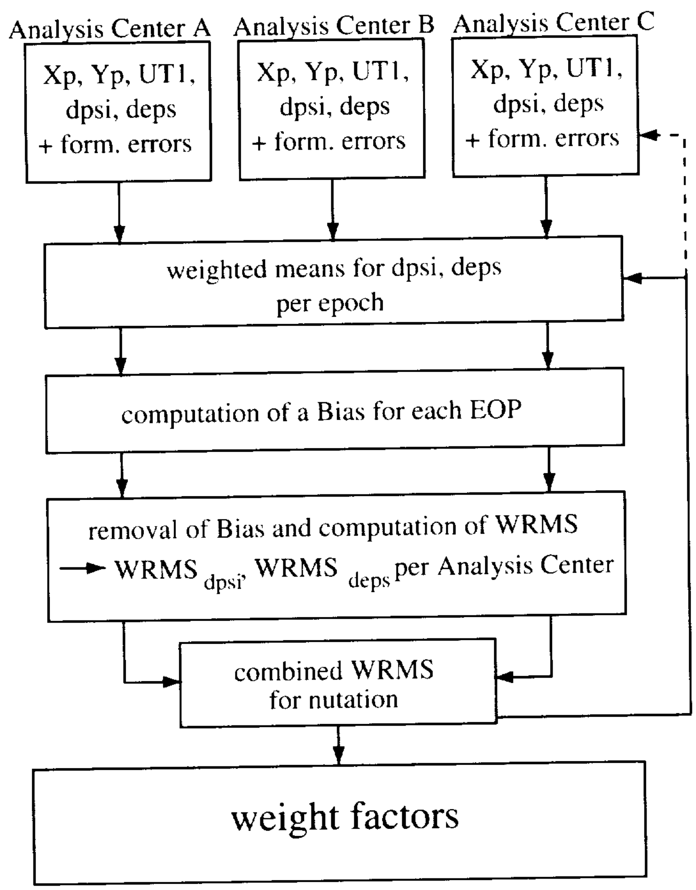


Figure 1. Comparison procedure

2.1.2. Offsets relative to IERS C04

Since the users of the combined series will also rely on the long term stability of EOP series this requirement has to be taken into account in the combination process. While the nutation offset series are fairly uncritical due to their young history and their direct connection to VLBI observations, polar motion and UT1-UTC series have a long history. Consistency with the reference series C04 of the International Earth Rotation Service (IERS) (e.g. IERS, 1996) is considered to be of importance and should, therefore, be maintained. The next step before combination is,

Table 1. Weighting factors

AC	weighting factor
BKG	1.06
GSFC	1.00
IAA	0.90
SPU	1.06

thus, the determination of offsets between the individual series and the IERS C04 series. Biases are computed from data sets of each individual Analysis Center which cover the period from the beginning of 1999 to September 30, 2000, the date immediately prior to the first epoch of combination. The computation is shown by example for the x component of polar motion.

At first, differences between the respective data point of each analysis center and the corresponding C04 point are calculated:

$$v_{x_{ij}} = x_{C04,j} - x_{ij} \tag{22}$$

The differences $v_{x_{ij}}$ are then used to compute the biases:

$$bias_{i,x} = \frac{\sum\limits_{j=1}^{m} p_{x_{ij}} v_{x_{ij}}}{\sum\limits_{j=1}^{m} p_{x_{ij}}} \tag{23}$$

As long as no changes in the strategy of the solution are introduced the biases are frozen (cf. Table 2). New biases are computed from time to time for controlling purposes and may be applied if necessary.

2.2. Final Combination

For each data point the respective bias and weighting factor are applied before a weighted average is computed yielding the combined EOP value (Fig. 2). As an example the formula for the combined x component of the polar motion for epoch j is given by the following equation (24):

$$x_{j,combi} = \frac{\sum\limits_{i=1}^{n} f_i p_{x_{ij}} (x_{ij} - bias_{i,x})}{\sum\limits_{i=1}^{n} f_i p_{x_{ij}}} \tag{24}$$

and for y and UT1-UTC analogously. For the combination of the nutation offsets cf. equation (27). The accuracy of one combination data point can be obtained by applying the law of error propagation (Koch 1988):

$$\sigma^2_{x_{j,combi}} = \frac{\hat{\sigma}^2_{0,x_j}}{\sum\limits_{i=1}^{n} f_i p_{x_{ij}}} \tag{25}$$

with the χ^2 per degree of freedom

$$\hat{\sigma}^2_{0,x_j} = \chi^2_{x_{j,combi}} = \frac{\sum\limits_{i=1}^{n} f_i p_{x_{ij}} [x_{j,combi} - (x_{ij} - bias_{i,x})]^2}{n-1} \tag{26}$$

In equation (24) the biases and the weighting factors are regarded to have no errors. In a refined strategy, which has to be set up soon, these errors have to be taken into account, too.

No bias is applied to the combination of the nutation offsets, only the weighting factors are used

$$d\epsilon_{j,combi} = \frac{\sum\limits_{i=1}^{n} f_i p_{d\epsilon_{ij}} d\epsilon_{ij}}{\sum\limits_{i=1}^{n} f_i p_{d\epsilon_{ij}}} \tag{27}$$

and for $d\psi$ analogously. The results of the combinations are regularly updated. They are available

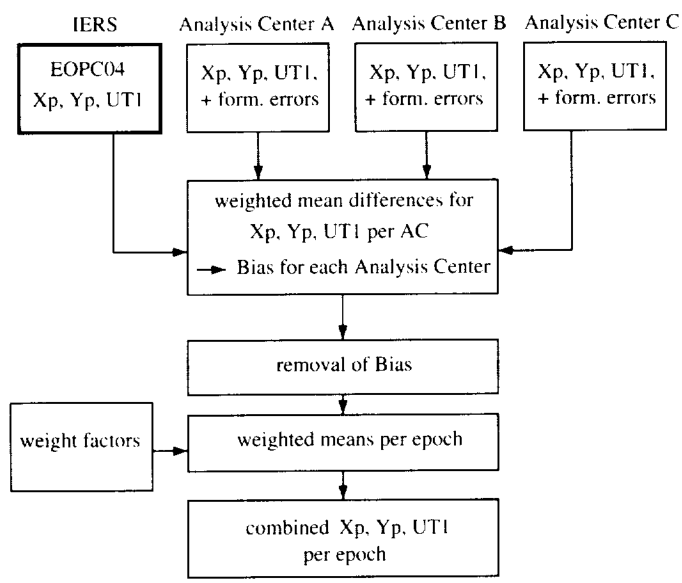


Figure 2. Combination strategy

both graphically and numerically on the IVS Analysis Coordinator's web page via the IVS Home page or directly from *http://miro.geod.uni-bonn.de/vlbi/IVS-AC/index.html.* As an example the combined series for polar motion is printed in Figure 3 and Table 2 summarizes the average statistics of the current combination solution.

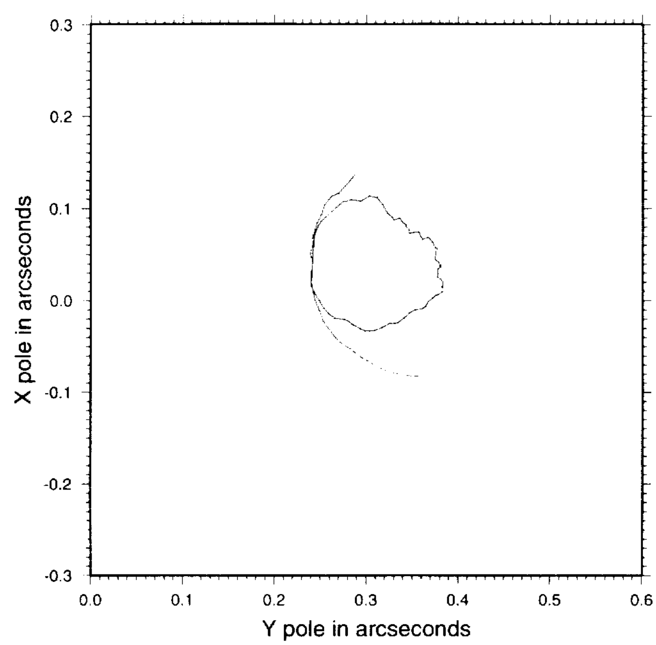


Figure 3. IVS combined polar motion

2.3. Further Investigations and known Problems

The strategy described above reflects the first steps towards a rigorous combination of Earth orientation parameters. Of course, there are well-known problems of the current combination procedures. These problems can be divided roughly into two groups:

- deficiencies of the stochastic model
- quality control and redundancy

The combination strategy presented implies actually a violation of the basic rule that the same data cannot be used twice in an adjustment process. This is presently neglected by treating the input data of the Analysis Centers as "new" data. The described deficiency can perhaps be mitigated by introducing a kind of correlation between the Analysis Centers since the data from VLBI experiments is limited. The question of the correct relative weighting has to be considered carefully, too.

Another task is the implementation of a suitable method for outlier detection and elimination to increase the reliability and robustness of the combined solution. A further extension to the stochastic model will be the estimation of variance-covariance components. Different methods of the estimation of variance-covariance components have to be checked. Furthermore, a rigorous link between EOP and TRF on the basis of SINEX input should be established in a refined combination procedure.

Table 2. Current average statistics

	x_p		y_p		$UT1 - UTC$		$d\psi \sin \epsilon_0$		$d\epsilon$	
	bias [μas]	wrms [μas]	bias [μas]	wrms [μas]	bias [μs]	wrms [μs]	bias [μas]	wrms [μas]	bias [μas]	wrms [μas]
BKG	-109	56	20	62	18	3	-26	43	-1	36
GSFC	22	66	-25	80	-17	3	8	45	20	60
IAA	87	77	-133	75	-6	3	-8	51	-9	44
SPBU	42	73	-147	72	-15	3	28	47	-3	37

3. IVS Data Centers

One of the key issues of a service like IVS is a timely and reliable dissemination of the raw observing data to the IVS Analysis Centers and of the results to the users. In this scenario the IVS Data Centers play an important role since the necessity of permanent accessibility requires constant maintenance of the equipment. A careful mirroring scheme guarantees that the data at the three primary IVS Data Centers at

- Bundesamt für Kartographie und Geodäsie (BKG) Leipzig, Germany
- Observatoire de Paris (OPA), Paris, France
- NASA Goddard Space Flight Center (GSFC), Greenbelt MD, USA

are always as consistent as possible. It is noteworthy that with this scheme and with the strong commitments of the Data Centers the IVS data and the IVS products have been available worldwide without interruption.

4. First IVS Analysis Workshop

On February 24, 2000 the first IVS Analysis Workshop was organized in conjunction with the IVS 2000 General Meeting at Kötzting on Feb. 21-24, 2000. In this workshop the many different geodetic and astrometric analysis activities were discussed and some basic aspects were coordinated (NOTHNAGEL, 2000). In view of the many tasks to be organized and to be distributed en route to the establishment of a service covering all products to be generated eventually this workshop was only a first basic step forward. A second workshop to be held in February 2001 will refine the initial ideas taking into account the achievements and experience of the first year.

During the first IVS Analysis Workshop five IVS Analysis Working Groups were established. However, the activities of the working groups were less enthusiastic than anticipated when they were established, a fact which will have to be looked at in the next workshop as well.

So far only the Analysis Coordinator's office regularly publishes combined Earth orientation parameters. However, other Analysis Centers are encouraged to take up this task in parallel in order to establish quality control and redundancy. The comparison with independent series or solutions is a helpful measure to reveal weaknesses or inconsistencies of the combination strategy in use.

Acknowledgements

The work of the IVS Analysis Coordinator would not have been possible without the many individuals who submitted data and results or provided support in any aspect of operation. Of equal importance are those who contributed in the discussions and made suggestions, of which not all could be realized. We are thankful for all these contributions.

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Koch K.-R. (1988): *Parameter Estimation and Hypothesis Testing in Linear Models*, Springer, Berlin

Nothnagel A. (2000): *Excerpts of the first IVS Analysis Workshop* International VLBI Service for Geodesy and Astrometry, 2000 General Meeting Proceedings; NASA/CP-2000-209893, Hanover MD, 393-396

Network Coordinator Report

Ed Himwich

Abstract

This report summarizes the activities of the IVS Network Coordinator from the establishment of IVS to the end of 2000. It includes an assessment of the network performance in yielding usable data over an approximately 12 month period. The report forecasts activities planned for the year 2001.

1. Network Coordination Activities

The activities of the Network Coordinator fell primarily into two areas: monitoring the status of network station performance and developing station configuration files.

The main effort in network coordination was monitoring the performance of the stations. This was done primarily by monitoring the "ivs-ops" messages from the stations, correlator reports (both prepass and final), and analyst reports. There were virtually no analyst reports in this period. The various reports were checked. If any problems were reported, they were pursued with the station and cognizant experts. Because this information was reported on a per session basis, it was rather difficult to get a clear view of how any particular station was performing. Consequently, it was decided that a station performance data base that stores the information by station should be developed. This data base was started in the spring of 2000. Currently, it is maintained by hand as an Excel spreadsheet. A summary of the station performance is presented in a separate section below.

One of the goals for network coordination is to develop a data base of information about each site and its configuration. During 1999 an ASCII template of information was developed. Each station can fill it out to describe the equipment and environment of the station. So far about half the IVS Network Stations have completed the form. The completed forms can be viewed from the Station Configuration Files link on the IVS Coordinating Center web page.

2. Network Performance

The station performance data base contains a wealth of information about station performance and problems. It includes all reports of problems from correlator pre-passes, correlation reports, analysts, and stations as well as a history of inquiries made about resolving problems. It was started in May of 2000 and includes all information since then. There were no analysts reports except for occasional e-mails about problems processing certain sessions.

It was decided that the correlator reports formed the most reliable, albeit not the most timely basis, for monitoring station performance. (Within the data base, the issue of timely response is addressed by the station and correlator pre-pass reports.) The coverage of sessions in the correlator reports is somewhat spotty due to delays in processing sessions, the unevenness of the delays, and problems related to the start up of the Mark IV. As of early January 2001 the set of correlator reports in the data base covers many, but not all, of the sessions from November 1999 through December 2000. The data base includes 69 sessions with 388 station days (about 5.6 stations per session on average).

Any assessment of station performance is somewhat arbitrary, but the following approach was used. For each station in each session an estimate is made of how large the data loss was. Each station day was then assigned to one of the following categories: (A) No data loss (0% lost), (B) Slight Data Loss (1-6% lost), (C) Moderate Data Loss (7-20% lost), (D) Severe Data Loss (21-70% lost), and (F) Failed (71-100% lost). Again these categories are somewhat arbitrary. The divide between slight and moderate loss was set so that loss of one channel (7%) was considered moderate. Consequently, the slight category includes mostly some RFI, and short data losses, up to a little less than 90 minutes. The divide between moderate and severe was set so that loss of three channels (21%) would be severe. This means that the loss of two channels or gaps of up to about 5 hours would be considered moderate. Severe data loss includes loss of three channels or more, operation with a warm receiver, long data gaps, and other severe problems. Failure includes any cases where the data from the station is not useful geodetically. The definitions of these categories will probably undergo some refinements in the future.

Using the above criteria, the 388 stations days in the data base are distributed as follows: (A) No Data Loss, 48%, (B) Slight Data Loss, 25%, (C) Moderate Data Loss, 12%, (D) Severe Data Loss, 3%, and (F) Failure, 6%. In essence this means that 94% of the station days was usable, although this statistic ignores the fact that some usable days were significantly degraded. In the future reports, the cause of the data losses will be described as well.

3. Plans

During the year 2001, the plans for network coordination include: further use and development of the station performance data base including possibly making it accessible from the web, encouraging the remaining stations that have not submitted site configuration files to do so, development of a local site survey data base and the development of performance standards.

It was recognized in 2000 that it would be useful to develop a data base of site tie information, both for connecting VLBI stations to local monuments, but also between VLBI and other collocated techniques. This will be developed further next year.

Technology Coordinator Report

Alan Whitney

Abstract

The main effort of the Technology Coordinator during 2000 was devoted to completing the VLBI Standard Interface hardware specification (so-called VSI-H). This specification is now complete and has been approved by both IVS and the astronomy community. Work is now beginning on the software counterpart, VSI-S. The VSI-H specification is available in the Special Reports section of this volume and at `http://dopey.haystack.edu/vsi/index.html`.

1. VLBI Standard Interface

After 18 months of effort, the VSI-H specification was formally approved on 7 August 2000 by the VSI Technology Coordination Committee. This followed many discussions and many iterations of VSI-H draft specifications, including an international 2-day meeting at Haystack Observatory in January 2000. The specification has been subsequently approved and adopted by both IVS, representing the geodetic community, and GVWG, representing the astronomy community. The VSI-H specification is the hardware part of the VLBI Standard Interface Specification, which will allow the transmission of data to and from heterogeneous VLBI Data Transmission Systems (DTS). The VSI goal is to specify a common interface to be compatible with traditional recording/playback system, network data transmission and even direct-connect systems. In order to do this, the design of the VSI must completely hide the detailed characteristics of the data-transport mechanisms and deal only with the interfaces to the outside world.

The following assumptions were made in the development of the VSI specification:

- The DTS is fundamentally a receiver and transmitter of *bit streams*
- The *meaning* of individual bit streams is not specified; normally, a bit-stream will be a stream of sign or magnitude bits associated with particular samples, but the actual meaning is to be mutually agreed upon between the data-acquisition system and the correlator.
- The received and transmitted bit-stream clock rates may be different (e.g. the playback rate to the correlator may be speeded-up or slowed-down); however all bit-stream clock rates on acquisition must be the same, and all bit-stream clock rates on transmit must be the same.
- The data-acquisition time-tag of every bit in every bit-stream must be fully recoverable with no ambiguity.

Some of the 'features' of the VSI-H specification include:

- definition of a 1 Gbit/sec 'Quantum Channel':
    1. 32 parallel bits streams
    2. 32 MHz (extensions to 64, 128 MHz for 2, 4 Gbit/sec 'quantum channel')
- One standard 80-pin connector per 'quantum channel':
- Standardized electrical and timing specifications

- Low-voltage differential-signal (LVDS) electrical signal interface
- Method of time-tagging data is totally internal to DTS and not specified by VSI-H
- Built-in Test-Vector Generator/Receiver capability
- Model-delay capability to simplify direct connection to correlator
- Two levels of compliance defined to ease transition to new systems
- Easy media translation (i.e. tape copying)

Work is now beginning on the software part of the VSI specification, dubbed VSI-S. We hope to complete this effort by the end of 2001.

I wish to extend special thanks to all the other members of the VSI Technology Committee for their many efforts to bring the VSI-H specification to reality:

- Wayne Cannon - York University, Canada
- Brent Carlson - DRAO, Canada
- Dick Ferris - ATNF, Australia
- Dave Graham - MPI, Germany
- Tetsuro Kondo - CRL, Japan
- Nori Kawaguchi - NAO, Japan
- Misha Popov - ASC, Russia
- Sergei Pogrebenko - JIVE, Netherlands
- Jon Romney - NRAO, U.S.
- Ralph Spencer - Jodrell, England
- Rick Wietfeldt - JPL, U.S.

The success of VSI-H may be measured in part by the fact that at least three institutions are already developing equipment designed to be in compliance with the VSI-H specification. The full 30-page VSI-H specification, along with an interesting historical chronology of its development, is reprinted in this volume and is available at `http://dopey.haystack.edu/vsi/index.html`.

2. Other Activities

Other planned and ongoing activities in the technology coordination area are:

1. Formation of a few small subgroups with interest in particular technology areas. The members of these subgroups will be drawn from IVS technology centers and other experts in the field. These sub-groups, interacting primarily via e-mail, will be asked to develop a list of concerns and goals and to suggest the steps needed to achieve them. The VLBI Standard Interface group serves as a prototype for this type of activity.

2. Coordination of an index of published papers and memos in all of the relevant VLBI technology areas. Ideally, this will be a Web-based index with links to electronic versions of the referenced material. All IVS technology development centers, as well as other experts in the field, will be invited to contribute.
3. As an ongoing activity, promote and encourage inclusion of topical sessions on advanced VLBI technology at international meetings and workshops.

NETWORK STATIONS

Algonquin Radio Observatory

Mario Bérubé, Calvin Klatt

Abstract

The Algonquin Radio Observatory (ARO) is situated in Algonquin provincial park, about 250 km north of Ottawa and is operated by the Geodetic Survey Division of Natural Resources Canada in partnership with the Space Geodynamics Laboratory, CRESTech.

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

This report summarizes recent activities at the Algonquin Radio Observatory.

Figure 1. Algonquin Radio Observatory 46m Antenna

1. Overview

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

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

2. Antenna Improvements

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

This antenna control system still uses the original azimuth and elevation encoders to determine antenna position. We are in the process of upgrading them in a way that should not affect scheduled operations.

The antenna field system was modified to allow satellite tracking.

The ARO is currently using a Mk3 VLBI system (on long-term loan from NASA) and we expect to upgrade to Mk4 early in 2001. ARO is equipped with an S2 data acquisition system and recording terminal and has played a crucial role in testing and development of the Geodetic S2 system.

We are developing an L-band receiver for bi-static radar applications. This receiver may be useful for reception of GPS signals.

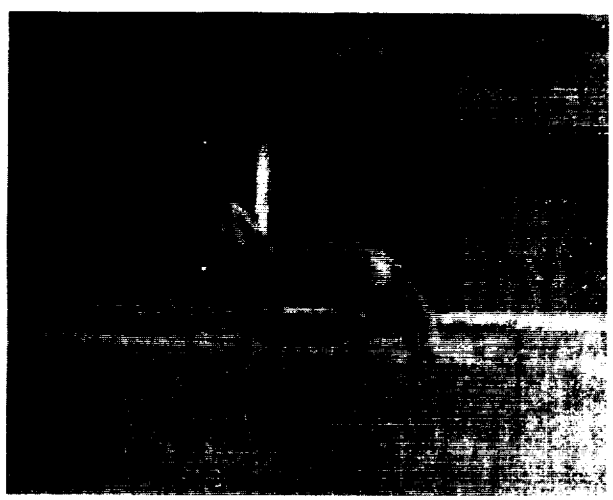


Figure 2. Fox at the Algonquin staff house

3. General specifications

- Latitude : N 45 57 19.812
- Longitude : E 281 55 37.055
- Elevation : 260.42 m
- Reflector : 46 m diameter with first 36.6 m made of 0.634 cm steel [illegible]

m of steel mesh.

- Foci : S and X band at prime focus. Gregorian capability with 3 m elliptical subreflector.
- Focal length : 18.3 m (prime focus)
- Focal ratio : f/D = 0.4 for full surface and 0.5 for solid surface.
- Surface accuracy : 0.32 cm for solid portion and 0.64 for mesh.
- Beamwidth : 3.0 arcmin at 3 cm wavelength (10Ghz)
- Azimuth speed : 24 degrees per minutes.
- Elevation speed : 10 degrees per minutes.
- Receiver : S and X cryogenic receiver.
- VLBI equipment : MkIII with thick tape drive. To be upgraded to MkIV in 2001.

  S2 data acquisition and recording terminal.
- PCFS version : 9.4.13
- Time standard : NR Maser
- GPS receiver : Rogue

4. Antenna Survey

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

We have recently re-measured the network. In addition to tying GPS and SLR to VLBI, we will attempt to study antenna deformation as a function of elevation angle.

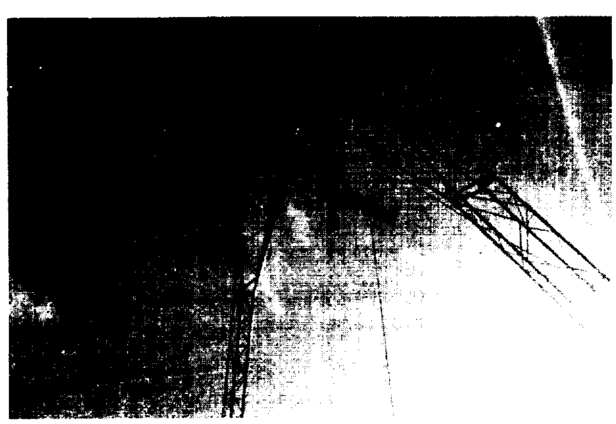


Figure 3. Rapelling off the Algonquin 46 m Antenna

5. Algonquin Operations

A new GSD staff member, Anthony Searle, has joined the VLBI group at GSD and has been assisting with experiment operations.

Algonquin Radio Observatory is involved in several international VLBI networks. We summarize below the geodetic VLBI activities in the reporting period.

A number of additional experiments have taken place in recent years at ARO. In September 1999 ARO was used to transmit high energy pulses to assist in the characterization of sensors on board satellites. ARO also participates in international astronomical observations as part of the "Polar Bear Network".

In 2001, the ARO is scheduled in weekly NEOS experiments plus 12 CORE experiments. We anticipate that it will also participate in 10-20 CGLBI (Canadian Geodetic Long Baseline Interferometry) S2-based experiments.

Experiments Performed March 1, 1999-December 31, 2000

Experiment Type	March-December 1999	January-December 2000
NEOS-A	10	31
CORE-A	21	6
CGLBI	6	17
CORE-B	6	3
CORE-1	0	6
NAVEX	2	0
CRF	1	1

2000 Activities Report of Fortaleza Station

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

Abstract

This report summarizes the activities performed at Fortaleza Station (ROEN: Rádio Observatório Espacial do Nordeste), Eusébio, CE, Brazil, managed by CRAAE (Centro de Rádio Astronomia e Aplicações Espaciais) in agreement with INPE (Instituto Nacional de Pesquisas Espaciais), in the time period starting March 1, 1999 and ending December 31, 2000.

1. Geodetic VLBI Observations

Fortaleza participated in 123 geodetic VLBI experiments as detailed in the table below:

Experiment	Number of Sessions
NEOS-A	91
IRIS-S	19
CORE-B	08
CORE-OHIG1	04
CRF	01

2. Development and Maintenance Activities

1. Replacement and alignment of magnetic heads of the tape recorder.
2. Antenna drives electrical alignment including controller card, high power amplifier, DC motor and tachometer for the elevation antenna axis.
3. Installation of a new and updated FS computer.
4. Replacement of the cold-head refrigerator of the cryogenic system.
5. Repairs on the following circuits, modules, or systems: Mark III video converters, Mark III decoder module, Mark III power supply module II, DC motor of elevation axis, UPS battery system, monitoring system of receiver, noise calibration diodes controller, hydrogen maser, the controller of motor-generator group, and the cryogenic system.
6. Creation of an english version of web site (http://www.roen.inpe.br) about ROEN activities.

3. GPS Operation

The IGS network GPS receiver operated regularly all the days. Data were collected and uploaded to the IGS computer.

4. Research

Continuation of Washington correlator data analysis on various celestial sources. Significant progresses obtained on structure of source 1803+784.

Gilmore Creek Geophysical Observatory

Rich Strand

Abstract

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

Figure 1. NOAA/NASA Data Acquisition and Geophysical Observatory. Fairbanks, Alaska

1. GCGO at Fairbanks

Gilmore Creek Geophysical Observatory (GCGO) is located 22 km NorthEast of Fairbanks, Alaska. The observatory is co-located with the NOAA weather satellite command and data acquisition station. The station sits on an 8,500 acre reservation that is mostly undeveloped wilderness. Ten antennas are in operation. The GCGO telescope can be seen in the photo as the last antenna on the right in the valley. GCGO was instrumented by NASA's Crustal Dynamics Project in the mid 80's for the Alaskan mobile VLBI campaign and used as the base station for those geodetic measurements [1]. The GCGO is part of the NASA Space Geodesy program in cooperation with the U.S. Naval Observatory.

Table 1. Address of GCGO near Fairbanks.

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

2. Technical Parameters of GCGO

The 26 meter telescope, Monument Number 4047, X-East Y-North, Latitude N 64° 58' 43.81288" and Longitude E 147° 29' 42.18552" Height 306.418 meters is hydraulically operated and controlled by a Modcomp computer system (see table 2). The DAT rack is a VLBA terminal and recorder (thin tape). The X/S band microwave receiver has a cryogenic low noise front end. VLBI Field System version 9.4.14 is used with a PC. Hydrogen Maser NR 5 is the time standard with an HP Cesium for the telescope computer. A CNS (TAC) receiver is monitored by the TAC32 software for GPS offset measurements. The station also runs two NASA/JPL Rogue receivers 8100 running JPL VO5 scintillation software. UCLA maintains the HIPAS receive system located in the GCGO. The Institut Geographique National in France operates their new DORIS beacon that is located near the NOAA VHF transmitter building.

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

GCGO is co-located with the NOAA data acquisition facility. The NOAA Manager is Jim Budd. The site is operated by the Lockheed Technology Services Group with Doug Ooms as Lockheed Project Manager and Roger Kermes, Lockheed Operational Manager. R. Strand and S. Caskey are assigned to GCGO technical staff with T. Knuutila, Z. Padilla, H. Grotsema, and D. Eubanks assisting. The telescope hydraulic system is maintained by M. Meindl, A. Sanders and F. Holan.

Figure 2. GCGO Ops crew Knuutila, Caskey, Strand

4. Status of Gilmore Creek Geophysical Observatory

GCGO will be observing eight sessions per month on average, with 102 sessions scheduled for year 2001. We observe NEOS every other week and IRIS once a month. CORE observing with R&D, APSG, CRF and Survey completes the program. Several dewar swaps were made during this reporting period. One 28V DC power supply failed in the DAR. The major data loss was the failure of the Y axis hydraulic pump on the telescope in Aug 2000. Field System software development continues by Ed Himwich, NVI, Inc., using the station's DAT racks and telescope for testing.

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

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

Table 3. VLBI observing at Gilmore Creek between 03/01/98 and 03/01/99.

Year 1999 Experiments assigned to GCGO - 93 Observations scheduled - 23817 Observations recorded - 23353 Efficiency - 98.05%
Year 2000 Experiments assigned to GCGO - 67 Observations scheduled - 20613 Observations recorded - 19605 Efficiency - 95.11%

5. Outlook

Increased observing for 2001 is scheduled.

References

[1] C.Ma,J.Sauber,L.Bell,T.Clark,D.Gordon,W.Himwich, and J.Ryan Measurement of Horizontal Motion in Alaska Using VLBI 1990, In:Journal of Geophysical Research, vol 95, No.B13, Pg 21991-22011, December 10,1990

Goddard Geophysical and Astronomical Observatory

Jay Redmond, Charles Kodak

Abstract

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

1. GGAO at Goddard

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

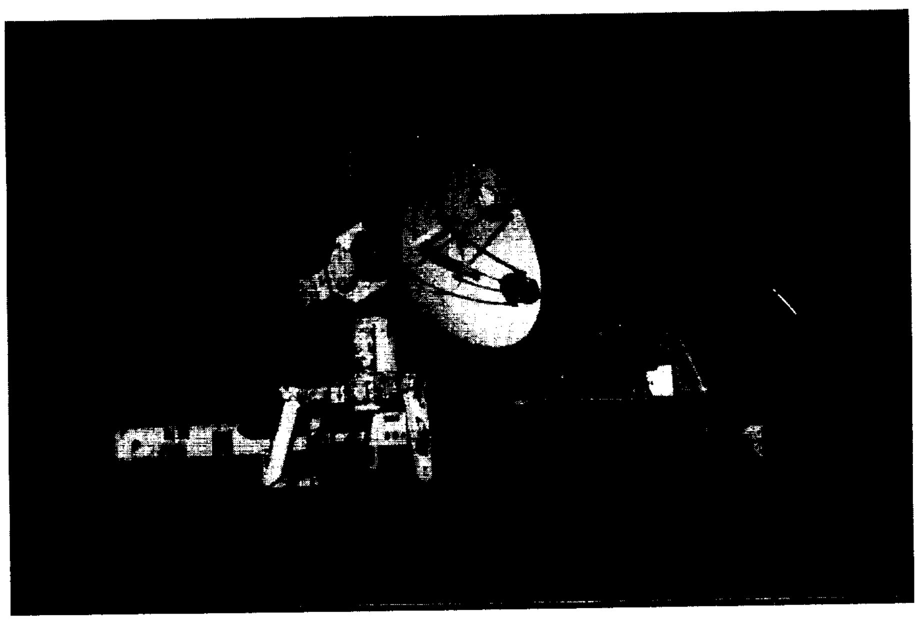


Figure 1. MV-3 VLBI antenna at GGAO.

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. The design criteria were

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

Table 1. Location and addresses of GGAO at Goddard.

Longitude	76.8265° W
Latitude	39.0219° 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	$0\ldots540°$
azimuth velocity	$3°/s$
azimuth acceleration	$1°/s^2$
elevation range	$0\ldots90°$
elevation velocity	$3°/s$
elevation acceleration	$1°/s^2$
X-band	$8.18 - 8.98\,GHz$
$receivingfeed$	$Cassegrainfocus$
T_{sys}	$24\,K$
$Bandwidth$	$800MHz, -2dB$
G/T	$32.1\,dB/K$
S-band	$2.21 - 2.45GHz$
$receivingfeed$	$primaryfocus$
T_{sys}	$19\,K$
$Bandwidth$	$240MHz, -2dB$
G/T	$21.2\,dB/K$
VLBI terminal type	MK4
recording media	thin-tape only
Field System version	9.4.113 (9.5 BETA)

3. Technical Staff of the VLBI facility at GGAO

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

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

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

4. Status of MV3 at GGAO

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

Table 4. Participation of GGAO in VLBI Experiments from March 8, 1999 to December 24, 2000.

Date	Experiment
1999-03-08	RDV13
1999-05-11	NA315
1999-08-03	NA327
1999-11-23	NA343
2000-05-22	RDV21
2000-07-06	RDV22
2000-10-23	RDV23
2000-12-24	RDV24

5. Outlook

GGAO will continue to support both scheduled experiments and developmental activities. The plan for 2001 consists of:

1. Continue testing of pre-release versions of PC-FS and new Linux kernel releases.
2. Continue with research on Mk4 hardware development.
3. Continually striving to improve the performance of the entire MK4 data collection and station specific equipment.

Hartebeesthoek Radio Astronomy Observatory (HartRAO)

Ludwig Combrinck

Abstract

This report summarises the current technical parameters of the HartRAO VLBI station. It also gives an overview of our geodetic VLBI activities during the period March 1999 to the end of 2000. A brief description of our involvement with other space geodesy techniques is given. Surface upgrading of the 26 m antenna which should improve the performance of HartRAO as a VLBI station is discussed.

1. Geodetic VLBI at HartRAO

HartRAO is located north of Johannesburg, South Africa, in a valley of the foothills of the Witwaters mountain range (see Table 1). 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.

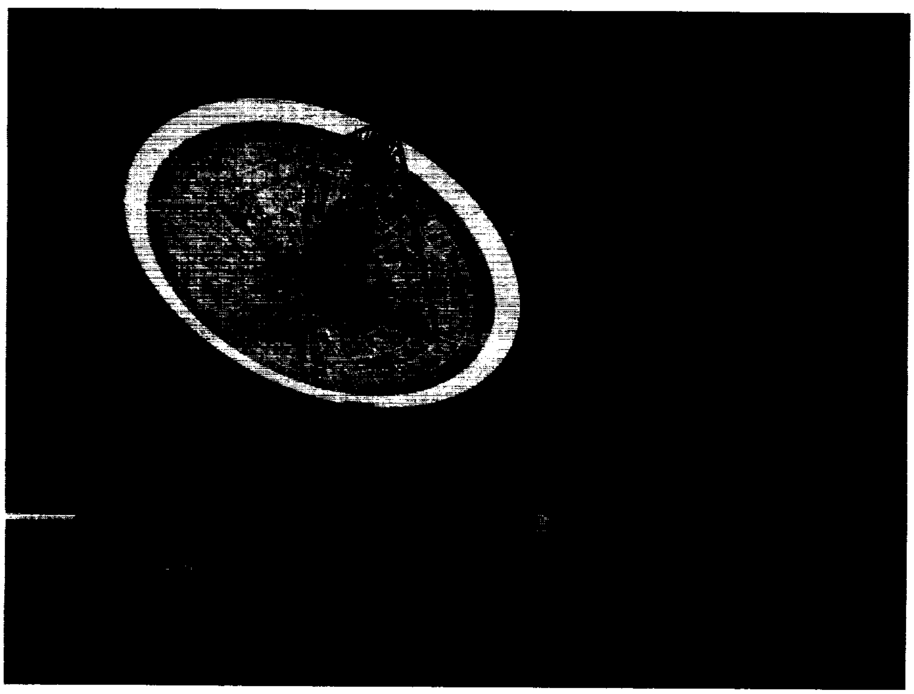


Figure 1. The 26 metre radio telescope. Solid panels have been fitted on the outer ring as part of the surface upgrade. All panels will eventually be replaced with non-perforated, higher tolerance panels. Typical rms accuracy of these panels is 170 microns.

2. HartRAO Radio Telescope Surface Upgrade

The upgrade of the radio telescope is well underway with the outer ring completed. It is expected that total rms surface accuracy after completion will be less than 0.5 mm. Improvement

Table 1. Location and addresses of HartRAO.

Latitude	25.889° S
Longitude	27.686° E
Hartebeesthoek Radio Astronomy Observatory Geodesy Programme PO BOX 443 Krugersdorp, 1740, SOUTH AFRICA	
http://www.hartrao.ac.za/geodesy/geodesy_index.html	

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

Parameter	HartRAO-VLBI
owner and operating agency	HartRAO
year of construction	1961
radio telescope mount	offset equatorial
receiving feed	Cassegrain
diameter of main reflector d	$25.914m$
focal length f	$10.886m$
f/d	0.424
surface contour of reflector	$\pm 2.0mm$
wavelength limit	2.5 cm
pointing resolution	0.001°
pointing repeatability	0.004°
X-band (standard $\nu = 8.580GHz, \lambda = 0.0349m$)	$8.180 - 8.980\,GHz$
T_{sys}	$65\,K$
S_{SEFD}	$1500\,Jy$
Point source	$17.1\,Jy/K$
3 dB beamwidth	0.092°
S-band (standard $\nu = 2.280GHz, \lambda = 0.1316$)	$2.210 - 2.344GHz$
T_{sys}	$40\,K$
S_{SEFD}	$1500\,Jy$
Point source	$9.7\,Jy/K$
3 dB beamwidth	0.332°
VLBI terminal type	MKIV
recording media	thin-tape only
Field System version	9.4.18
attended VLBI observations	24h, mode C

at X band will be approximately 60%. The new panels are being manufactured on site. The manufacturing technique includes the use of a 'bed of bolts' which can be adjusted very accurately. High precision measurements are made of each panel to monitor quality and shape of the panels. Holography will be used to ascertain the parameters of the shape of the resurfaced dish for adjustment and efficiency calculation purposes.

The technical parameters of the radio telescope are summarised in table 2.

3. Staff Members Involved in VLBI

The Geodesy Programme has undergone some changes in its staff complement. With the addition of the MOBLAS-6 SLR unit, several new staff members were recruited as part of the SLR project. We have incorporated several of these staff members into the VLBI operations and envisage that they will improve and enhance our geodetic VLBI activities, after adequate training. The staff members listed have direct VLBI responsibilities, but other staff are sometimes involved in supporting and maintenance roles.

Table 3 lists the HartRAO station staff who are involved in geodetic VLBI.

Table 3. Staff supporting geodetic VLBI at HartRAO.

Name	Background	Dedication	Function	Programme
Ludwig Combrinck	Geodesy	30%	Programme Manager	Geodesy
Jonathan Quick	Astronomy	5%	Hardware/Software	Astronomy
William Moralo	Technical	30%	Shift Operator	Geodesy
Johan Bernhardt	Technical	10%	Shift Operator	SLR
Marisa Nickola	Logistics	10%	Shift Operator	SLR

4. Status of the HartRAO Geodetic VLBI Component

During the period of this report (March 1, 1999 - December 2000) HartRAO participated in the IRIS-S, CORE-A, RDV, COHG and SYOWA VLBI projects. We have been participating in VLBI experiments on a regular basis since 1986. Currently about 15 percent of available telescope time is allocated for geodetic VLBI. Upgrades to our VLBI equipment during 2000 includes:

1. 3.5cm Dual Polarisation receiver upgrade.
2. New Mark IV decoder installed.
3. Headstack replaced after repair – long-standing reproduce problem now fixed.
4. S2 recorder transports underwent service replacement.

5. Future Plans

In order to bring geodesy closer to home and the African continent, the Geodesy Programme is in the process of establishing a Geodetic Institute for Africa. The purpose of this Institute at HartRAO will be to take Africa into the future by developing and nurturing country specific projects in space geodesy. These projects will be tied in a unifying structure which will advance and support Africa's role in geodesy. It will support and promote the activities of the IVS, ILRS and IGS.

We are continuing our footprint survey, which has as its main purpose the determination of eccentricities between the GPS, VLBI and SLR reference points as well as the maintenance of a control network to enable stability monitoring of the site on a local scale. The current eccentricities between VLBI and SLR (Table 4) were determined using GPS (Combrinck & Merry 1997) and the SLR to GPS eccentricities values are from 1998 footprint results. We are processing HRAO in a 17 station regional (IGS) network and envisage processing the SLR (MOBLAS 6) data for eccentricity determinations. This will strengthen collocation and with accurate eccentricities should tie the independent ITRF (Table 5) coordinates to a high degree of accuracy. HartRAO has several upgrades in progress which will affect VLBI and general radio telescope performance. The main projects for 2001 are:

1. Upgrade of radio telescope surface.
2. Automation of dichroic.
3. Improvement of pointing map; especially the far south and north can do with improvement.

Table 4. Table of eccentricities, VLBI telescope to SLR and GPS (HRAO) reference points.

Reference	Coordinate	Δ	σ (mm)
SLR	X	41.680	15.8
SLR	Y	-66.564	7.5
SLR	Z	-8.131	3.9
HRAO	X	90.236	15.8
HRAO	Y	-132.190	7.5
HRAO	Z	-34.704	3.9

Table 5. Table of Geodetic reference points, ITRF96 Epoch 1997, VLBI, SLR and GPS (HRAO).

Reference	Coordinate	Cartesian (m)	σ (m)	Velocity (m)	σ (kxm)
VLBI	X	5085442.780	0.006	0.0007	0.0009
VLBI	Y	2668263.483	0.005	0.0192	0.00101
VLBI	Z	-2768697.034	0.005	0.0164	0.0007
GPS	X	5085352.500	0.009	0.0007	0.0009
GPS	Y	2668395.681	0.007	0.0192	0.00101
GPS	Z	-2768731.692	0.006	0.0164	0.0007
SLR	X	5085401.135	0.101	0.0007	0.0009
SLR	Y	2668330.108	0.063	0.0192	0.00101
SLR	Z	-2768688.865	0.071	0.0164	0.0007

References

[1] Combrinck W.L. and Merry, C.L. *Very long baseline interferometry antenna axis offset and intersection determination using GPS*. JGR. Vol.102, NO.B11, pages 24,741-24,743, 1997.

Kashima 34m Radio Telescope

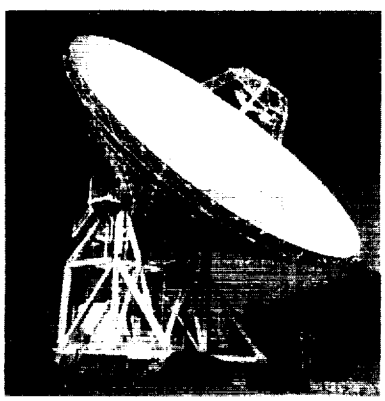
Junichi Nakajima, Eiji Kawai, Hiroshi Okubo

Abstract

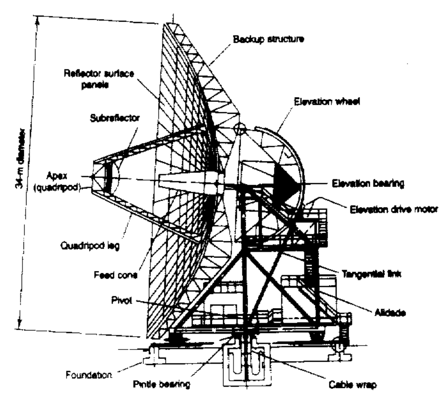
Kashima 34m radio telescope is a facility of the Kashima Space Research Center, Communications Research Laboratory. The telescope is mainly used for geodetic VLBI and other astronomical observations. Here we present its status as of year 2000 and progress of related project.

1. Introduction

Communications Research Laboratory (CRL) constructed the Kashima 34m telescope in 1988. Since the operation started, 12 years have passed. The telescope is kept in a good condition and joined various VLBI observations continuously. The Kashima Space Research Center of CRL was founded in 1964 near the Pacific ocean and is located 100 km east of Tokyo. The 34m telescope shown in the figure is currently operated by Radio Astronomy Applications Group. The telescope structure below the alidade section is almost identical to NASA DSN 34m stations, but the equipped frequency range, feed and electronics are different.



a.Image of 34m



b.Structure

Figure 1. The Kashima 34m radio telescope

2. Antenna Specifications

2.1. Mechanical system

Although the Kashima 34m telescope has a maximum slew rate of 1 degree per second in azimuth, we reduced its speed to prevent wear. Telescope mechanical performance is shown in Table 1. Annual inspection of the electric motors and preparation of spare motors reduced unexpected troubles. In recent years, there has been no observation failure due to mechanical trouble. Last year major modifications to AZ and EL encoder system were carried out. Through the modifications we replaced an old encoder interface with a new one and the telescope system increased its reliability. Sub-reflector FRP surface was cleaned and re-painted from metal paint layer. One third of backup structure inspection and main reflector panel supports replacement were finished in 2000. The rest of the telescope will be maintained in 2001.

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

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

2.2. Receiver system

Available receivers are L, C, K and S/X band and they are summarized in Table 2. A computer controls the feed groups in the cassegrain secondary focus. In our telescope feed groups are mounted on elevator units named "trolley". With the trolley, the selected feed and receiver are moved to the secondary focus. The other receivers are retracted to lower positions. In the case of the C-band receiver additional sub-reflector adjustment is needed because of its feed position offset. All receivers except C-band are cooled HEMTs around 12K physical temperature. The C-band LNA, formerly in an ambient environment, is now cooled around 100K using closed cycle refrigerator. We need approximately 15 minutes to 1 hour to switch the receivers to another band. The IF (intermediate frequency from receiver) is transmitted from the telescope to the observation room via optical fibers. The IF except K-band are in the range of commonly used 100-600 MHz band. Additional up converters in the observation room can up convert the 100-500 MHz to 600-1000 MHz. On the other hand the K-band receiver IF is 5-7 GHz. Whole IF bandwidth is also transmitted with fibers, wide-band E/O and O/E. Then they are converted to baseband or other IF frequency. Recently we have strong RFI interference in L-band. These are from artificial satellites and mobile phone base station. With the satellite phone service, we negotiated to prohibit terminal transmission near the telescope to prevent receiver saturation.

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

Band	frequency(Hz)	Trx(K)	Tsys(K)	Efficiency
L	1350-1750	18	43	0.68
S	2150-2350	19	83	0.65
C	4600-5100	25	108	0.70
X	7860-8680	41	52	0.68
K	21900-23900	300	330	0.57

2.3. Standard signals

Two K-4 type (Anritsu) hydrogen masers are used for frequency standard. The same masers are also used for KSP Kashima 11m station. We have another Russian maser for reference and backup.

As for H-1PPS comparison to the GPS-UTC, the AOA receiver and the Totally Accurate Clock-2 are in operation. Expensive GPS receivers will be replaced by the TAC-2. TAC-2 encouragement to domestic institute and their TAC-2 kit assembly support is done by the CRL Kashima group.

2.4. VLBI back-end system

As of January 2000, K3-A (Mark-IIIA compatible), VLBA, K4, VSOP, S-2 and Giga-bit VLBI systems are available. The newly installed S-2 system and Gbit system are fully in operation. K4, VLBA and S2 are controlled by the Field System (FS-9) as well as the telescope. Other equipment are still controlled from their original field system. K4 and VSOP observations can use automatic tape change robot during their observations. A digital spectrometer with auto-correlation and total power recording by DAT are also possible.

3. On-going Projects and Major Result of 2000

Following are the major VLBI observation projects which are currently running at Kashima 34m radio telescope.

K4-TIE experiment In collaboration with the Geological Survey Institute and others, Intensive K-4 TIE experiment to tie the KSP VLBI network to a global terrestrial reference frame (ITRF) was carried out. Final session is planned in February 2000.

Pulsar VLBI (Asia Pacific Telescope) Since 1997 regular observations were carried out between the Kryazin 64m telescope in Russia and Kashima 34m. A K4 system is installed on the Russian side. Periodic observations revealed the intrinsic motion of pulsars in high resolution after data analysis. Pulsar timing observations were carried out too.

VSOP (VLBI Space Observatory Program) In collaboration with ISAS (Institute of Space Astronautical Sciences), Kashima 34m joined the project as a ground telescope. Mainly C-band and L-band receivers are used. The Kashima 34m role is complementary work with ISAS 64m.

J-NET (Japanese domestic astronomical VLBI network) With three other stations in Japan (Nobeyama 45m, Mizusawa 10m and Kagoshima 6m), proposal based observations were made. Focused on astronomical side, most of the JNET observations are tuned in K-band water maser. A number of sources were found under intensive observations of the VERA Survey in 2000. We found reference continuum sources near water maser sources concentrated at low Galactic latitudes.

GALAXY (Giga-bit Astronomical Large Array with cross connect) Utilizing optical networks, three large telescopes in Japan are optically connected via ATMs. Kashima 34m and Usuda 64m were connected in September 1998. Kashima 34m and Nobeyama 45m were also connected on 7th June 1999. Koganei KSP correlator is now used for regular GALAXY experiments. In 2000, we have tried to start Mitaka-FX as the second real-time correlator. A 2.4 Gbps optical transmitter was successfully developed at NAO. Real-time Giga-bit observation using the network is planned in 2001.

GIFT (Gifu University Telescope) A 3m telescope of CRL was moved to Gifu university. We have performed initial observations and geodetic analysis to start up the university site. A

Gbps system was also introduced and the small telescope was spot lighted again.

Giga-bit VLBI Experimental Giga-bit observations were carried out both in geodesy and astronomy. High sensitivity Gbps observations for radio astronomy are starting now. The 1024 Mbps recorders work with JNET 256 Mbps simultaneously and double its sensitivity.

4. Technical Staff for the Kashima 34m Radio Telescope

Engineering and Technical staff members who are contributing to observations and operations of the Kashima 34m are listed below.

- Eiji Kawai, Technical responsibility for overall operations and maintenance.
- Junichi Nakajima, Engineering leader of the 34m.
- Yasuhiro Koyama, Field system developments and monitoring software.
- Mamoru Seido, Hydrogen maser and standard signal distribution.
- Hiroshi Okubo, Technician for mechanical and RF maintenance
- Hiroo Osaki, Technician for software and mechanical maintenance.
- Yuki Watababe, Engineer from Rikei Corporation. Rikei is the contract agency of Vertex corporation TIW division.

5. Outlook

The subreflector control unit will be replaced for high reliability. Receiver physical temperature read out will be replaced too. A new HEMT 43 GHz receiver will be installed by Kagoshima University and NAO. Publication of a special issue of CRL journal which summarizes related recent results is planned in April 2001.

Key Stone Project VLBI Stations (Kashima, Koganei, Miura, and Tateyama)

Yasuhiro Koyama

Abstract

Four stations of the Key Stone Project Network at Kashima, Koganei, Miura, and Tateyama continued frequent and automated VLBI observations throughout the period from March 1999 to December 2000. From the end of June 2000, unusual motions of Tateyama and Miura stations were detected as the results of volcanic and seismic activities near the Miyakejima and Kozushima Islands. To investigate and monitor the motions of Tateyama station, the frequency of the VLBI observations at Tateyama, Kashima, and Koganei stations were included and the observations were performed every day almost continuously from June 2000 through November 2000.

1. Introduction

The Key Stone Project (KSP) VLBI Network consists of the four stations at Kashima (Ibaraki), Koganei (Tokyo), Miura (Kanagawa), and Tateyama (Chiba). The geographic locations of these four stations are shown in Figure 1.

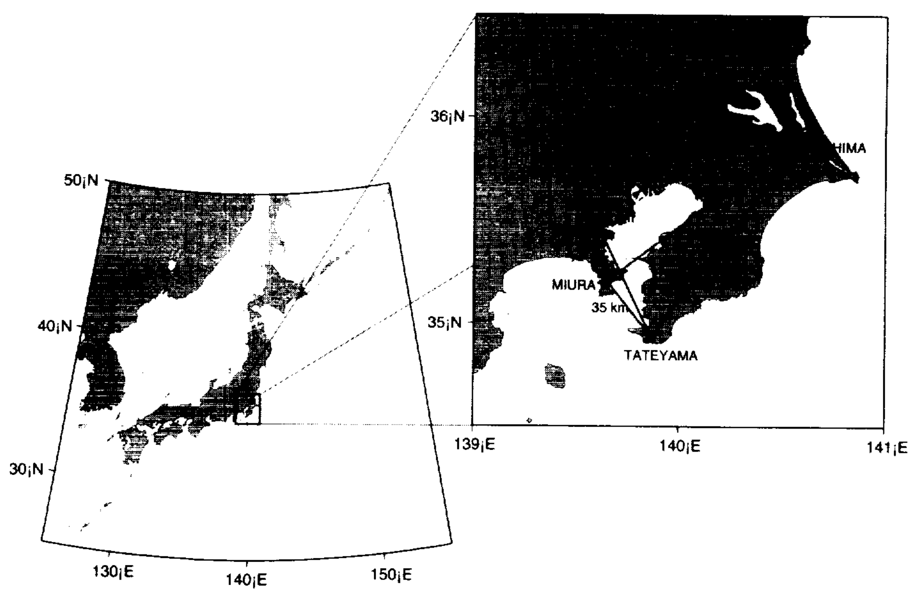


Figure 1. Geographic locations of four Key Stone Project network sites.

Each station is equipped with an 11-m diameter antenna. Kashima, Koganei, and Tateyama stations are connected with the real-time VLBI system while the Asynchronous Transfer Mode (ATM) network to Miura station became unavailable in May 1999. Since the correlation processing of the tape-based VLBI data takes longer than the real-time VLBI system, the frequency of the VLBI observations at Miura station was decreased from every two days to every six days since May 1999. Observation data rate is 256 Mbps since October 1998.

2. Activities

Table 1 lists the number of successful VLBI sessions performed at each station during the period between March 1999 and December 2000.

Table 1. Number of successful VLBI sessions performed at each station.

Station names	Number of successful sessions
Koganei	398
Kashima	391
Miura	123
Tateyama	394

The number of VLBI sessions performed with the Miura station is smaller than the other three stations since the Miura station has participated only in the tape-based VLBI sessions which were performed every six days since May 1999. Considering that the total number of days during the period is 672 days, the other stations were performing VLBI observations about 60% of the time. The reason why the number of VLBI sessions exceeded 50% by about 60 days was because daily VLBI sessions were performed with four stations in March 1999 and with the three stations except Miura station between July 22 and November 11, 2000. The daily VLBI sessions were performed in March 1999 to obtain continuous VLBI data before the ATM network link to the Miura station was terminated in May 1999. The other daily VLBI sessions from July 22, 2000 were performed to follow the unusual site motion of the Tateyama station due to the volcanic and seismic activities near the Miyakejima and Kozushima Islands [1]. Both of these attempts to perform daily continuous VLBI observations for such a long period were successful and valuable data were obtained. These achievements demonstrated how robust the four KSP VLBI Network stations are and the high reliability of the automated observation and data processing systems.

3. Future Plans

It was planned to terminate the operations of the Tateyama and Miura stations in September 2000 since the project was originally started as a five-year project. However, unusual site motions were detected for Tateyama and Miura stations in July 2000 and the operations of these two stations were extended. The operation of the Miura station was extended for three months and the operation of the Tateyama station was extended more than one year. The last VLBI session with the Miura station was completed January 5, 2001. The antenna and the observation facilities of the Miura station will be transported to the Tomakomai Experimental Forest of the Hokkaido University (Figure 2). On the other hand, the antenna and the observation facilities of the Tateyama station will be transported to the campus of the Gifu University in 2002. Both of these stations will be used for geodetic and astronomical VLBI observations in the future.

References

[1] Yasuhiro Koyama, Ryuichi Ichikawa, Mamoru Sekido, Tetsuro Kondo, Hitoshi Kiuchi, Jun Amagai, and Taizoh Yoshino: Site position displacements due to the seismic and volcanic activities in the area

of Izu islands detected by the KSP VLBI Network, CRL IVS Technology Development Center News, No. 17, pp.8-10, November 2000.

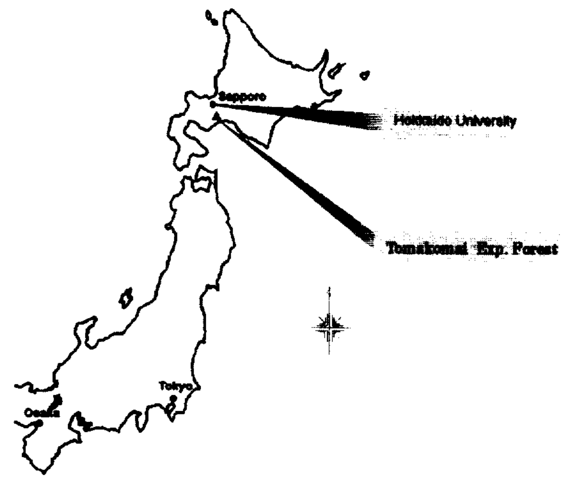


Figure 2. Geographic location of the Tomakomai Experimental Forest of the Hokkaido University. The antenna and the VLBI observation facilities of the Miura station will be transported to the site in 2001.

Kokee Park Geophysical Observatory

Clyde A. Cox

Abstract

This report summarizes the technical parameters and the technical staff of the VLBI system located on the Island of Kauai. Included is an overview of the VLBI activities from March, 1999 through the end of December 2000.

1. KPGO

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

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

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

A Mark IV system was planned to be installed during 1999. However delays have the installation date into the year 2001.

In July 2000 Kokee Park started daily (Monday through Friday) participation in the Intensive sessions for NEOS.

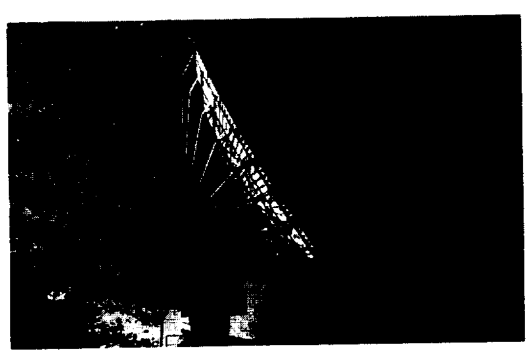


Figure 1. Kokee Park Geophysical Observatory 20m antenna.

Table 1. Location and Addresses of Kokee Park Geophysical Observatory

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

2. Technical Parameters of the VLBI System at KPGO

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

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

3. Technical Staff of the VLBI system at KPGO

The staff at Kokee Park consists of six people who are employed by Honeywell-TSI under contract to NASA for the operations and maintenance of the Observatory.

4. Status of KPGO

Kokee Park has participated in many VLBI experiments since 1984. We started observing with GAPE and are continuing until now with NEOS and CORE. We also participate in the RDV experiments.

We averaged 1.5 experiments per week during calendar year 2000 and are increasing to an average of 2 weekly experiments of 24 hours with daily Intensive experiments during year 2001.

Kokee Park also hosts other geodetic measurement systems, including PRARE, a DORIS beacon, and a Turbo-Rogue GPS receiver. Kokee Park is an IGS station. These three systems are shown in Figure 2.

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

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
recording media	thin-tape only
Field System version	9.4.18

5. Outlook

Mark IV equipment is expected to be installed during the first part of this calendar year. Increased operations are expected with the coming of CORE.

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Matera CGS VLBI Station

Giuseppe Colucci, Domenico Del Rosso, Francesco Vespe

Abstract

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

1. General

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

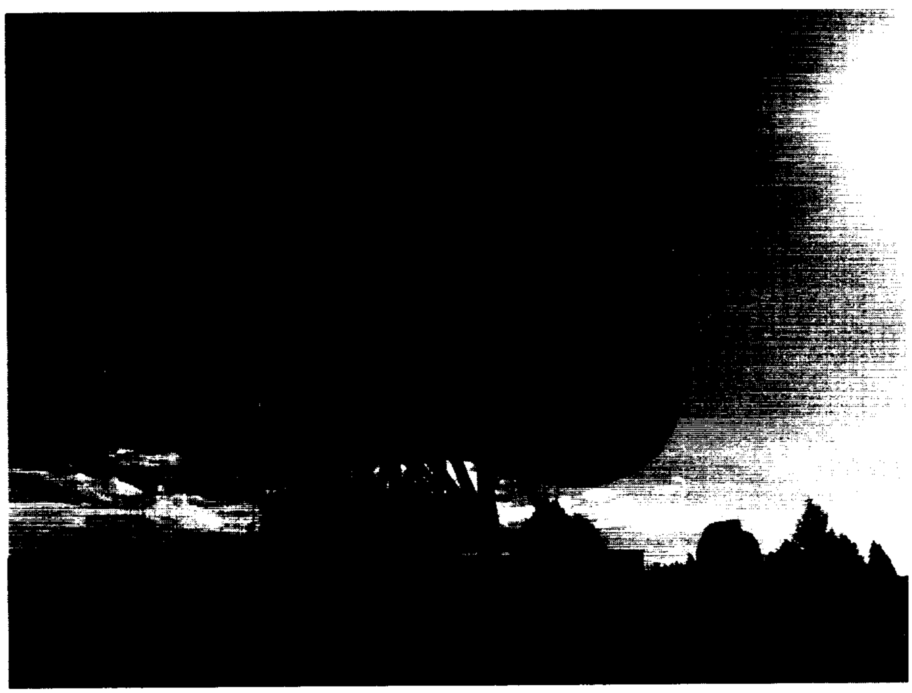

Figure 1. The Matera "Centro di Geodesia Spaziale" (CGS)

of the Italian Space Agency came into operation in 1983 when a Satellite Laser Ranging SAO-1 System was installed at CGS. Fully integrated in the worldwide network, SAO-1 is in continuous operation since 1983, providing high precision ranging observations of several satellites. The new Matera Laser Ranging Observatory (MLRO), the most advanced Satellite and Lunar Laser Ranging facility in the world, installation is in progress. 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 377 experiments up to December 2000. In 1996 the receiver was upgraded to standard wideband and at the end of 1999 a Mark IV formatter and decoder were installed by MIT Haystack.

In 1991 we started GPS activities, participating in the GIG 91 experiment installing in Matera a permanent GPS Rogue receiver. In 1994 six TurboRogue SNR 8100 receivers were purchased in order to create the Italian Space Agency GPS fiducial network (IGFN). At the moment 10 stations are part of the IGFN and all data from these stations, together with nine other stations in Italy, are archived and made available by the CGS WWW server GeoDAF (http://geodaf.mt.asi.it).

At the beginning of 1996 the operations of the Precision RAnge and Range-rate Experiment (PRARE) started. Thanks to the colocation of all precise positioning space based techniques (VLBI, SLR, GPS and PRARE), CGS is one of the few "fundamental" stations in the world. With the objective of exploiting the maximum integration in the field of Earth observations, in the late 1980s ASI extended CGS involvement also in remote sensing activities for present and future missions (ERS-1, ERS-2, X-SAR/SIR-C, ENVISAT).

2. Technical/Scientific

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

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

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

The control computer is a SWT Pentium/233 PC running Linux and FS version 9.4.13.

Table 1. Matera VLBI Antenna Technical Specifications

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

3. Staff

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

Table 2. Matera VLBI staff members

Name	Agency	Activity	E-Mail
Dr. Giuseppe Bianco	ASI	CGS Director	bianco@asi.it
Dr. Francesco Vespe	ASI	CGS Geodesy Manager	vespe@asi.it
Domenico Del Rosso	Telespazio	Operations Manager	domenico_delrosso@telespazio.it
Luciano Garramone	Telespazio	Station Engineer	garramone@asi.it
Giuseppe Colucci	Telespazio	VLBI contact	colucci@asi.it

4. Status

The Matera station is involved in CORE-A and EUROPE experiments. Table 3 summarizes the experiments performed during 2000. Figure 2 shows the summary of acquisition up to December 2000 in terms of hours of acquisition.

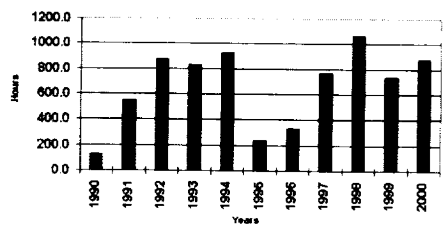

Figure 2. Summary of acquisition from May 1990 to December 2000

Table 3. Summary of experiments

Month	CORE-A	EUROPE	NEOS	RDV	ESO
January	2	1	1		
February	1	1	1	1	
March	1	1		1	
April	1		1		
May		1		1	1
June	1				
July	2			1	
August	2	1	1		
September	3	1			
October	2			1	
November	2		1		
December	2			1	
TOTAL	19	6	5	6	1

5. Outlook

During the current year (2001) a check of the antenna efficiency is planned.

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[1] G.Colucci, D.Del Rosso, L.Garramone: "Matera VLBI Station Report on the Operational and Performance Evaluation Activities from January to December 1999", available on-line at this address: http://geodaf.mt.asi.it/GDHTL/matera.html

Medicina Station Report

Alessandro Orfei, Franco Mantovani

Abstract

In the following we will briefly summarize the relevant events, changes and upgrading at the two radio astronomy stations of Medicina during the recent past.

1. Maintenance

a) An inchworm motor broke. It was replaced with an EVN (spare part) inchworm.
b) A new degausser (model V91M) has been bought.
c) The Haystack dry air kit was mounted on the tape recorder.
d) Both the write and read heads were replaced in 1999. The new heads are triple cap made by Spin Physics.
e) The latest version of the Field System (9.4.14) was installed.
f) The 8-16 MHz bandbass problem was fixed with the substitution of VC components.
g) The 0.125 MHz and 0.5 MHz filters were added to the first 8 VCs, which now have the full set of filters.

2. Telescope Upgrading

a) Medicina will be a "thin tape only" station from September 2000 on for astronomical observations.
b) The frequency agility project was slowed down; the main reasons for the delay are that the active surface project for the Noto antenna, which will allow the telescope to operate at 43 GHz with good sensitivity, was started, and that unexpected problems occurred with the grout supporting the azimuth rail of the antenna, which needed to be replaced.
c) The active surface project consists of a movable system for the primary mirror panels of the antenna to recover the gravity deformations of the surface. The components that are required are in mass production right now. The design for the network of electro-mechanical actuators is ready. The control software is almost completed. For information about the installation see the Noto Station report next.
d) The grout supporting the rail was changed. A new approach was followed: the rail is placed on a continuous bed of steel plates (50mm thick); the interface between the foundation and plates is made by a reinforced fibers grout.

3. Geodetic VLBI Observations in year 2000

Project	Date
EUROPE-53	27 January
VLBA19	31 January
EUROPE-54	07 February
VLBA20	13 March
EUROPE-55	16 March
EUROPE-56	15 May
VLBA21	22 May
VLBA23	23 October
VLBA24	04 December
EUROPE-60	06 December

Report from the Noto VLBI Station

G. Tuccari, C. Stanghellini

Abstract

This report describes recent, current and planned changes at the Noto VLBI station. The report also summarizes Noto's 2000 geodetic activities.

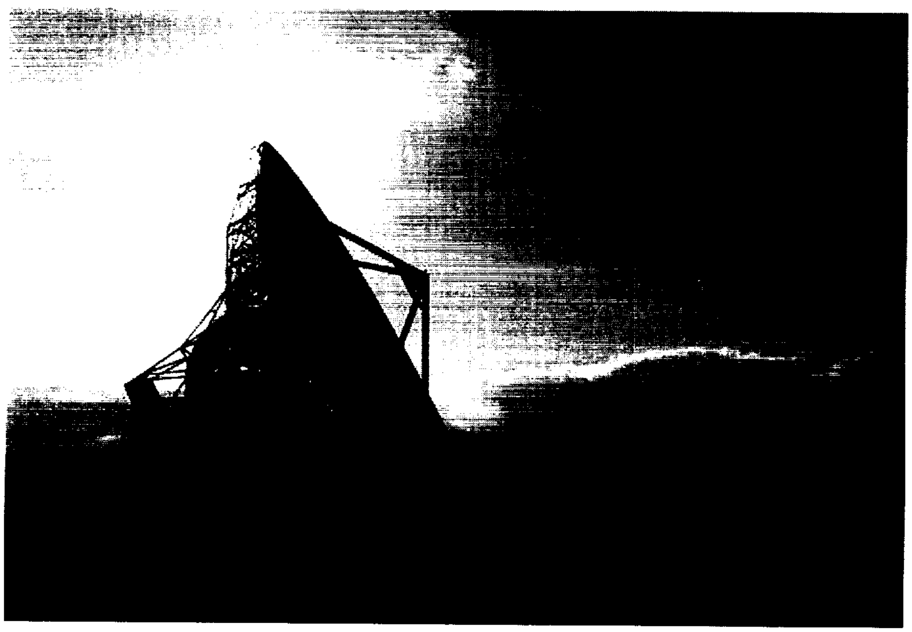

Figure 1. The Noto antenna.

1. Changes at the Noto VLBI station

The MKIV formatter is now used as the standard in the VLBA4 Terminal. This avoids manually switching between VLBA and MKIV modes, which requires connecting different cables and changing the setup in the Field System. Such modification is to be considered as a simplification in the station operations, improving the reliability.

The realisation of a new version of TTY distributor to be used in the VLBA4 environment was completed. It has been produced for Cambridge, Effelsberg, Noto, Shanghai, Torun, Metsahovi, Yebes, Pico Veleta, and three units for Haystack.

The assembly of the headstack boards for the Noto recorder and a second station is in progress and at completion the recorder will be upgraded as a full two heads recording system for 1 Gbit/s recordings.

The upgrade program (SXL-UHF receiver construction) was delayed, due to the delay in the CSELT production of the L and S/X band feed systems. Production order was placed before the end of 1999. The feeds are in construction and some parts realised. The third and last module of the receiver is completed, while the other two have been successfully tested. The cryogenic section is in construction. A new software environment is under development to drive the complex system, operating on the full set of receivers, in primary and secondary focus.

The active surface for the Noto antenna, developed by the Medicina staff, will be installed in the last quarter of 2001. The necessary parts are in the acquisition stage and will be assembled in Medicina then transferred to Noto.

A Heybond bonding machine has been acquired. A study of cryogenic low noise amplifier was undertaken that should produce L, S, C band front-end as first result.

Methods to realise microwave vacuum windows are under evaluation, and a dedicated oven has been acquired to cure the foam.

2. Geodetic Experiments in Noto during 2000

Geodetic experiments in Noto need to deal with the heavy scheduling of the antenna for VSOP experiments: nevertheless the Noto antenna is involved in Europe experiments and could participate in a couple of CORE B experiments. Problems at the correlators also caused the delay and sometimes the deletion of planned geodetic observations.

During 2000 the following geodetic experiments have been done:

Table 1.

EURO53	27 Jan
EURO54	07 Feb
EURO56	15 May
EURO57	07 Aug
EURO58	04 Sep
CB801	12 Jan
CB802	02 Nov

NYAL Ny-Ålesund 20 Metre Antenna

Helge G. Digre, Hans-Peter Plag

Abstract

In the report period (April 1999 - December 2000), the 20 m VLBI antenna at the Geodetic Observatory at Ny-Ålesund has participated in VLBI experiments at the scheduled level. Several maintenance and repair activities were required and changes in station staff have occurred. Considerable work has been devoted to footprint studies including classical surveys and GPS campaigns on the local control network.

1. Introduction

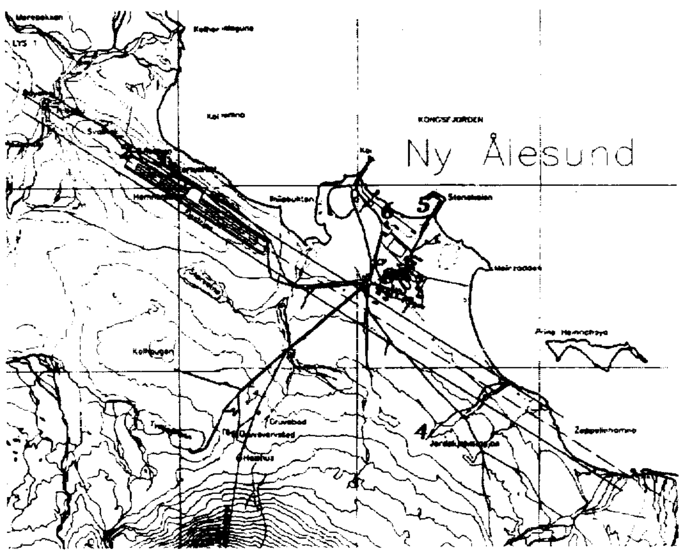

Figure 1. Location of the infrastructure of the Geodetic Observatory in Ny-Ålesund. 1: VLBI antenna; 2: SATREF (real-time GPS), CHAMP (low-latency GPS) and GLONASS receivers; 3: IGS receivers NYAL and NYA1 as well as cryogenic gravimeter and absolute gravity point; 4: Relative LaCoste-Romberg Earth tide gravimeter, also seismic observatory; 5: tide gauge; 6: Tide gauge bench mark; 7: DORIS; 8: Water vapour radio meter and balloon sounding. Scale is approximately 1:25000 and North is up. From [3].

The Geodetic Observatory at Ny-Ålesund is located at 78.9°N and 11.9°E at the west coast of Spitsbergen, Svalbard. Over recent years, the observatory has developed into a fundamental geodetic station with co-location of most of the space-geodetic techniques and additional geophysical instruments (see Figure 1). The VLBI antenna participates in experiments within VLBA/RDV, CORE-B, VLBI-Europe, and NEOS. The different techniques are tied together by means of a control network which is periodically re-surveyed both with classical methods and GPS. This so-called inner network is embedded in an outer control network covering roughly an area of about 50 km in diameter, which is observed in annual GPS campaigns. For a more detailed description of the geodynamic setting and other observational activities at the observatory, see e.g. [1]. For technical details of the VLBI antenna, see [2].

The observatory participates in the Large Scale Facility (LSF) Ny-Ålesund [1]. In the context of this EU-funded programme, 11 research projects have been carried out in the report period at the observatory with participants from several European VLBI groups. For more details, see [3].

2. Staff Related to the Space-Geodetic Observatory in Ny-Ålesund

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

Hønefoss:	Section Manager:	Rune I. Hanssen
	Station responsible, Hønefoss:	Svein Rekkedal
Ny-Ålesund:	Station manager:	Helge G. Digre
	Permanent staff:	David C. Holland
		Roar Kihle (05.1999 - 04.2000)
	Rotation group:	Kari Buset
		Bente R. Andreassen (only one shift)
		Kjetil Ringen (only two shifts)
		Tom Pettersen
	6 months contract	Nils Petter Rognstad (10.2000-03.2001)

The "permanent" staff at the observatory is employed on the basis of renewable one-year contracts. Expecting an increase in experiment activity for 2000, an extra person was employed on a yearly contract in May 1999 (Table 1). With the lack of correlator capacity reducing activity in 2000, this contract was not renewed.

The four members of the rotation group have or had permanent positions at the Norwegian Mapping Authority (NMA). The contract period is three years ending in June 2001. Each member spends 3 months at a time in Ny-Ålesund. It was planned that each member would serve a total of 9 months at the observatory. However, one member resigned from NMA, while another one is no longer available due to internal change of duties. Therefore, a new staff member was employed on a temporary basis to fill the gap.

3. Status of the VLBI Antenna in Ny-Ålesund

The overall operation of the VLBI antenna in the report period has been smooth, though some periods posed more problems than normal. The antenna participated successfully in 77 experiments, while for two experiments participation was unsuccessful due to technical problems.

A number of more or less routine upgradings, maintenance and repair operations were carried out. For example, the maser had its scheduled bi-annual maintenance check in June 1999. The field system is now FS 9.4.17. The TAC system has been upgraded to a CNS TAC with monitor, counter and computer. The azimuth gears on the antenna have been checked and repaired. The azimuth brakes have been renovated and are working again. The Peltier elements on the antenna were checked in summer 2000 and worn fans were replaced. In autumn, both Peltier power supplies had to be repaired after failures. In the helium system, the cold head was replaced in June 1999,

[1] see http://www.npolar.no/nyaa-lsf/.

and the compressor in November 2000.

A number of more serious crashes and break-downs happened, which partly are due to a more rapid ageing of parts in the severe weather conditions at the observatory. Problems were caused by fading and eventually disappearing antenna signals. After eliminating the connectors as a source for these errors, it was found that all the signal cables were broken or damaged in the elevation link. The cables have been repaired temporarily by cutting away the bad pieces of cable and replacing them by new pieces of cable.

When one of the running encoders caused increasing problems, it was discovered that the spare encoder was defective. The spare encoder returned from repair after 3 months just in time to replace one of the working encoders, which died totally. Recently, there were severe problems in getting the encoder signal. The source for these problems was located in a short circuit in one cable out of the encoder.

The crash of a rather new hard disk in December 1999 happened at the worst possible time, resulting in the setting up of a new back-up procedure for the disks.

In the often severe weather conditions, safety of staff during operations on the antenna requires particular attention. In particular, a safety report was written in spring 2000, and equipment has been acquired to make the manhole in the antenna safer.

The problem of radio interference (RFI) appears to be mounting even at the remote location of Ny-Ålesund. The VLBI antenna is sheltered from RFI from geo-stationary satellites by mountains to the south. However, local activities of other research institutes and the operator of the research town are increasingly in conflict with the condition of radio-quietness imposed on Ny-Ålesund. For example, the operator of Ny-Ålesund, Kings Bay, operated a local wireless LAN-net in the 2.4 GHz area from February to June 2000. NMA is actively working to protect the important environmental quality of radio-quietness by exploiting legal regulations as well as regular contacts to all other groups active in Ny-Ålesund.

4. Site surveys and other activities

In summer 1999, a small instrument house was built above the existing stable platform previously used for absolute gravity measurements. This house was required for the superconducting gravimeter (SCG), which was installed there in September 1999 by Professor Tadahiro Sato, Earth Rotation Division, National Astronomical Observatory, Japan. Daily operation of the instrument is provided by the station staff, while major maintenance work such as annual refill of liquid helium is carried out by visitors of the Japanese team. After some minor initial problems, the instrument is running smoothly and providing high-quality data. The data is accessible to the Japanese team via Internet.

Prior to the building of the house, two GPS receivers (SATREF and NYA1) were operated on steel masts mounted on the gravity platform. For the time being, NYA1 is continuing to operate there. In addition, a semi-permanent receiver was set up at one of the pillars in the control network in order to monitor any changes in NYA1 due to the building activities.

In 1999, a roof was built on an existing foundation about 300 m to the north-west of the VLBI and IGS site (No. 2 on Fig. 1). This new construction provides an appropriate environment for continuous GPS sites. In the centre of the large ground floor room, there is a 4x4x4-meter pedestal with concrete walls, well insulated to reduce any temperature effects. Inside the pedestal, a data room is located, which is connected to the net in the main building by a fibre optic cable. On top of the pedestal, a stable tower reaches through the roof as the monument for GPS antenna.

Among others, a GPS receiver of the GFZ, Potsdam, has been installed at this new location, which contributes to the low-latency network supporting the CHAMP mission.

Several LSF projects provided contributions relevant to the IVS goals. In particular, a GPS antenna was installed permanently on the VLBI antenna. Whenever the antenna is in Zenith position, the GPS data can be used to monitor the tie between VLBI and GPS directly. The VLBI antenna has been surveyed with classical methods twice, providing accurate coordinates of the antenna reference point. The inner control network was reobserved with classical techniques by visiting groups in 1999 and by NMA staff in 2000. Absolute gravity measurements were carried out in summer 2000 providing a calibration of the SCG and, additionally, a remeasurement of gravity after initial measurements in 1998. NMA carried out GPS campaigns on the inner and outer network in 1999 and 2000. Together with the campaign on the outer network in 1998, the analysis results show a stability of the network on the 1 mm/yr level, except for one pillar which apparently is moving [3].

5. Outlook

In 2001, the observatory will participate in the CORE-3 experiments as well as other experiments such as the VLBI Europe once. A number of repairs, maintenance, and upgrades are planned. For example, the bi-annual maintenance of the maser is due in summer 2001. The FTS 8400 will be retired and shipped back to Honeywell.

The repair of the azimuth 1 antenna brake was temporary and some parts need to be replaced. The elevation brakes need to be checked, and all signal cables will be replaced in the summer. A re-routing in the elevation link area will be considered. The new encoder will arrive in spring. The azimuth encoder then has to be sent to the manufacturer for check. The formatter will be upgraded to be able to handle the CORE-3 experiments. The Field System will be upgraded to the next Linux version.

Concerning station staff, the experience made with the rotation group arrangement will be evaluated. A decision concerning future employment schemes for the staff at the observatory will be made on the basis of this experience.

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[2] Digre, H. G., Rekkedal, S., Holland, D. C., Hanssen, R. I. and Plag, H.-P., 1999: NYAL Ny-Ålesund 20-metre antenna. In Vandenberg, N. R. (ed.): International VLBI Service for Geodesy and Astrometry Annual Report 1999. NASA, Greenbelt, MD, USA, 80-84.

[3] Plag, H.-P., Bockmann, L., Kierulf, H. P., Kristiansen, O., 2001: Foot-Print Study at the Space-Geodetic Observatory, Ny-Ålesund, Svalbard. In Tomasi, P., Mantovani, F., and Perez-Torres, M.-A. (eds.): Proceedings of the 14th Working Meeting on European VLBI for Geodesy and Astrometry, Castel San Pietro Terme, Sept. 8 - Sept. 9, 2000. In press.

German Antarctic Receiving Station O'Higgins

Andreas Reinhold, Reiner Wojdziak

Abstract

Ten VLBI sessions of 24 hours have been observed successfully during the last three Antarctic campaigns. A H-maser failure stopped the last experiment. The local ties have been controlled. Modifications of the timing system by a TAC have been done. The collocated geodetic systems (GPS, PRARE, etc.) continued to provide data. The upgrade to MkIV is planned for the spring campaign 2001.

1. Observation Campaigns at O'Higgins 1999/2000

During the period from March 1999 to December 2000 three VLBI observation campaigns were organized at the German Antarctic Receiving Station (GARS) O'Higgins by staff members of BKG (Federal Agency for Cartography and Geodesy) in cooperation with the colleagues from DLR (German Aerospace Center - responsible for SAR Data Acquisition).

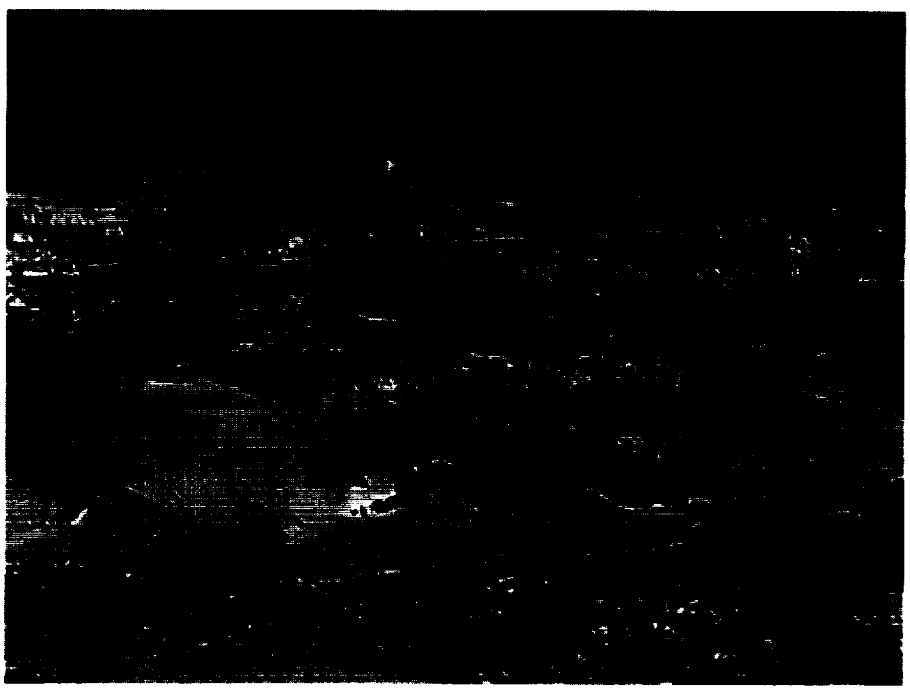

Figure 1. Schmitt Island with the Chilean base and the annexed German station O'Higgins during the Antarctic spring time - October 1999.

During the three campaigns at O'Higgins altogether ten 24-hour VLBI experiments were carried out. The observations were mainly focused on the special IVS CORE O'Higgins (COHIG) experiments, namely the experiments COHIG 7 to COHIG 13. In addition the O'Higgins telescope was involved in IRIS South 144, 147 and 155 experiments. Due to a H-maser failure the IRISS 155 experiment had to be interrupted after about 14 hours of observation. The external ion pump of the maser vacuum system was broken and the H-maser lost lock.

All the observed experiments could be correlated successfully and the data were used in various analysis for station position determinations and Earth Orientation Parameter evaluations.

At the end of 1999 first experiments were conducted with the JARE station Syowa, which is the second VLBI station in Antarctica.

2. Status of VLBI and Other Geodetic Equipment

There were no major changes in the VLBI equipment of the O'Higgins station since 1999. The main components of the VLBA/MkIII equipment worked stably and with respect to the special Antarctic conditions with sufficient quality.

Only the station timing system had to be modified. Since November 1999 the station sync is realized by a TAC-GPS tracking system. The Cs-atomic frequency standard HP5061 failed. It is planned to replace it by a new cesium frequency standard HP 5071 during the year 2002.

In January 2000 the survey of the antenna reference point was repeated. No changes in the eccentricities between the various systems at O'Higgins station were detected.

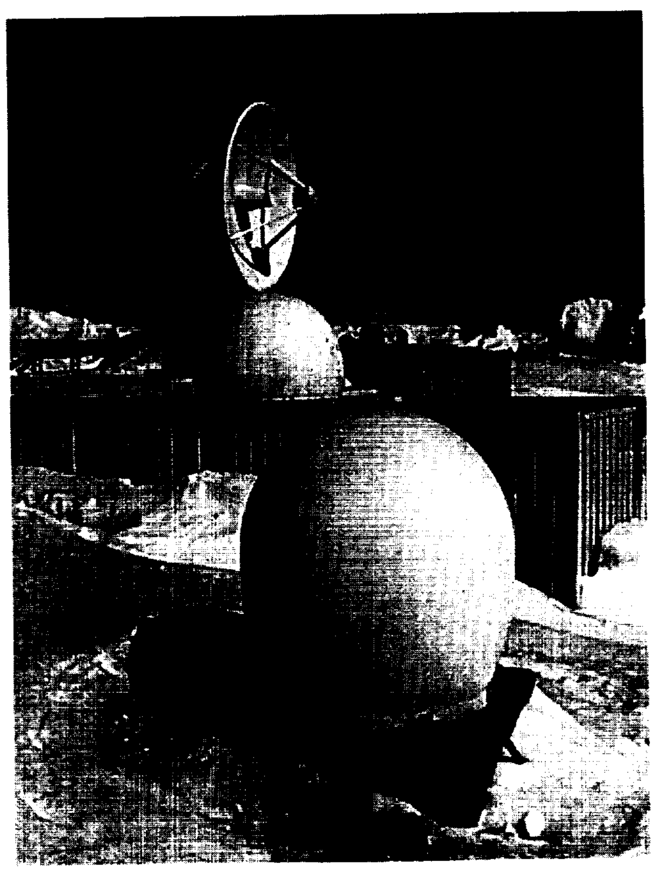

Figure 2. The VLBI Antenna at O'Higgins, in front the GPS-Antenna and the PRARE ground unit protected by different radomes (October 1999).

The additional geodetic systems collocated in O'Higgins are working continuously. Sometimes interruptions in the continuous data acquisition occurred – especially during those periods when the station is unmanned.

The permanent GPS tracking system, a TURBO ROGUE, is included in the IGS network. The data and additional information can be found under the ID character OHIG and under the IERS DOMES No. 66008M001.

The PRARE ground unit at O'Higgins can be found under COSPAR No. 7710.

Since February 1999 a new tide gauge system provides continuously data of the variations of the sea surface level around O'Higgins.

3. Outlook

The upgrade of the O'Higgins station to a VLBA/MkIV station including the thin tape equipment and the field system 9.xx is in progress.

All the necessary racks, parts, computers and tools are shipped to the station and will arrive there during the first weeks of the year 2001.

It is planned to install and to test all the new systems at the station during the first campaign 2001 in January/February. The first experiments employing the new equipment are scheduled for the weeks 7 and 8 of the year 2001.

Regarding the installation of TIGO in Conception (Chile), it has to be pointed out that the importance of O'Higgins VLBI station (GARS) as a reference point close by will increase and common observations will improve the results tremendously. Therefore, it is planned to continue the campaigns in the next years, if possible twice a year.

The IVS Network Station Onsala Space Observatory

Rüdiger Haas, Gunnar Elgered, Sten Bergstrand, Lubomir Gradinarsky, Borys Stoew, and Karl-Åke Johansson

Abstract

We give a short overview of the status of the Onsala Space Observatory in its function as an IVS Network Station. The activities during 1999 and 2000, the current status, and future plans are described.

1. Introduction

The IVS Network Station at the Onsala Space Observatory (OSO) has been described to some extent in the last IVS annual report [1]. There are only minor changes in the technical setup of the station. The staff associated with the IVS Network Station remained the same as reported in [1] with the exception that Rune Byström left the observatory.

2. Geodetic VLBI observations

The observatory has been involved in the geodetic VLBI-series CORE-B, CORE-3, EUROPE and RDV during 1999 and 2000 [2] (see Table 1). Two experiments have been lost due to pointing problems and due to encoder problems, respectively. During one experiment we had tape recording problems due to usage of wrong recorder vacuum for some period. The weak S1 channels during two CORE-3 experiments were due to a problem in the formatter firmware with the 1-bit, 1:2 fanout observing mode. A PROM with the necessary firmware update to solve this problem was shipped to us by Haystack Observatory and was installed successfully during November 2000.

Table 1. Geodetic VLBI experiments at the Onsala Space Observatory during 1999 and 2000.

Exper.	Date	Remarks (problems)	Exper.	Date	Remarks (problems)
EURO47	990201	high parity errors	RDV18	991220	
RDV13	990308		RDV19	000131	
RDV14	990415		EURO53	000127	high parity errors on one tape
EURO48	990426	high parity errors	EURO54	000207	formatter jump
RDV15	990510		RDV20	000313	
CB602	990519		EURO55	000316	
RDV16	990622		EURO56	000515	
EURO49	990629		C3001	000712	high parity errors
CB603	990630	tape speed problems	EURO57	000807	some recording problems
RDV17	990802		C3002	000823	lost due to encoder problems
EURO50	990816		EURO58	000904	two bad tracks
CB604	990823	lost due to pointing problem	C3004	001018	channel S1 weak
CB605	991004	tape speed problems	C3005	001101	channel S1 weak
EURO51	991011		EURO59	001207	
EURO52	991013		C3006	001213	
CB606	991018				

3. Monitoring the Performance of the VLBI System

The log file of each experiment is analysed in order to detect problems and fix them accordingly. The cable delay, the difference between GPS and formatter time, the physical temperature in the dewar for the front end HEMT amplifiers of the receivers, the measured system temperatures and the parity errors are monitored (see figures 1–3). The monitoring of the parity errors indicates some transient problem with tracks numbers 31–33 in recent experiments. Currently investigations are ongoing to identify the reasons.

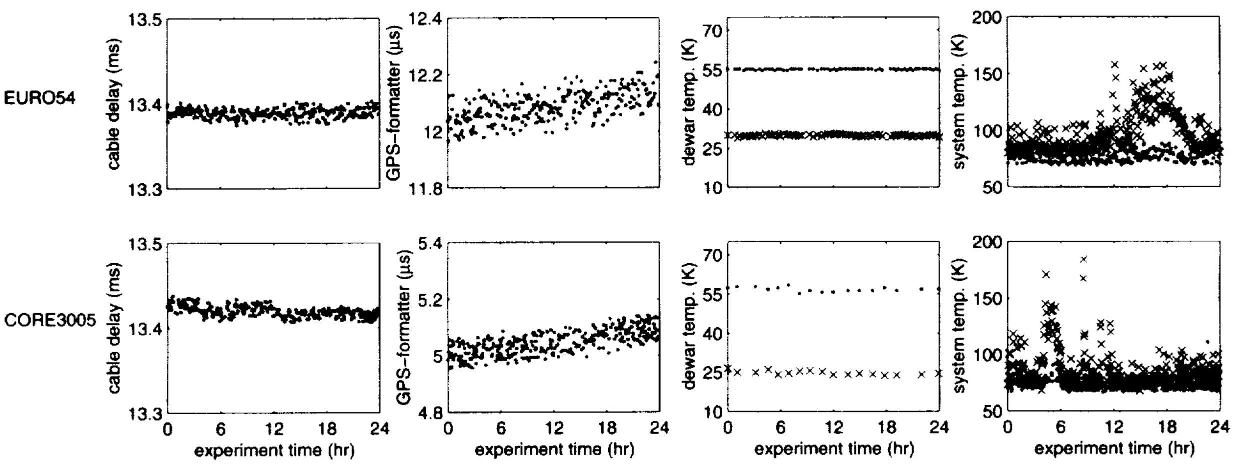

Figure 1. Cable delay, GPS-formatter time difference, dewar temperatures (20K station marked with crosses, 70K station marked with dots) and system temperatures (IF1 marked with crosses, IF2 marked with dots) for EURO54 and CORE3005.

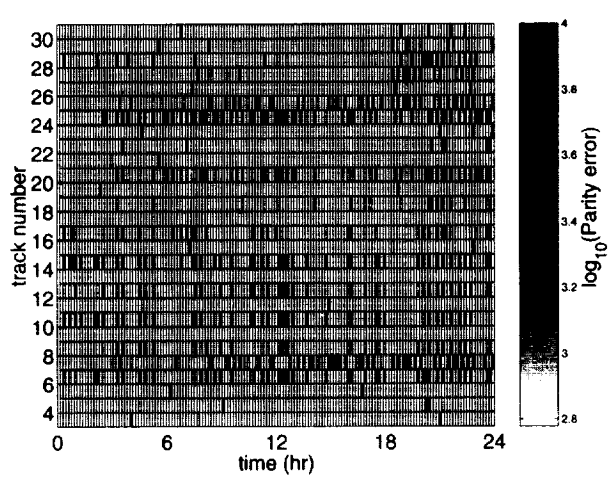

Figure 2. EURO54 parity errors. The colour code covers 600 to 10000 parts per million (ppm), values below 600 ppm are shown in white.

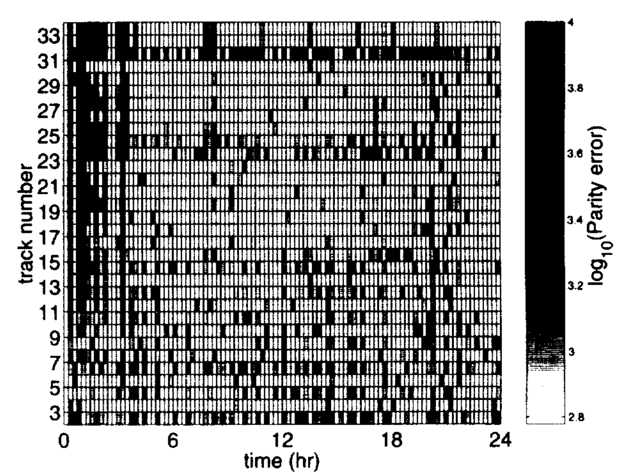

Figure 3: CORE3005 parity errors. The colour code covers 600 to 10000 parts per million (ppm), values below 600 ppm are shown in white.

Since there have been tilting problems of the recorder heads, they had to be sent to Haystack

Observatory for repair in early 1999. Since May 1999 no further changes were done to the head assembly and its run time is now more than six thousand hours. In order to stabilise the recording quality a dry air kit including humidity and temperature sensors has been installed.

Figure 4 shows daily mean values for the offsets GPS-maser and their corresponding root-mean-square (rms) scatter. Since end of February 1999 the Russian Kvarts Ch1-75 maser is used as station clock. The data gap in December 1999 is due to problems with the monitoring computer. The frequency of the maser has been adjusted in March 2000 and the next adjustment is expected to be necessary in several years. Note also the drop in the rms-scatter due to the deactivation of the selective availability (SA) for the GPS system in May 2000.

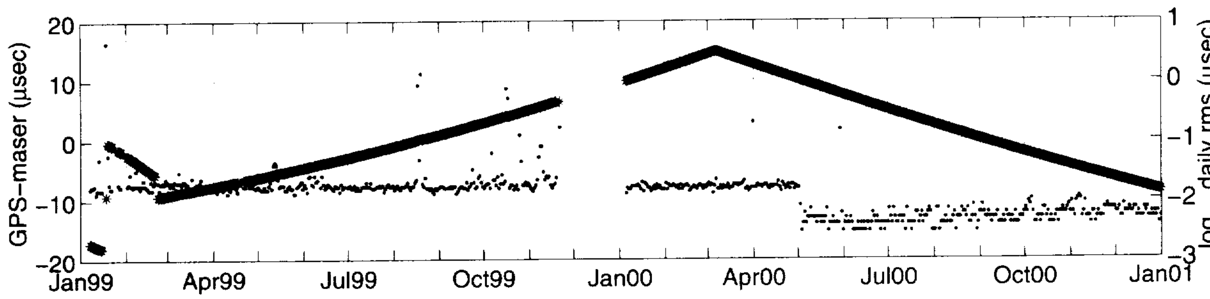

Figure 4. GPS-maser daily offsets (stars, left scale) and root-mean-square scatter (dots, right scale).

4. Monitoring the telescope stability and local ties

The change of the vertical position of the telescope tower, mainly due to thermal expansion, is monitored continuously using an invar rod measurement system [3] (see Fig. 5).

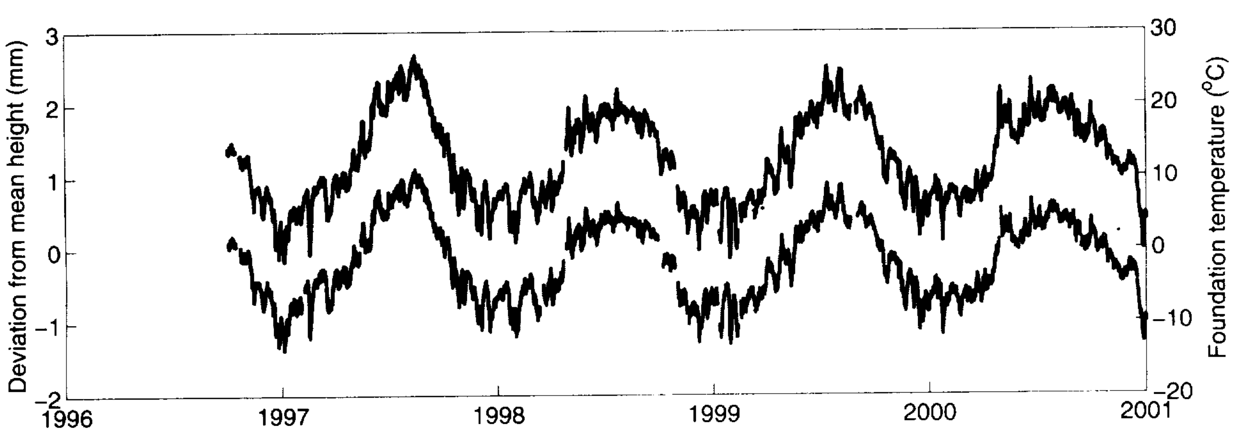

Figure 5. Invar measurements of vertical height of the telescope tower (bottom curve, left scale) and mean temperature in the concrete wall of the foundation (top curve, right scale).

During 1999 a new VLBI-GPS local tie at OSO has been established by mounting two GPS antennas on top of the VLBI telescope [4]. The GPS measurements are performed on a campaign basis whenever the telescope is available for our purposes and not occupied by astronomical observations or geodetic VLBI. The results are also compared to the vertical height changes measured with the invar rod measuring system [5].

5. Outlook

The Onsala Space Observatory will continue to participate in the observation series CORE-3, RDV and EUROPE. For the year 2001 a total of 24 experiments is planned.

A repeated measurement of the local footprint of the Onsala site and a classical survey of the telescope reference point are planned for spring/summer 2001. The footprint measurements will concentrate first on the inner network with baselines of an approximate length of 1 km and then on the outer network with baselines reaching 20–70 km.

The measurement of the vertical height of the telescope tower with the invar rod measurement system will go on continuously and the GPS observations on top of the VLBI telescope will be repeated at regular intervals.

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Seshan VLBI Station Report

Xiaoyu Hong, Shiguang Liang, Xinyong Huang, Wenren Wei

Abstract

The following reports the status of the Seshan VLBI station, including its facilities, personnel, observations made during the reporting period and its future plans.

1. Introduction

The Seshan 25 meter radio telescope is an alt-az antenna run by Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). The telescope is located about 30 km west of Shanghai. It is one of the five main astronomical facilities of Chinese National Astronomical Observatories. The VLBI station is a member of the EVN, APT and IVS.

2. Facilities

2.1. Receivers

Five bands of VLBI observations are available at Seshan Station. The parameters of the receivers are listed in Table 1.

Table 1. VLBI Receivers of Seshan Satation

Band (cm)	**Bandwidth** (MHz)	**Efficiency** (%)	**Type**	**System temperature** (K)
18	1620-1680	40	Room Temperature	~ 100
13	2150-2350	45	Room Temperature	~ 100
6	4700-5100	58	Cryogenic	45-50
3.6	8200-9000	48	Cryogenic	~ 50
1.3	22100-22600	~20	Cryogenic	~110

The Seshan station is equipped with S/X dual band receivers for astrometric and geodetic observations.

The X-band system has been upgraded to the wideband system, from 8200 MHz to 9000 MHz, successfully last year. We will join wideband experiments this year. The test experiment C3006 has been done on Dec. 13, 2000. The correlated results showed good quality of data. The results also showed the large increase in SEFD's from low to high frequency. The situation will be improved.

2.2. Recording System

VLBA, MK4 (VLBA4), and S2 recording systems are available now at Seshsan VLBI station. Upgrade of Seshan MKIV recording system had been done successfully in the end of Aug. 2000.

MKIV upgrade of Seshan station has been carried out with the great help of Team China # 2 in April, 2000. Team China # 2 was composed of six experts from Europe and US. They are Dr.

Ralph Spencer, Dr. Les Parry, Dr. Michael Wunderlich, Dr. Gino Tucarri, Dr. Chopo Ma, and Dr. Ed Himwich.

The first fringe test experiment was done on Apr. 14 with VLBA4 rack and recorder. It failed to find good fringes, several tracks were dead, and the parity errors of several tracks were very high because of problems with the flat cables of the read/write modules, bad connectors, capacitors and soldering. The problems were solved later on.

Fringes were found in the second fringe test with VLBA and MK4 formatters on Aug. 27. Fringes were found also on FT003 and C00C3 experiments later. Seshan MKIV participated in experiments of EVN, NASA, VSOP, APSG etc. since the end of Aug. 2000. Many thanks to JIVE, EVN, NASA, Team China #2, Dan Smythe, and all people who worked on our upgrade.

3. Personnel

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

Table 2 - The main staff in Seshan VLBI Station

Name	Position	email address
Xiaoyu Hong	Research Professor and Chief Scientist	xhong@center.shao.ac.cn
Shi-guang Liang	Research Professor and Chief Engineer	sgliang@center.shao.ac.cn
Zhihan Qian	Research Professor	qzh@center.shao.ac.cn
Xinyong Huang	Senior Engineer	xhuang@center.shao.ac.cn
Wenren Wei	Senior Engineer	wwr@center.shao.ac.cn
Zhuhe Xue	Senior Engineer	zhxue@center.shao.ac.cn
Jiazheng He	Senior Engineer	jzhe@center.shao.ac.cn
Qing-yuan Fan	Senior Engineer	qyfan@center.shao.ac.cn
Song-lin Chen	Engineer	slchen@center.shao.ac.cn
Xiu-ling Chen	Engineer	xlchen@center.shao.ac.cn

The email accounts for the station are: seshan@center.shao.ac.cn; vlbish@online.sh.cn.

4. Geodetic Observations

13 geodetic experiments have been run by the Seshan Station from March 1999 to the end of 2000. The experiments are listed in Table 3.

5. Future Plans

The improvement of quickly switching frequencies of Seshan station will be implemented in this year. After that, it will be easy to switch between S/X band and L- or C- or K-bands.

The Geodetic VLBI observation plan of Seshan VLBI station for 2001 is listed in Table 4.

Table 3 List of Geodetic VLBI observations From Mar. 1999 to Dec. 2000

DATE	EXPERIMENT	HOUR
07-APR 1999	CORE-B502	24.0
21-APR 1999	CORE-B503	24.0
26-JUL 1999	CRF-08	25.0
28-JUL 1999	CORE-B504	24.0
01-NOV 1999	APSG05	11.0
03-NOV 1999	APSG06	25.0
04-NOV 1999	CORE-B505	24.0
29-DEC 1999	CORE-B506	24.0
12-JAN 2000	CORE-B801	24.0
26-SEP 2000	CORE-1004	06.0
02-OCT 2000	APSG7	24.0
02-NOV 2000	CORE-B802	24.0
14-NOV 2000	CORE-3006	06.0

Table 4 The Geodetic observation plan of Seshan VLBI station for 2001

DATE	EXPERIMENT	HOUR
05-Feb 2001	CORE-1009	24.0
05-Mar 2001	CORE-1010	24.0
26-Mar 2001	CONT-M3	24.0
27-Mar 2001	CONT-M4	24.0
28-Mar 2001	CONT-M5	24.0
16-Apr 2001	CORE-1011	24.0
14-May 2001	CORE-1012	24.0
25-Jun 2001	CORE-1013	24.0
09-Jul 2001	CORE-1014	24.0
20-Aug 2001	CORE-1015	24.0
10-Sep 2001	CORE-1016	24.0
22-Oct 2001	CORE-1017	24.0
05-Nov 2001	CORE-1018	24.0
12-Nov 2001	APSG-8	24.0
19-Nov 2001	APSG-9	24.0
03-Dec 2001	CORE-1019	24.0

Simeiz Station: Geodetical Experiments and Single Dish Observations

N. Nesterov, A. Volvach

Abstract

This report summarizes an overview of the VLBI activities during 5 years. Horizontal station velocity was determined and estimates of its accuracy were obtained. An overview about the single dish activity and of the stability of the station with respect to local marks is given also.

1. Observations and Data Analysis

1.1. IVS

All available dual-band geodetic MARK III VLBI observations for 21 years, from 1979.59 till 2000.72 were used in the analysis: 3 058 sessions, 3 005 651 observations including 36 successful sessions with participation of the station Simeiz for 6 years: 1994.48–2000.36 with 19 631 good measurements of group delays (Petrov et al., 2000).

Simeiz station moves with respect to the Eurasian tectonic plate considered as rigid with rate 2.8 ± 0.9 mm/year in the direction with azimuth 27 deg. Thorough investigation of possible systematic effects has been done and the reliability of the estimate of the uncertainty has been evaluated. Performance of the receivers and H-maser was examined. The stability of the station with respect to local marks was investigated and an enhancement of inclination of the azimuthal axis (Pisa effect) of the telescope with velocity $2''\!.6$ per year was disclosed (see Fig.1).

The following position of the station Simeiz at the epoch 1997.0 and its rate of change in the ITRF97 system were obtained:

$$X = 3D3785231.070 \pm 0.006 \text{ m} \qquad \dot{X} = 3D6.8 \cdot 10^{-10} \pm 0.3 \cdot 10^{-10} \text{ m/sec}$$
$$Y = 3D2551207.415 \pm 0.004 \text{ m} \qquad \dot{Y} = 3D5.0 \cdot 10^{-10} \pm 0.4 \cdot 10^{-10} \text{ m/sec}$$
$$Z = 3D4439796.360 \pm 0.008 \text{ m} \qquad \dot{Z} = 3D2.1 \cdot 10^{-10} \pm 0.8 \cdot 10^{-10} \text{ m/sec}$$

The details of the analysis are stated in paper of Petrov et al., 2000.

1.2. Single Dish

The antenna temperatures from ten sources were measured by the standard ON–OFF method. Before measuring the intensity, we determined the source instrumental position by scanning. The radio telescope was then pointed alternately on the source and on the distance of 5 beamwidths off source. The antenna temperature from a source was defined as the difference between the radiometer responses averaged during 10 s at two different antenna positions. Depending on the intensity of the emission from sources, we made a series of 20–60 measurements and then calculated the mean signal intensity and estimated the rms error of the mean. The fluxes from the objects under study were calibrated using measurements of the calibration sources Cyg-A, Cas-A, Tau-A, Vir-A, whose flux densities are given in Mark-IV Field System Documentation (1993).

Table 1 shows measured flux densities of sources at 8 GHz as follows: column (1) - IAU source designation, column (2) and column (3) - date and time of observations, column (4) - flux densities, column (5) - the rms errors of the measured flux densities.

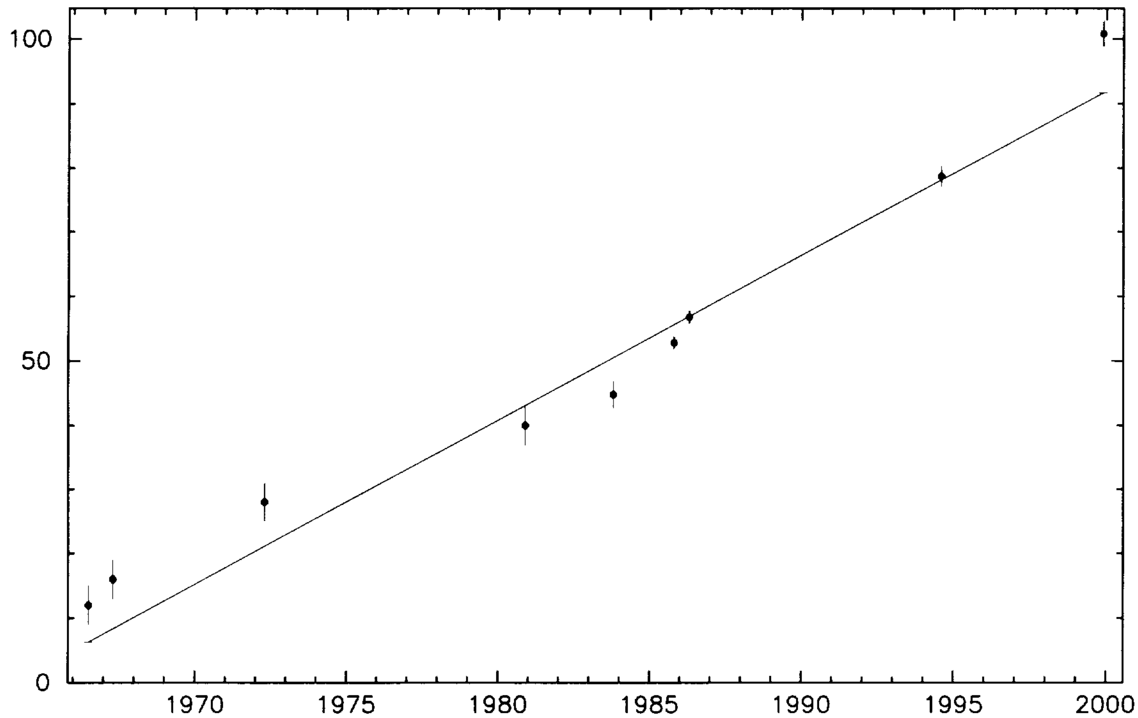

Figure 1. Deviation of azimuthal axis of the radiotelescope with respect to the local plumb line (in arc seconds) at different epochs.

Table 1. Single dish 8 GHz measured flux densities.

SOURCE	DAT(YY.MM)	TM(DD.UT)	FLUX(Jy)	SIGM(Jy)
0316+413	97.09	4.931	22.4	1.1
	97.12	10.668	20.9	1.4
0528+134	97.09	5.149	3.3	0.7
	98.02	1.685	3.1	0.9
0552+398	97.09	4.999	5.2	0.5
0642+449	97.09	30.294	1.9	0.3
	98.02	1.622	3.3	0.9
	98.04	20.303	2.7	0.8
	98.06	23.474	2.5	0.5
1226+023	97.08	29.651	30.5	3.7
1253-055	97.08	29.668	22.3	1.4
2037+421	97.09	4.898	19.2	1.6
	97.12	10.661	21.2	0.7
	98.02	2.344	20.9	1.0
2145+067	98.02	2.355	6.2	1.3
2200+420	98.02	3.406	3.8	1.3
2251+158	98.02	3.417	11.2	1.7

2. Discussion of Results and Conclusions

Estimates of the horizontal velocity of the radioastronomical station Simeiz were obtained using VLBI observations carried out under geodynamics programs during 1994-2000. The complete set of 3 million VLBI observations has been analyzed and it was found that the station moves with respect to the Eurasian tectonic plate considered as rigid with rate 2.8 ± 0.9 mm/yr in a north-east direction. Thorough study of possible local systematic effects has been done and the reliability of the estimate of the uncertainty has been evaluated. The stability of the station with respect to local marks was investigated and an inclination of the azimuthal axis (Pisa effect) of the telescope with velocity 2$''$.6 per year was disclosed. The estimate of vertical motion of the station 2.6 ± 3.0 mm/yr is not statistically significant.

The results of single dish S/X observations of sources used for geodesy investigations can be then reviewed after experiment to check the consistency of data from each source.

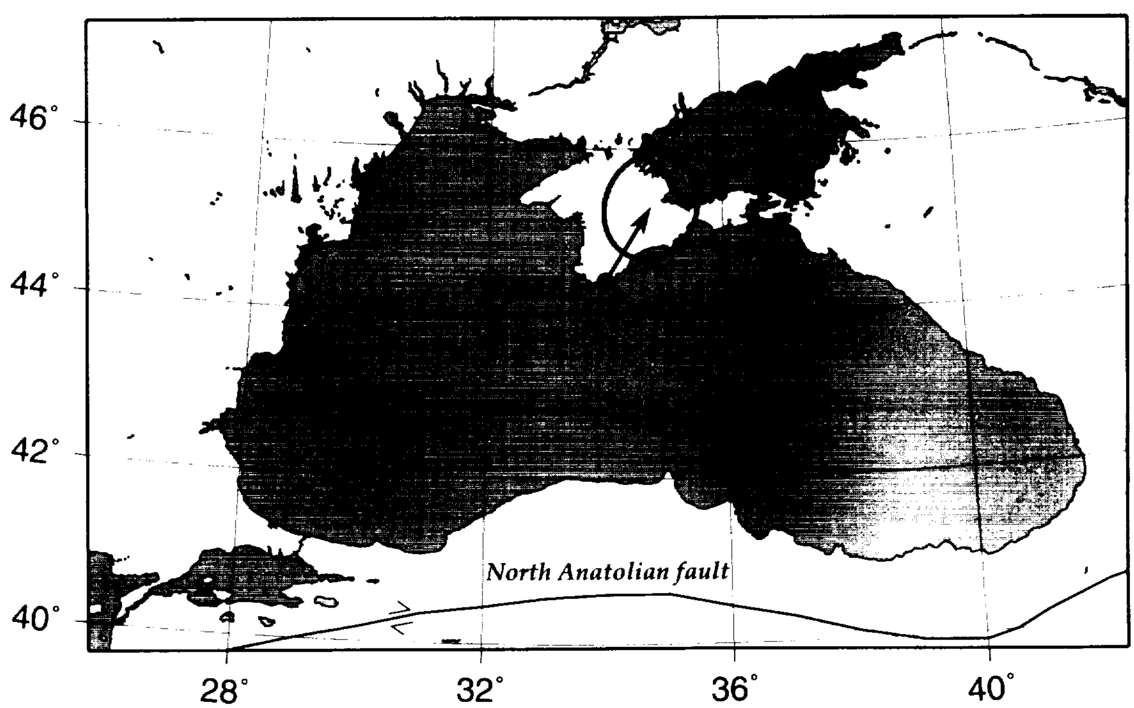

Figure 2. Motion of the station Simeiz.

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Svetloe Radio Astronomical Observatory

Sergey Smolentsev, Dmitriy Ivanov, Zinovy Malkin

Abstract

This report provides information about changes in the Svetloe Radio Astronomy Observatory status in the period after the last IVS report.

1. Introduction

Svetloe Radio Astronomical Observatory was founded by the Institute of Applied Astronomy (IAA) as the first station of Russian VLBI network QUASAR. Sponsoring organization of this project is the Russian Academy of Sciences (RAS). The site is located at the Karelian Neck near Svetloe village in about 100 km towards North from St. Petersburg. The basic instruments of the observatory are 32-m radio telescope RTF-32 and technical systems provided realization of VLBI observations. In addition, a permanent GPS receiver was installed at Svetloe in 1996.

During last two years Svetloe observatory regularly participated in various radio astronomy programs including VLBI and RL VLBI observations of quasars, Sun, planets, asteroids using recording terminal S2-RT.

Svetloe observatory participated in several regional and global geodetic projects and is a EUREF permanent station.

2. Radio telescope and VLBI equipment

The results of measurements of radiotelescope parameters (for LRP) are presented in Table 1.

Table 1. Parameters of the radio telescope RTF-32.

Wave band, cm	SEFD	T_{sys}, K
3.5	430	58
6	180	32
13	300	43

Field System is now fully involved in observation, registration, and investigation process. Corrections for radio telescope deformations are determined and used for pointing.

A new automatic meteo station was installed at Svetloe in 2000. It has been manufactured by the "Taifun" Enterprise, Obninsk, Russia, and provides measurement of temperature, pressure, relative humidity, wind 3D velocity and direction.

Figures 1–4 show a common view of Svetloe observatory, RTF-32 radio antenna and other equipment.

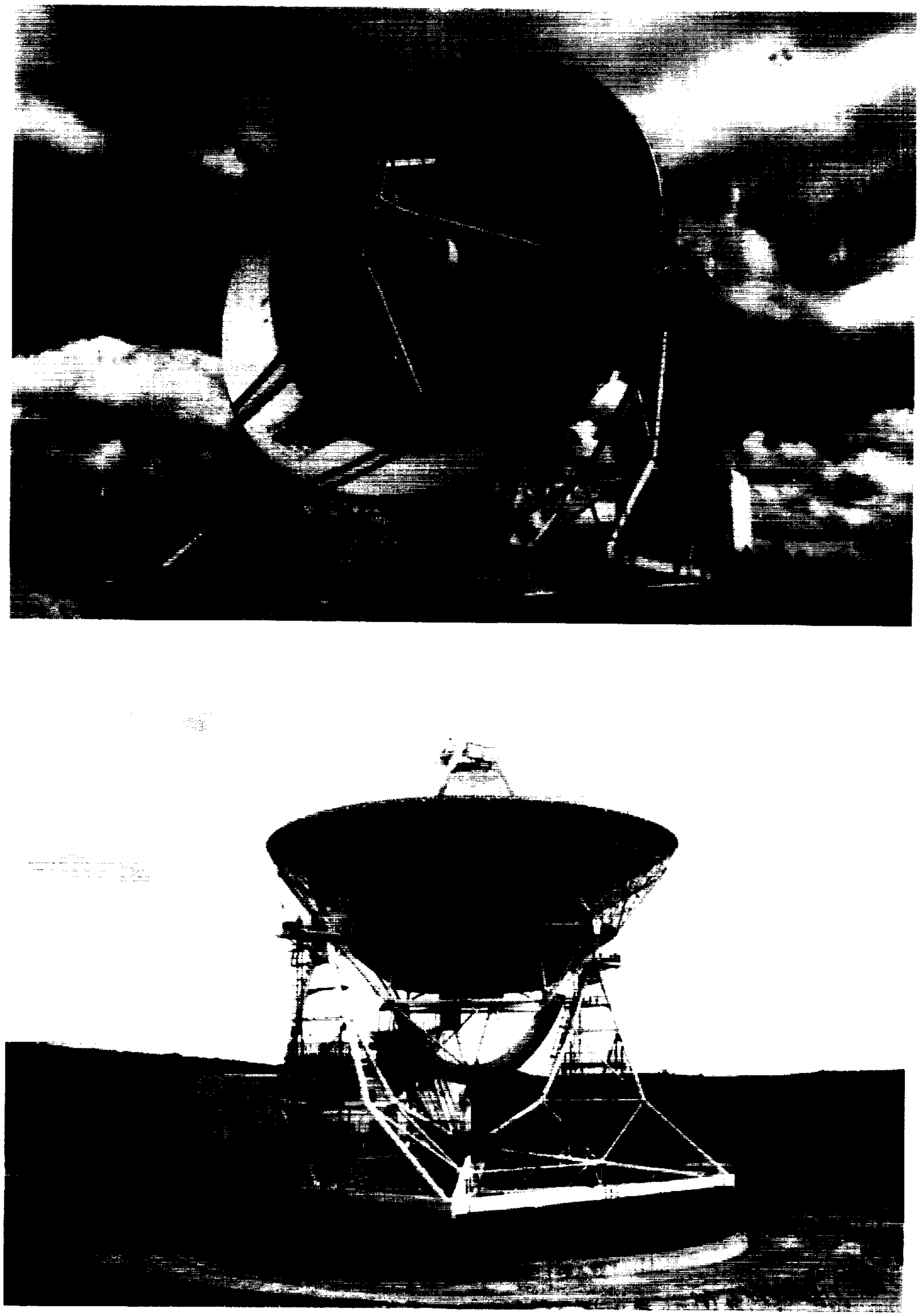

Figure 1. Radio telescope RTF-32.

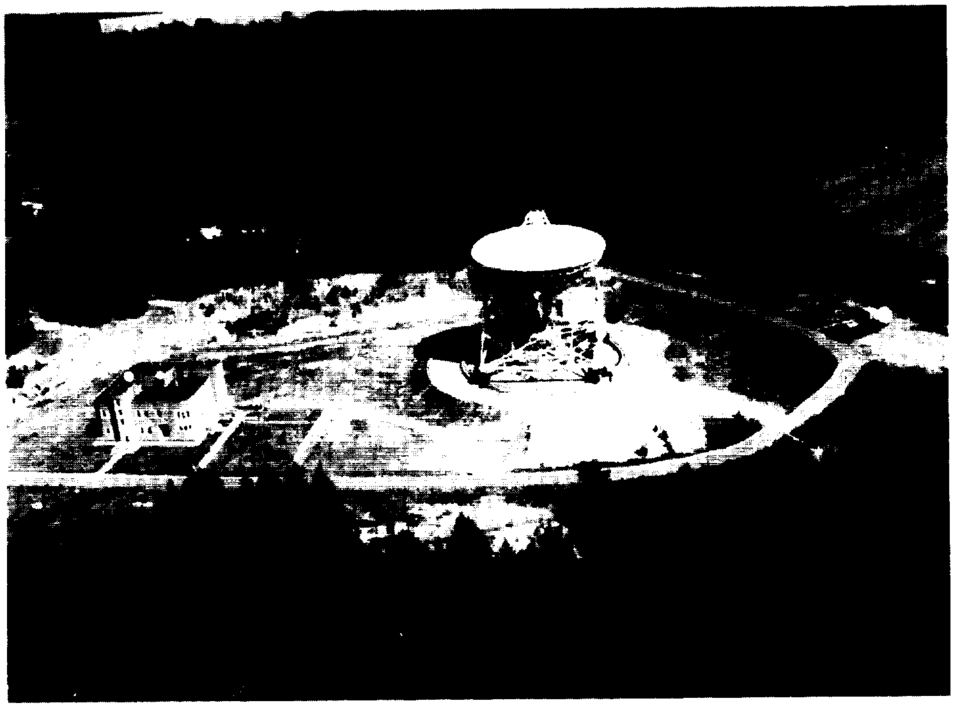

Figure 2. Svetloe station: laboratory building and radiotelescope RTF-32.

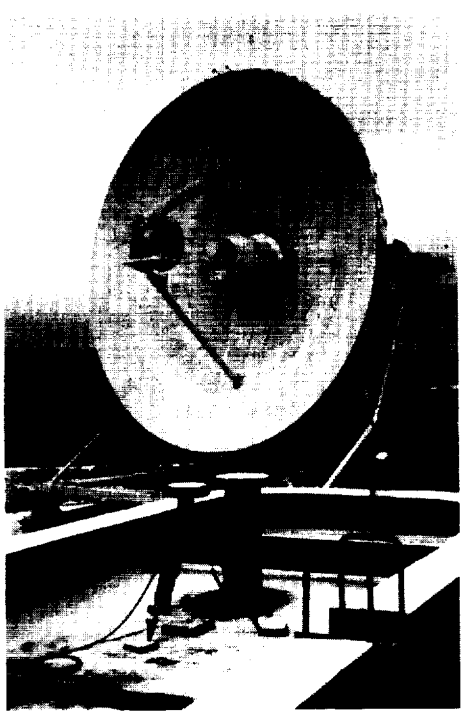

Figure 3. RTF-32 antenna, Trimble GPS and Javad GPS/GLONASS receivers during IGEX campaign.

Figure 4. Radio receivers for 3.5 and 13 cm wave bands.

3. Geodetic Survey at Svetloe Observatory

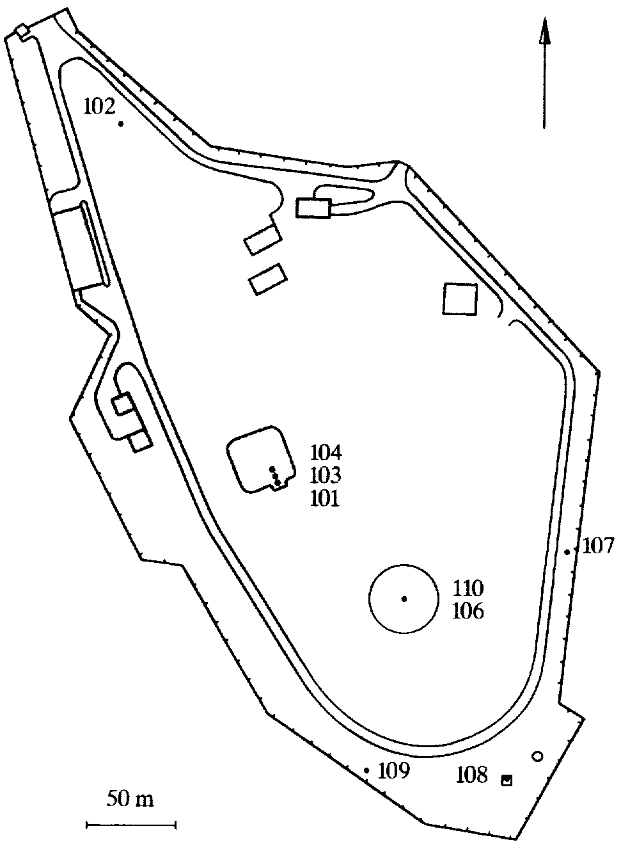

Figure 5. Local geodetic network at Svetloe.

Local geodetic network at the Svetloe observatory includes 9 reference points (see Figure 5): 102, 107, 108, 109 are ground marks (the latter connected with a pad for mobile systems), 101, 103, 104 are located at the roof of two story laboratory building and designed for installation of GPS/GLONASS receivers or conventional geodetic units, 110 is the intersection of radiotelescope RTF-32 axis, and 106 is intermediate mark on its foundation. GPS receiver Trimble 4000SST is permanently installed on the 101 mark (12350M001, SVTL).

Since the last report several new measurements were made at the network and mutual eccentricity between marks were derived from common adjustments of GPS and conventional surveys made in 1993–1999. Accuracy of the local geodetic network is about 2 mm and intersection of radio telescope axis is tied to the network with accuracy about 5 mm.

4. Outlook

We plan for the near future:

- Begin experimental VLBI observations on Svetloe-Zelenchukskaya baseline (IAA observatory Zelenchukskaya located in North Caucasus is the second station of the QUASAR network).
- Install the first two channels of the new DAS developed at the IAA.
- Install a new radio telescope control system.

JARE Syowa Station 11-m Antenna, Antarctica

Kazuo Shibuya, Shigeru Aoki, Koichiro Doi

Abstract

The Antarctic geodetic VLBI sessions with participation of Syowa Station (69.0 degS, 39.6 degE) 11-m S/X band paraboloid antenna continued during 1999-2000. Seven 24-hour experiments were made each year with the University of Tasmania at Hobart 26-m antenna and the Hartebeesthoek Radio Astronomical Observatory (HartRAO) 26-m antenna. In the year 2001, four similar experiments are planned. Syowa antenna participated/will participate also in the CORE-OHiggins sessions.

1. Introduction

As reported in [1], regular geodetic VLBI experiments started from February 1998 at Syowa Station (69.0 degS, 39.6 degE) by the 39th Japanese Antarctic Research Expedition (JARE-39). The southern hemisphere VLBI sessions with participation of Syowa Station 11 m antenna, the University of Tasmania 26 m antenna at Hobart and the Hartebeesthoek Radio Astronomical Observatory (HartRAO) 26 m antenna, were named the SYW sessions and seven 24-hour experiments have been made in each year of 1999 and 2000. The observation system is maintained by trained JARE wintering members. They change over at February 1 every year. We had already 6 wintered-over staffs: two for each of JARE-39 (1998 Feb. - 1999 Jan.), -40 (1999 Feb. - 2000 Jan.) and -41 (2000 Feb. - 2001 Jan.). Syowa Station is always being reformed and its overview in February 2000 is shown in Figure 1.

Figure 1. Overview of Syowa Station in February 2000 and the antenna radome.

2. Antenna Specifications

There was no significant change to the configuration of the "mechanical system", "receiver system", "hydrogen maser systems and time comparison", and "VLBI backend system" which were described in the 1999 IVS Annual Report [2]. Therefore notices in the maintenance and changes in the operational procedure after the above report are briefly summarized. (1) Accidental power failures occurred several times, and several modules (ACU control PC, DC power supply, hard disk etc.) had damages. Changing to spare parts enabled uninterrupted experiments. (2) In January 1999, HP workstation was installed to make a schedule file at Syowa Station, and the file was transferred to the IVS Coordinating Center in order that the other two stations can access the file. Schedule format was adjusted to the standard S2-FS9 system with the support of the IVS Coordinating Center. (3) Test source receiving was repeated to obtain more precise receiver performance and the revised parameters are summarized in Table 1. The tabulated values correspond to good conditions of the air temperature above -10 degC, and they become worse as the air temperature becomes lower. (4) Hobart antenna system was found to be affected by artificial noise around the S-band 14th channel, so that the CDP narrow-band frequencies of the S band were shifted 10 MHz lower than the previous one after the SYW995 (Sep. 09, 1999) experiment. The recording rate (64 or 128 Mbits/s), channel number (8 ch) and the frequency range (2217 - 2302 MHz) were not changed. (5) One hydrogen maser set (Anritsu RH401A; 1002C) began malfunctioning at 21 July 2000, but 1001C is operational under good conditions. The system GPS timing receiver (Model 9000B from the TRAK Co. Ltd.) was also malfunctioning around November 1999, but backup GPS receiver enabled us to monitor the UTC-recorder time offset within 4 microseconds.

Table 1. Receiver performance of the Syowa 11-m antenna.

Band	Frequency (MHz)	Tsys (K)	Efficiency	SEFD (Jy)
S	2200-2320	114	0.55	6000
X	7860-8600	128	0.53	7000

3. On-going Project

As part of JARE Earth science program titled "Study of dynamical process of the Earth by geodesy and solid-earth geophysics", JARE-40 and -41 continued geodetic VLBI experiments at Syowa Station after JARE-39. As compared to 48-hour experiments of SYW981 through SYW984 during JARE-39, 24-hour experiments were made by JARE-40 and -41 as summarized in Table 2. For the year 2001, the number of the SYW experiments will be reduced to 4. Syowa Station also participated in the CORE-OHiggins sessions. Although there were some uncertain points in the performance of the overall Syowa system at changeover of JARE-39/-40, the SYW991 experiment with Kashima (both use K4 system) gave reasonable baseline solution as referred to the 1990 experiment, which ascertained good performance of the Syowa system. The SYW experiment data are being processed at the VSOP correlator center of NAO Mitaka. The SYW981 (1998, Feb), SYW982 (1998, May), and SYW984 (1998, Nov) data were correlated and the FITS database has been created. However, geodetic solutions for these and the later experiments are not obtained yet because of delay of the baseline analysis software adaptation for the FITS database. The main difficulty with the VSOP correlated FITS database is deletion of time-tags during the S2-K4 copying. We are trying to solve this problem by making an S2-K4 copier which keeps the original S2 time-tag and shifts it into the copied K4 tape, as this procedure will produce the MarkIII database to be linked to the standard SOLVE software. Development of the K4-MarkIV copier in

GSI enabled participation of Syowa Station in the CORE-OHiggins sessions [3].

Table 2. Summary of the SYW experiments in the years 1999 and 2000

Code	Start time	Obs. hour	Obs. number
SYW991	1999/Feb/17 05:00	24 h	123
SYW992	1999/May/13 06:00	24 h	172
SYW993	1999/Jul/15 08:00	24 h	163
SYW994	1999/Aug/26 08:00	24 h	180
SYW995	1999/Sep/09 08:00	24 h	189
SYW996	1999/Oct/07 08:00	24 h	199
SYW997	1999/Nov/18 08:00	24 h	220
SYW008	2000/Feb/02 10:00	24 h	183
SYW009	2000/Mar/20 08:00	24 h	215
SYW010	2000/Jul/03 08:00	24 h	182
SYW011	2000/Aug/09 08:00	24 h	175
SYW012	2000/Sep/11 08:00	24 h	178
SYW013	2000/Oct/05 08:00	24 h	198
SYW014	2000/Nov/20 08:00	24 h	229
SYW015	2000/Dec/07 08:00	24 h	214

4. Staffs for the JARE Syowa Station 11-m antenna

- Kazuo Shibuya, Project coordinator at NIPR.
- Koichiro Doi, Liaison officer at NIPR.
- Seiji Manabe, Project coordinator at NAO Mizusawa.
- Takaaki Jike (from NAO Mizusawa), Chief operator of JARE-39 (Feb. 1998 - Jan. 1999).
- Teruhito Tanaka (from NEC), Antenna maintenance staff of JARE-39.
- Yoshihiro Fukuzaki (from GSI), Chief operator of JARE-40 (Feb. 1999 - Jan. 2000).
- Takeshi Ino (from NEC), Antenna maintenance staff of JARE-40.
- Koichiro Doi (from NIPR), Chief operator of JARE-41 (Feb. 2000 - Jan. 2001).
- Seiji Takao (from NEC), Antenna maintenance staff of JARE-41.

5. Collocated Observations

Syowa Station is located on the interior of the geologically stable Antarctic plate. It is situated on firm bedrock without sedimentary layer. Syowa VLBI antenna was registered 66006S004 as the IERS Domes Number, and 7342 as the CDP Number. Collocated observations by GPS (IERS Dome Number 66006S002) and DORIS (IERS Dome Number 66006S003) are continuing. PRARE (CDP Number 7711) stopped observations after 1997. Other geophysical instruments running are broadband seismometer (STS-1), superconducting gravimeter (GWR TT70), pressure-type sea level meter, fluxgate magnetometers, etc.

References

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Transportable Integrated Geodetic Observatory

Hayo Hase

Abstract

This report summarises the activities within the TIGO project to provide a new fundamental station for geodesy at Concepción, Chile. The VLBI module of TIGO will serve as a new IVS network station.

1. Progress in the TIGO Project

The Transportable Integrated Geodetic Observatory (TIGO) consists of a 6 m radio telescope for VLBI, a 50 cm optical telescope for SLR, a GPS array of four GPS permanent receivers, a super-conducting gravity meter, a broad spectrum seismometer, meteorological sensors including a water vapour radiometer and an ensemble of atomic clocks like cesium clocks and hydrogen masers (see [1]). In 2000 TIGO was still located at the site of the Fundamentalstation Wettzell, where it was constructed and tested during the last 5 years (see Fig. 1).

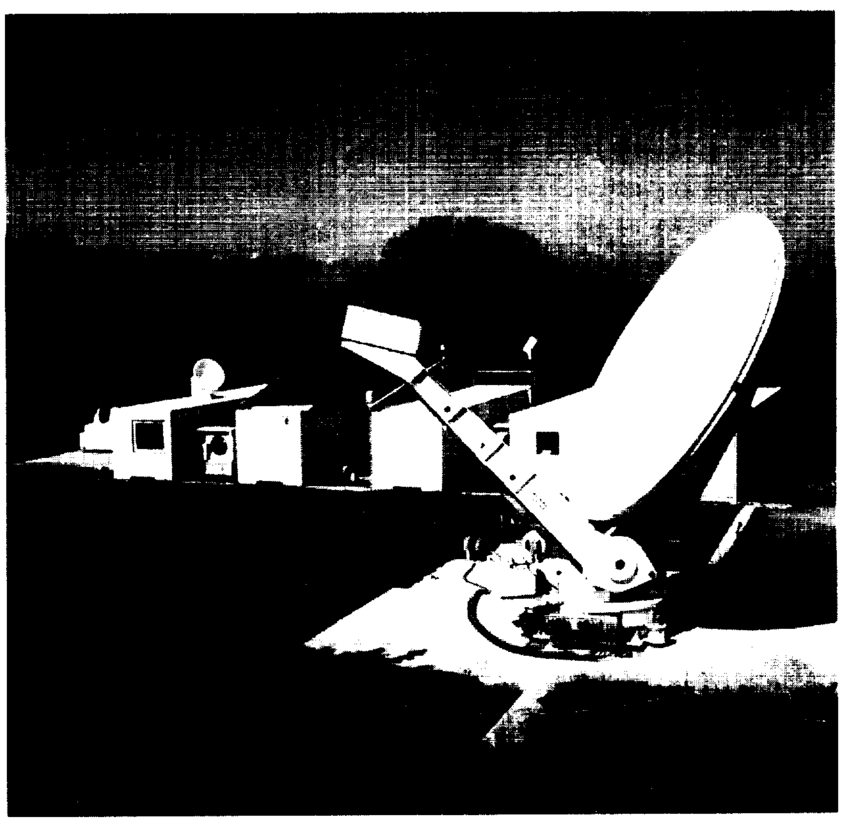

Figure 1. TIGO at the Fundamentalstation Wettzell 1999-2000.

During 1999 an "Announcement of Opportunity" was sent worldwide to many agencies, institutions and universities which are working in geodesy or geoscience. By the deadline September

30, 1999, twelve promising locations had been proposed which were inspected during November/December 1999 (see Fig. 2).

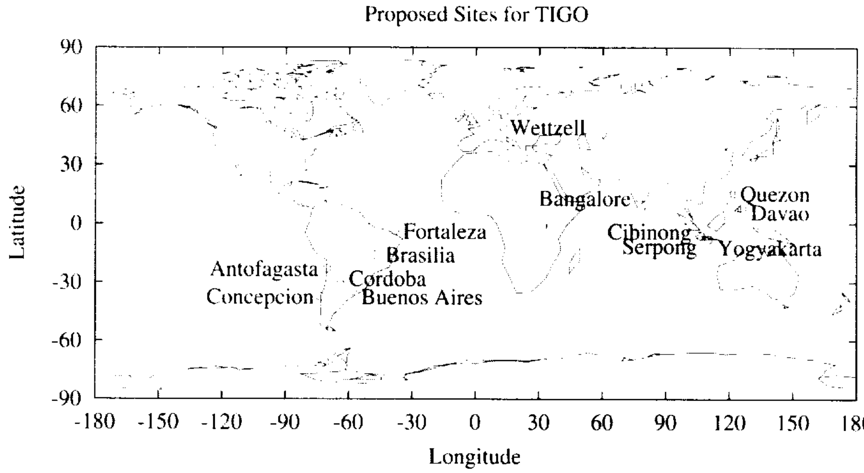

Figure 2. TIGO sites which were proposed by interested institutions, September 30, 1999.

On January 21, 2000, the German Scientific Committee of the Research Group for Satellite Geodesy (FGS) gave first priority to the applying Chilean consortium of Universidad de Concepción (UdeC), Universidad del Bío Bío (UBíoBío), Universidad Católica de la Santísima Concepción (UCSC) and Instituto Geográfico Militar (IGM), Santiago, which offered to host TIGO at Concepción. Concepción is the most southern location among the offers, which is of importance for improving existing networks. The consortium could also fulfill the demand of BKG to supply 11 engineers/operators which will work under the supervision of three experts from BKG in the operation of TIGO.

In March 2000 several sites in the surroundings of Concepción had been investigated due to the microwave pollution in S- and X-band. Finally a hill about 2.5 km distance from the university campus was defined to be the selected TIGO site (see Fig. 3, Tab. 1).

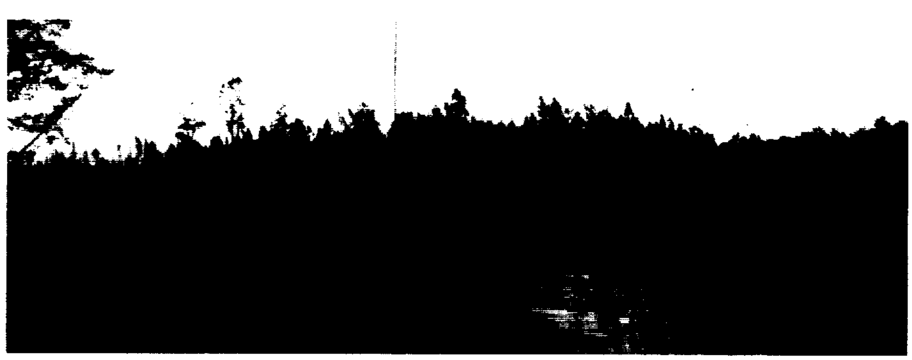

Figure 3. The selected TIGO site is on top of the left hill at the campus area of Universidad de Concepción.

On June 21, 2000, an arrangement between BKG and UdeC on behalf of the Chilean consortium for hosting TIGO was signed at BKG Frankfurt by the president of BKG, Prof. Dietmar Grünreich,

Table 1. Approximate coordinates of the TIGO site in Concepción (taken from topographic map). The IVS letter code is "Tc = TIGOCONC".

Longitude	$+73°01'25''$ W ($\approx +73.023611°$)
Latitude	$-36°50'30''$ S ($\approx -36.841667°$)
Altitude	150 m

and the rector of UdeC, Prof. Sergio Lavanchy. TIGO will be in Concepción for a minimum period of 3 years with the option of extensions year by year.

In August/September 2000 the three BKG experts visited Concepción for discussions of platform details for the construction and for taking Spanish classes. Among the five cooperating partner institutions a scientific board for the scientific use of TIGO constituted itself. The scientific board selected the first four Chileans who will work at TIGO in the future.

In October/November/December 2000 the four Chileans Eduardo Carvacho (UdeC), Carlos Bustamante (UBíoBío), Raul Escobar (UCSC), Oscar Cifuentes (IGM) visited Wettzell for a first introduction and training on the TIGO instruments.

In order to ship TIGO to Chile and get residential and work permission for the BKG experts a bilateral note needs to be exchanged between Chile and Germany. This bureaucratic process was initiated in August 2000 and is hoped to be finished during 2001. The ratification is a necessity before TIGO can be shipped from Wettzell to Concepción.

In the beginning of 2001 a platform for TIGO and the access road to the platform will be built. It is envisaged that the TIGO operation will start at Concepción in mid 2001.

2. Status of the TIGO VLBI module

TIGO's VLBA4 terminal was finally completed with the installation of the Mk4 formatter and decoder during 2000.

It is intended to equip the VLBI module of TIGO also with the Canadian S2 VLBI data acquisition system in order to complete existing S2 VLBI networks across the Pacific. The delivery is anticipated for 2001.

TIGO participated also during 1999/2000 in several VLBI experiments (see Tab. 2).

3. Outlook

During 2001 a new fundamental station will be realized by TIGO in Concepción for a minimum period of 3 years. The joint operation between BKG and the Chilean consortium will be dedicated to the international services like IVS, ILRS, IGS and BIPM. Scientific projects in relation to TIGO will be supervised by the Scientific Board of TIGO, while the operation of TIGO will be supervised by the three TIGO experts from BKG.

The VLBI part of TIGO will be operated under the supervision of the author by three Chilean engineers who will be novices to geodetic VLBI, but with some experience in microwave techniques, electronics and computers.

Due to the lack of a dense space geodetic network in South America we expect a regular scheduling of the TIGO instruments. The VLBI module of TIGO is prepared for serving the IVS with regular observations.

Table 2. Participation in VLBI-Experiments of TIGO 1999-2000. Experiments with reference frequency offset (5MHz - 0.1Hz) allowed short baseline determinations with the Wettzell 20m-radio-telescope.

Date	Experiment	Remarks
1999-02-01	EUROPE-47	reference frequency offset
1999-02-04	WZTIE-1	reference frequency offset
1999-02-23	NA304	
1999-02-25	WZ4TS	reference frequency offset
1999-06-29	EUROPE-49	reference frequency offset
1999-07-01	BRD01	reference frequency offset
1999-08-16	EUROPE-50	reference frequency offset
1999-10-11	EUROPE-51	reference frequency offset
2000-01-28	EUROPE-52	reference frequency offset
2000-02-07	EUROPE-53	reference frequency offset
2000-05-16	EUROPE-56	reference frequency offset
2000-06-19	IRIS-S151	reference frequency offset
2000-07-24	IRIS-S152	reference frequency offset
2000-11-13	IRIS-S156	
2000-12-18	IRIS-S157	

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[1] Hase, H., Böer, A., Riepl, S., Schlüter, W., Cecioni, A.: TIGO - Transportable Integrated Geodetic Observatory, VI Congreso Internacional de Ciencias de la Tierra, Santiago de Chile, August 7-11, 2000, http://www.wettzell.ifag.de/publ/wtz153.pdf

Tsukuba 32-m VLBI Station

Yoshihiro Fukuzaki

Abstract

This report summarizes the activity at the Tsukuba 32-m VLBI station (Fig 1) by the Geographical Survey Institute (GSI) VLBI group. The Tsukuba 32-m VLBI station has participated in several international VLBI sessions. Domestic experiments (JADE sessions) are carried out periodically using GSI's domestic network, which includes the Tsukuba 32-m VLBI station. We have a plan to increase the JADE sessions and perform collocation surveys at the Tsukuba and Aira stations.

1. Activities

Tsukuba 32-m VLBI station has participated in several international VLBI experiments that are listed in Table 1.

GSI has five permanent stations in Japan. Distributions of these stations are shown in Fig 2. The network is named GARNET (GSI Advanced Radiotelescope Network). In 1999 and 2000, domestic experiment using GARNET was carried out four times a year. This session is named JADE (Japanese Dynamic Earth observation by VLBI). From JADE-0003 Gifu station with 3m antenna owned by Gifu University has participated in JADE session. The network has now six stations and ten baselines. The result of the JADE sessions is available on the GSI VLBI Web page (http://vldb.gsi.go.jp/sokuchi/vlbi/english).

A tie experiment among the stations that have a large antenna, Kashima 26-m, Kashima 34-m and Tsukuba 32-m, was carried out in 2000. This session is named JPNTI. The purpose of JPNTI sessions is to transfer the coordinates of Kashima 26-m and Kashima 34-m established by a long period of observation to Tsukuba 32-m VLBI station. Four KSP stations also participate in this session.

The data for CORE-OHIG6,7,9,12 sessions in Syowa station, Antarctica were dubbed from K4 into MarkIIIa at Tsukuba 32-m VLBI station. These data were correlated at Bonn Correlator and analyzed at GSFC.

Table 1. International experiments at Tsukuba 32-m VLBI station after Nov. 1999

Experiment	Code
CORE-A	CA075,76,77,79,80,81,82,83
CORE-1	C1001,02,03,04,05,06,07
CORE-B	CB701,702
VLBA	RDV19,20,21,22,23,24
JPNTI	JPNTI2,3,4,5,6
Other	NEOS-A351, SURVEY001, CRF09, APSG07

2. Changes

The staff of VLBI group at GSI has changed. Table 2 lists the present staff.

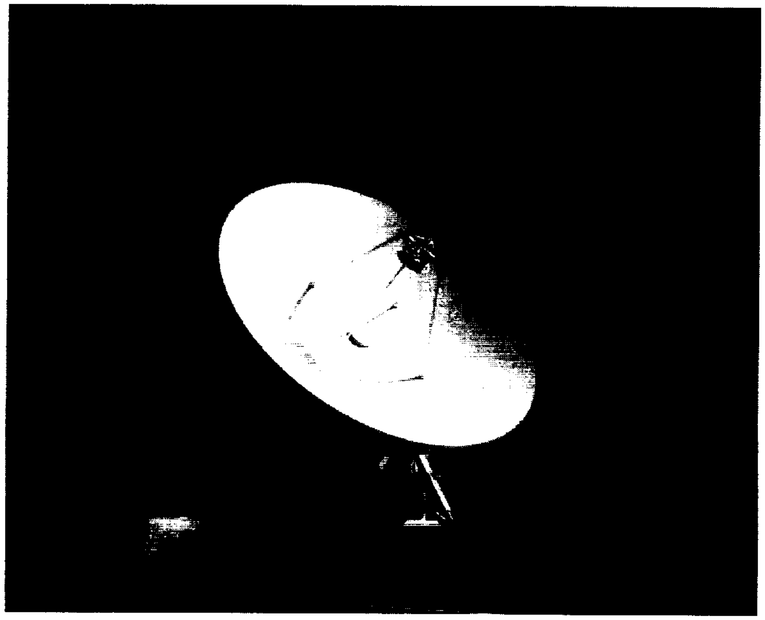

Figure 1. Tsukuba 32-m VLBI antenna.

Six months after installing Tsukuba 32-m antenna, the Azimuth rail, which was 73 kg per meter and 10 cm width, was cracked because the stress from the wheel was larger than the value designed by the antenna manufacturer. In April 1999, the rail was replaced with a larger one (Fig 3). So far, no significant problems with the rail have occurred. By this replacement of Azimuth rail, the height of the reference point of Tsukuba 32-m antenna has changed +43.7mm.

GSI's internet domain name has been changed from gsi-mc.go.jp to gsi.go.jp since January 2001.

Table 2. Staff working at GSI VLBI group

Name	Position	Jobs
Shigeru MATSUZAKA	IVS Networks Representative	
Yoshihiro FUKUZAKI	Leader of VLBI group	
Tadayuki AKIYAMA	Collocation chief	Collocation, Operation
Kousei SHIBA	Operation chief	Experiments Coordination, Operation
Kazuhiro TAKASHIMA	Visiting scientist at GSFC	Improvement of software for VLBI analysis
Masaru YAZAWA	Analysis chief	Baseline Analysis, Operation
Shinobu KURIHARA	Operator	Baseline Analysis, Operation
Michiko ONOGAKI	Operator	Antenna and H-maser maint., Operation
Kohei MIYAGAWA	Correlation chief	Correlation, Operation
Kyoko KOBAYASHI	Assistant	Correlation, Operation

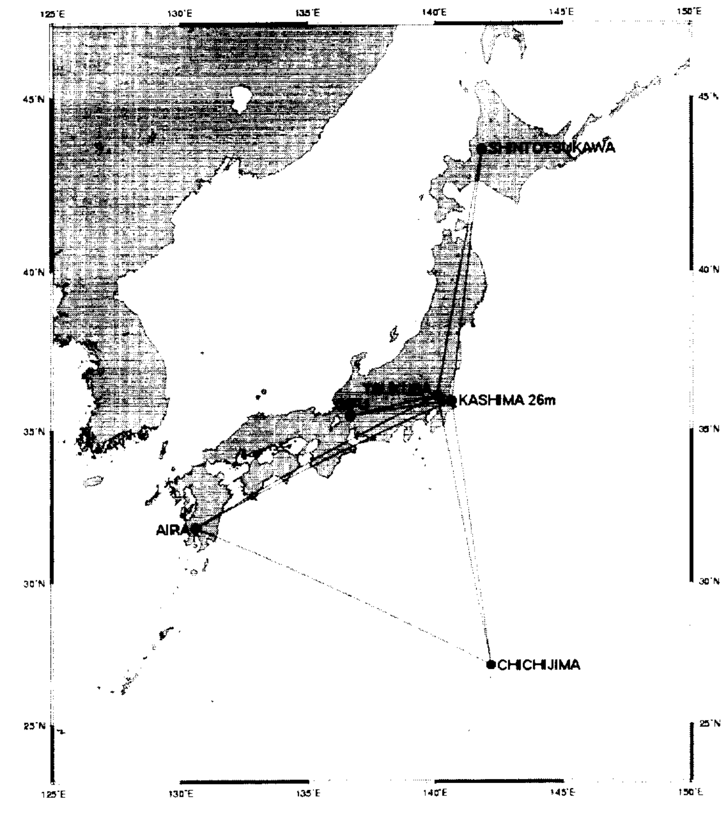

Figure 2. GSI domestic VLBI network and Gifu station.

Figure 3. Azimuth rail replacement (Left: before Right: current).

3. Prospect

It is planned to increase JADE sessions from four times a year to eight.

IGS station (TSKB) is close by the 32m VLBI antenna (300m) at Tsukuba station, and a GPS station of GSI Earth Observation Network is close by the VLBI antenna at Aira station. Collocation survey at Tsukuba and Aira station will be performed in 2001.

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[1] Ishihara, M., K. Nemoto, M. Iwata, K. Shiba, K. Takashima, and S. Matsuzaka: Tsukuba 32-m VLBI station, IVS 1999 Annual Report, pp.115–118, August 1999

[2] Ishihara, M., K. Nemoto, M. Iwata, K. Shiba, K. Takashima, and S. Matsuzaka: Tsukuba VLBI Center, IVS 1999 Annual Report, pp.160–163, August 1999

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

Nanshan VLBI Station Report

Liu Xiang, Zhang Jin

Abstract

This report summarises the VLBI activities, parameters and staff changes at Nanshan station of the Urumqi Astronomical Observatory from 1st March 1999 to the end of 2000.

1. The VLBI Activities

The VLBI geodesy experiments of NASA CORE-B and APSG projects were operated during the time period; they are CB502, CB503, CB504, APSG5, APSG6, CB505, CB506, CB801, CB802, APSG7.

A new horn for 13 cm band was installed; the system temperature at this band is 130 K. The cables from the IF devices to the backend were replaced with new ones. The communication between the Nanshan station and outside world has been much improved with the installation of a new optical fiber link to Urumqi. Thus, it is now possible to reach Nanshan via telephone and email (tel: 86-0991-5933075, e-mail: uao@mail.wl.xj.cn). The station was evaluated by a Visiting Board of the Chinese Academy of Sciences in September of 1999. The L-band dual-polarization system with the frequency range 1380-1700 MHz has been completed and installed at the 25 meter radio telescope. A new horn for three bands 30 cm, 49 cm and 92 cm and their receivers are under construction here.

A new FS computer from U.S. arrived at Nanshan station in 1999. With help from Ed Himwich and Xue Zhuhe, Liu Xiang and Yang Wenjun have installed a new Y2K-compliant Field System (version 9.4), adapted for the specific hardware configuration at Nanshan. In early 2000, with help from Himwich, Wang Na, Chen Maozheng, Liu Xiang worked on the communication between the FS computer and the antenna control computer. It was nearly finished when TeamChina came. In April, TeamChina came and worked on upgrading Nanshan to thin tape and MKIV. The team members were Ralph Spencer, Chopo Ma, Ed Himwich, Les Parry, Michael Wunderlich and Gino Tuccari. First, Michael worked on the recorder, then the others came and joined the work on recorder, installing formatter, modifying Field System and inspecting baseband convertors, and later, Gino Tuccari continued to work on the system at Urumqi. The local staff Zhang Hongbo and Yang Wenjun were involved in the work. Ed Himwich also worked on the communication between the FS computer and the antenna PC with the staff here, and they completed it in time. Now the antenna can be controlled by FS and also can do pointing and on-off measurement via FS. The MKIV upgrade of Nanshan was successful; it gives fringes from experiments EVN: C00C3, C00L4 and NASA: CB802. But some problems took place after that experiment in the recorder; investigation and fixing are now under way.

The problems of the MKIV recorder are expected to be resolved, and also minor problems of phase-cal and cable measurement. One H-maser will be sent to Shanghai for evaluation and upgrade. In 2001, we will participate in the CB901, CB902, CB903, CB904, APSG8, APSG9 experiments of geodesy.

Table 1. Receiver parameters

Band	Frequency range	LO	Pol.	Tsys	SEFD
1.3 cm	22100-24000 MHz	22000 MHz	LCP	180 K	2732 Jy
3.6 cm	8200-8600	8080	RCP	40	330
6 cm	4750-5150	4620	LCP	35	320
13 cm	2150-2450	2020	RCP	130	1762
18 cm	1380-1700	1300	LCP+RCP	85	1394
30+49 cm	under construction				
92 cm	317-337	0		90	1265

Table 2. Nanshan staff

Prof. Zhang Jin	chief scientist and general engineer, zhangj@ms.xjb.ac.cn
Zhang Hongbo	vice general engineer, zhanghb@ms.xjb.ac.cn
Liu Xiang	scientist, head of vlbi operation group, liux@ms.xjb.ac.cn
Wang Na	scientist, mainly working on single dish observation
Aili Yusup	engineer, vice general engineer
Dong Yousuo	engineer, vice general engineer
Shao Minhui	engineer, responsible for H-masers
Wang Weixia	engineer, responsible for receivers
Sun Zhengwen	engineer, responsible for receivers
Chen Maozheng	engineer, responsible for receivers
Aili E	staff of the operation group
Jarken Y	staff of the operation group
Yang Wenjun	staff of the operation group
Ma Lu	secretary
Wang Meifang	secretary

Westford Antenna

Michael Poirier

Abstract

Technical information is provided about the antenna and VLBI equipment at the Westford site of Haystack Observatory, and about changes to the systems since the 1999 IVS Annual Report.

1. Westford Antenna at Haystack Observatory

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

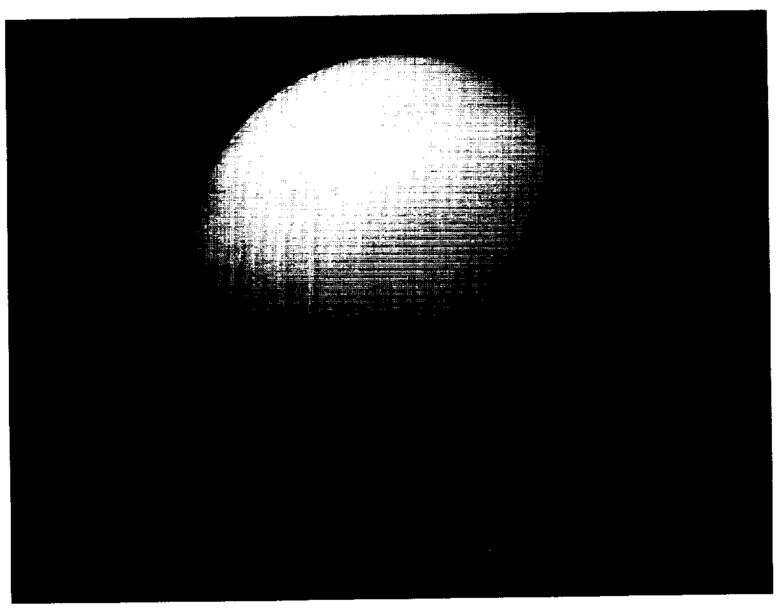

Figure 1. The radome of the Westford Antenna.

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

Table 1. Location and addresses of Westford antenna.

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

2. Technical Parameters of the Westford Antenna and Equipment

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

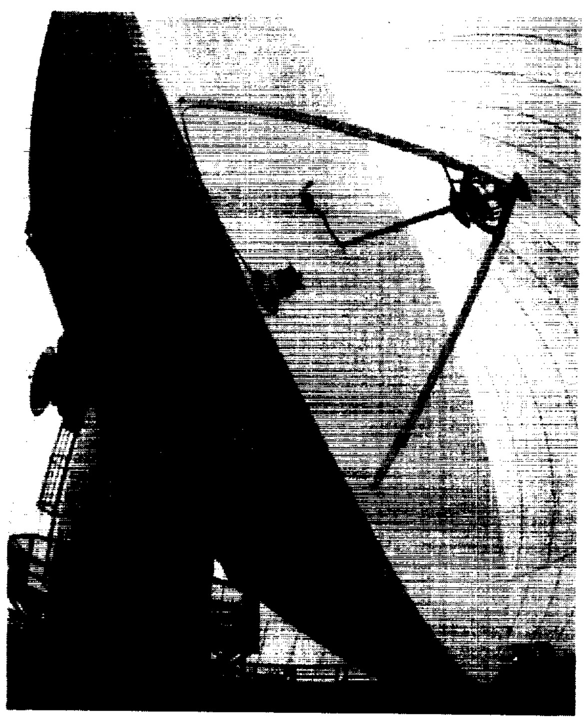

Figure 2. Wide-angle view of Westford antenna inside the radome. The VLBI S/X receiver is located at the prime focus. The subreflector in front of the receiver is installed when observing with the TAL receiver (see Section 4), which is located at the Cassegrain focus.

The antenna is enclosed in a 28-meter-diameter, air-inflated radome made of 1.2-mm-thick, Teflon-coated fiberglass see Figure 1. When the radome is wet, system temperatures increase by 10 20 K at X-band and by a smaller amount at S-band.

The major components of the VLBI data acquisition system are a Mark IV electronics rack, a

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 GHz	2210-2450 GHz
T_{sys} at zenith	50–55 K	70–75 K
aperture efficiency	0.40	0.55
SEFD at zenith	1400 Jy	1400 Jy

Mark IV tape drive, which is used for recording thin tapes only, and a Pentium-class PC running PC Field System version 9.4.12. The primary frequency and time standard is the NR-4 hydrogen maser. A CNS Clock GPS receiver system provides independent timing information and comparisons between GPS and the maser.

Westford also hosts the WES2 GPS site of the IGS network. A Dorne-Margolin GPS antenna is located on top of a tower ~60 meters from the VLBI antenna, and a TurgoRogue receiver acquires the GPS data.

A meteorology package provided by the NOAA Forecast Systems Laboratory continually logs meteorological data, which are downloaded daily and are available from the IGS and cignet archives.

3. Westford Staff

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

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

4. Status of the Westford Antenna

Westford participates regularly in the CORE-1, CORE-3, IRIS-S and RD-VLBA series of geodetic experiments, as well as in occasional NEOS experiments, fringe tests, and various ad hoc experiments. During the period 1999 March 1 - 2000 December 31, Westford participated in a total of 74 24-hour geodetic experiments.

Upgrades to the antenna and VLBI systems over the same time period include:

- Installation of secondary drive motor systems in both azimuth and elevation. This has allowed more precise positioning control of the antenna.
- Replacement (in progress) of the 17 bit incandescent bulb encoders with 19 bit LED-based encoders. The elevation encoder has been replaced and the azimuth replacement is expected in the near future.

The only significant equipment failure during this time period occurred in the hydrogen maser microprocessor and vacion pumps. Allied Signal (now HTSI) replaced the faulty items and completed repairs quickly.

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. Outlook

With the increased efficiency of the Mark IV correlators and the more intensive observing of the CORE program, we anticipate being able to participate in all seventy-two experiments that are scheduled for Westford in 2001.

Station Report of the 20m Radiotelescope at Wettzell

Richard Kilger, Ehrhard Bauernfeind, Gerhard Kronschnabl, Raimund Schatz, Walter Schwarz, Reinhard Zeitlhöfler, Rudolf Zernecke

Abstract

As in past years, the main activities in the year 2000 with the 20m Radiotelescope Wettzell have been concentrated on participation in geodetic and astrometric observing programs of the IVS. Some technical improvements have been carried out during regular maintenance. A GPS receiver has been placed on top of the radiotelescope, right behind the secondary reflector for measuring deformations of the 20m antenna and for deriving elevation dependencies of the GPS antenna. A repetition of the local survey has been performed in order to control the ties of the reference point of the VLBI telescope to the other geodetic systems.

1. Participation in the Observing Programs

Since 1983 the Radiotelescope Wettzell has contributed to geodetic and astrometric observing programs. Extended times series exist for the station position and for the velocity. In 2000 the 20m Radiotelescope participated in experiments. Due to the transition of the MKIII to MKIV

Table 1. Summary of observation activities.

52	NEOS-A
12	IRIS-S
228	DUT1 Intensive
7	EUROPE
6	RDV
6	CORE
3	Astronomy

correlator, which limited the correlator throughout 2000, the amount of observation was slightly less compared to the previous years.

Due to consequent maintenance the system failures have been minimized; nevertheless some components failed and resulted in loss of observations. Unexplained problems in the interference resistance were the reason for unexpected failures of the Antenna Control Unit (ACU), which required occasionally a reset. Unexpected power failures e.g. during lightning led to failures of the cooling system of the S/X receiver. Both events occasionally caused losses of tracks.

2. Technical Improvements

Some technical improvements have been made in order to increase reliability and automation. The current implemented Field System version is FS-9.4.18. A software routine has been set up which automatically controls the transfer of log files and schedule files to and from the respective data bases to make sure that the last versions of those files were received. As an extension to the regular Field System a software routine has been implemented which allows tracking of satellites. So far an old HP 5316A counter was used for measuring the cable delays and the fmout - gps values. The old system has been replaced by an HP 53132A counter. The required GPIB driver has been written for the integration into the Field System.

Last year the automatic antenna control unit was replaced by a new system. Due to unexplained effects, occasionally unexpected interferences occurred and resulted in undefined status of the ACU. This leads to failures of the 20m antenna. In 2000 some efforts and investigations have been made to overcome the problem. So far it has been minimized but not sufficiently solved. Actions were the employment of an uninterruptable power supply, the replacement of the RS232 connection by fiber optics and improvements in grounding. Futher investigations are ongoing.

The MKIII decoder has been replaced by a MKIV unit.

The thermal insulation of the antenna concrete support construction (basement up to the moving part), which minimizes the influence of the direct sunshine to the construction, has been completely replaced. Over the years water penetrated the shielding and decreased the insulation capacity (figure 1).

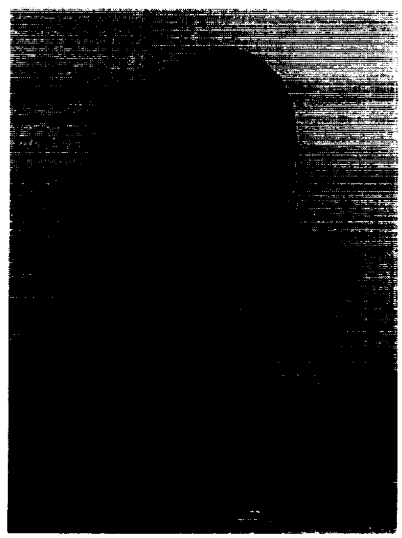

Figure 1. 20m radiotelescope with new insulation of the concrete supporting construction.

A K4 system – on loan from the Communications Research Laboratory (CRL) / Japan – had to be removed and returned at the end of 2000. The system has been used for joint observations with Tsukuba and Kashima. We are obliged to thank CRL for having the system for a long time in Wettzell.

3. Local Survey

A GPS antenna (ASHTECH-Choke ring) was installed behind the secondary reflector centered on the telescope pointing axis (figure 2). The receiver itself was placed in the elevation cabin to monitor GPS observations. The objective is to observe bending or deformation of the 20m antenna and to derive elevation dependencies of the GPS antenna. Usually, when no VLBI program is observed and the 20m antenna is not in use for some hours, GPS observations should be taken. GPS derived positions will be compared with the positions derived by taking into account the

VLBI reference point and the corresponding eccentricities calculated from the pointing angles of the antenna and the radial distance between GPS and Antenna reference point. So far observations have been taken at various elevation and various azimuth positions.

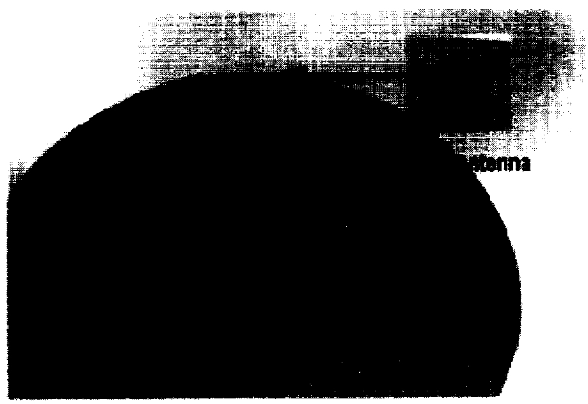

Figure 2. GPS Antenna mounted behind the Secondary Reflector in line of the pointing axis.

The measurements employing an invar wire for measuring the variations in height due to temperature variations in the telescope support structure have been performed successfully in 2000. Figure 3 shows the time series. The replacement of the reference mass of 1kg by 2kg at the lower end of the wire changed the zero point by a constant offset in February 2000.

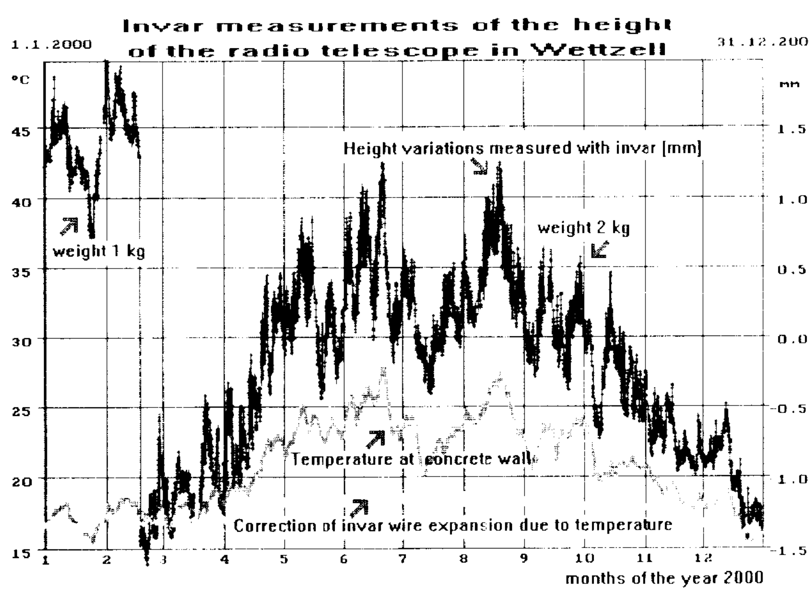

Figure 3. Height variations of the VLBI reference point due to temperature, measured with an invar wire.

The local survey of the Fundamentalstation Wettzell has been repeated for the control of the local ties between the various geodetic systems and for the inclusion of the new Lasergyroscope "G". The local network is shown in figure 4.

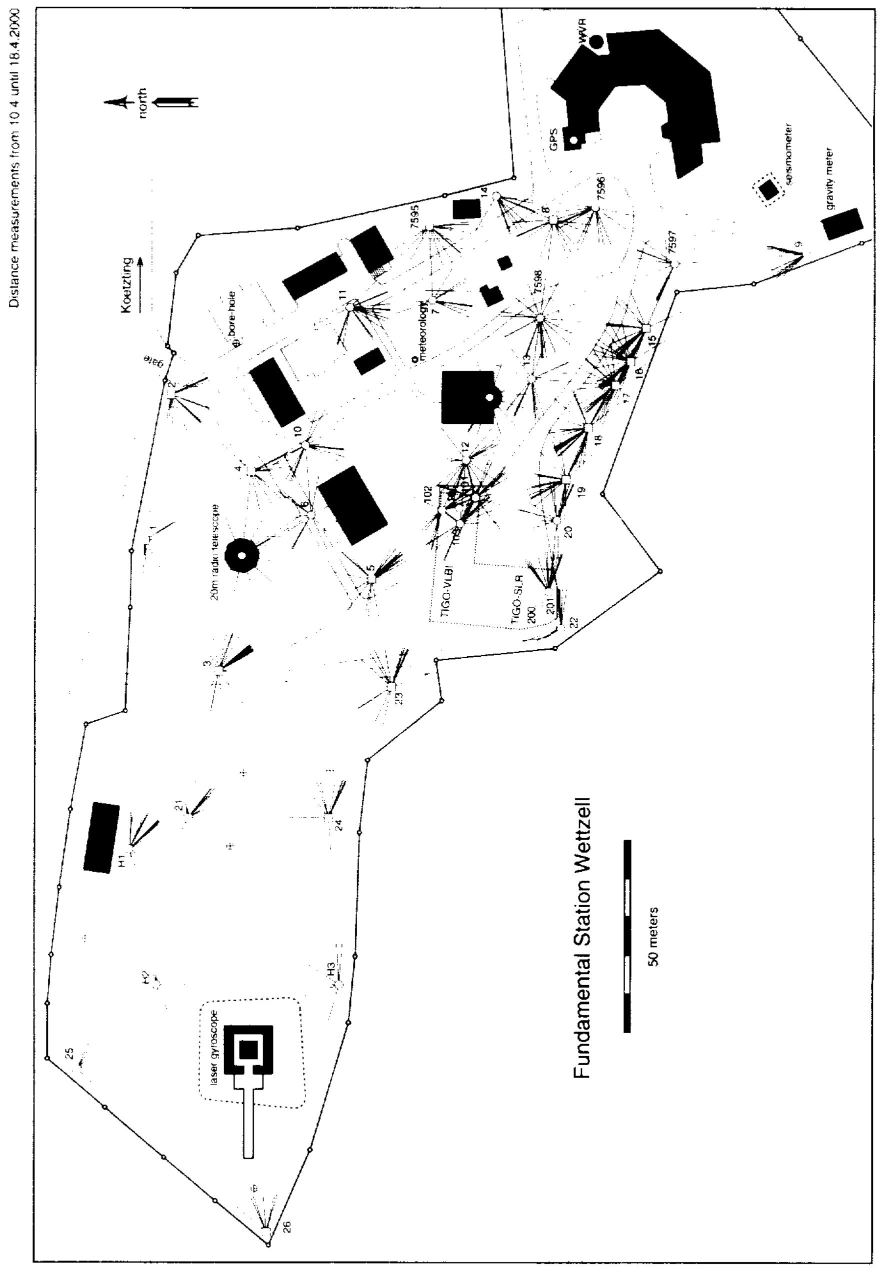

Figure 4. Local survey network of Fundamentalstation Wettzell.

Observatorio Astronómico Nacional

Francisco Colomer

Abstract

This report updates the description and details of the OAN facilities as a network station in IVS. The 14 meter radiotelescope at Yebes participates regularly in the geodetic VLBI campaigns (EUROPE and CORE), as well as astronomical VLBI experiments as part of the European VLBI Network (EVN). The institute staff is also involved in technical development and geodetic research.

1. The OAN Facilities

The Observatorio Astronómico Nacional (OAN) of Spain operates a 14 meter radiotelescope at Yebes (Guadalajara, Spain; see location in Fig. 1). This facility is a network station in IVS, and participates regularly in the geodetic VLBI campaigns to study the tectonic plate motions in Europe (project EUROPE), Earth rotation, and pole motion (project CORE).

The institute is currently involved in the construction of a new 40 meter radiotelescope (Fig. 2) which is expected to be available for geodetic VLBI observations in 2004.

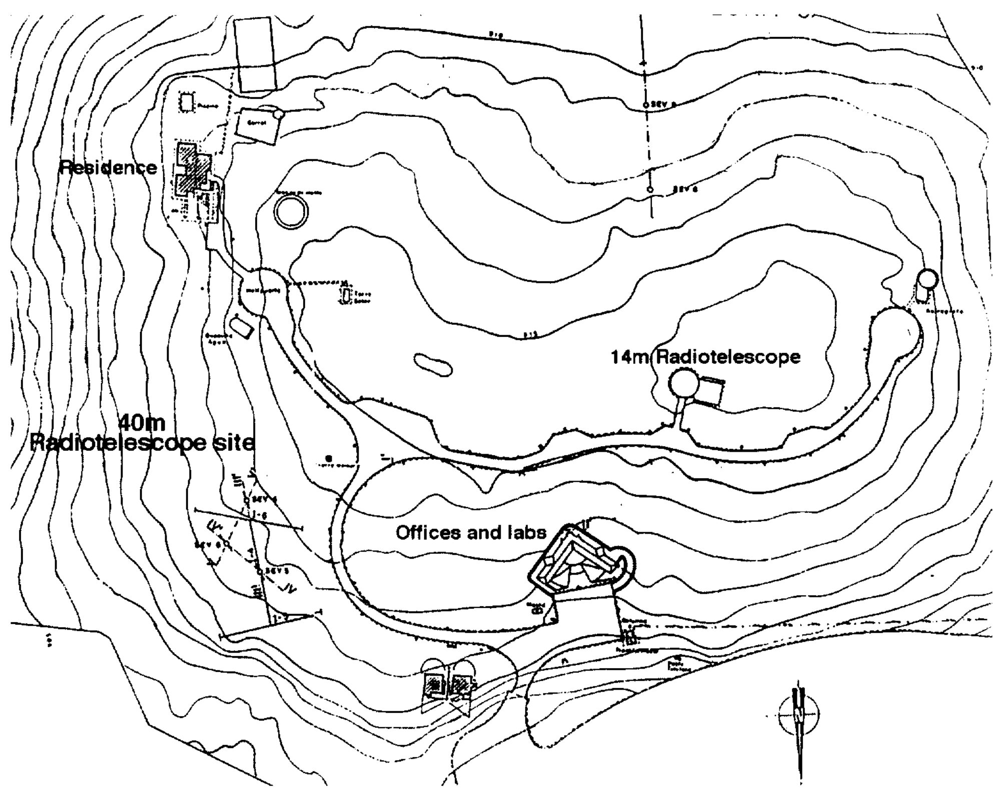

Figure 1. Map of the Yebes site, showing the location of the current 14 m and future 40 m radiotelescopes.

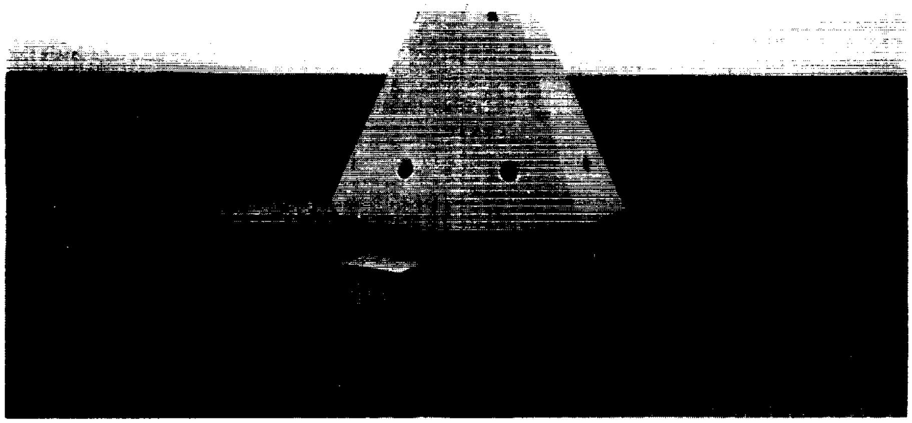

Figure 2. Status of the construction of the new 40 meter radiotelescope of OAN at Yebes (Guadalajara, Spain). The finished concrete pedestal is shown.

2. Description of the OAN Station at Yebes

The main instrument at OAN is nowadays the 14 meter radio telescope used for VLBI. There have not been any substantial changes in the equipment since the last IVS Annual Report in 1999. Relevant changes are listed in Table 1.

Table 1. Characteristics of the VLBI equipment.

VLBI terminal type	VLBA4 (Mark IV formatter, VLBA-G rack and VLBA recorder)
recording media	thick and thin tape, 1″ wide
Telescope control computer	HP1000 + HP2100
VLBI system computer	Pentium II/350
Operating system	Debian 2.1r3 (kernel 2.0.34)
Field System version	FS 9.4.6
H-maser frequency standard	KVARTZ CH1-75
GPS receiver	6 channel TrueTime XL-DC-602
Meteorological station	SEAC-300

On the other hand, the OAN engineers have been continuously working since 1985 in the development of cryogenic HEMT amplifiers to be used in receivers at Centro Astronómico de Yebes (CAY), and in other radio astronomy observatories. One of the last products is the low noise amplifier at X-band (centered at 8.3 GHz) designed and built for ESA tracking stations.

The CAY laboratories are completely prepared for the fabrication and test of cryogenic amplifiers with modern equipment. The workshop uses CNC milling machines for the preparation of chassis. The microwave printed circuits are engraved on soft substrates using an LPKF CNC milling machine or photolitographic techniques. Chassis and circuits are also gold plated in our laboratories. As HEMT devices in chip form are employed in the amplifiers, special equipment has to be used for their assembly (ultrasonic wire bonding and welding machines, stereo microscopes and metallurgic microscopes). For noise and gain measurements, and stability analysis at cryogenic temperatures, a dedicated cryostat with a CTI 350 cryogenic refrigerator is used. Noise temperature is measured with a computer controlled noise figure meter, with special software to obtain adequate accuracy at cryogenic temperatures (using the cold attenuator method). A vector (up to 50 GHz) and a scalar (up to 110 GHz) network analyzer are also available for gain and reflection measurements. Spectrum analyzers and power meters are used to check the stability. Finally, a computer controlled quad power supply is used for DC analysis of active devices.

Finally, we will mention that the reference station of the permanent GPS network in Spain (coded "YEBE") is operated at Yebes by the Instituto Geográfico Nacional (IGN) of Spain, host institute for OAN. The data are analysed and sent weekly to the coordinating center of EUREF in Frankfurt. More information can be found at the URL `http://www.geo.ign.es/`.

3. OAN Staff Working in VLBI

There have been no changes in OAN staff for VLBI since our 1999 report. Contact information is provided at the URL `http://www.oan.es/vlbi/`.

4. Status of the Geodetic VLBI Activities at OAN

The main contribution of OAN to IVS is the realization of geodetic VLBI observations in the EUROPE and CORE projects: the OAN radio telescope at Yebes has participated in eight EUROPE and six CORE experiments since March 1999. Problems with the antenna control system, plus failure of an element of the MKIV formatter, prevented successful participation in the experiments of the last quarter in 2000. The institute also participates in the European VLBI Network (EVN) for astronomy, taking part in its logistics and carrying out technical development.

On the other hand, several projects of geodetic scientific research are being developed:

- Combination of geodetic space techniques (VLBI and GPS) to investigate the potential of new analysis techniques that could provide a better estimate of the parameters of interest: a combination of GPS estimates of the tropospheric delay into the VLBI data analysis. If proven successful, the technique would have a large impact also in astronomy, making possible longer integrations at millimeter wavelengths.
- Determination of the phase-center of a VLBI antenna (Ny Ålesund 20m), comparing the VLBI and GPS results (which differ in particular in the vertical component). Two epochs of observations are planned to study the stability of the antenna structure.

5. Outlook

The OAN radio telescope at Yebes continues participating regularly in the campaigns for the **EUROPE** and **CORE** projects.

We foresee the upgrade of the VLBI equipment to high capacity by installing the needed hardware (second headstack and electronics for high speed tape operation at the recorder, new firmware, etc.). We are also working on the upgrade of the telescope control system, to replace the current HP2100 computer by a VME programmable computer.

Finally, the construction of a new 40 meter radiotelescope at Yebes is progressing well. The concrete tower, that will serve as pedestal for the instrument, is finished. This telescope is expected to be operational at S/X bands in 2004.

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Yellowknife Observatory

Mario Bérubé, Calvin Klatt

Abstract

The Yellowknife VLBI antenna is a 9 meter diameter antenna which was formerly the "MV-1" mobile antenna. The MV-1 was a proof-of-concept for mobile VLBI and in 1991 NASA and NOAA offered the system for use at Yellowknife. The antenna is located at the Yellowknife Geophysical Observatory and is operated by the Geodetic Survey Division, Natural Resources Canada. This report gives an update on recent activities.

Figure 1. Yellowknife Geophysical Observatory 9m VLBI Antenna

1. Overview

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

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

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

2. General Specifications

- Latitude : 62.48 North
- Longitude : 114.48 West
- Reflector : 9m
- Receiver : S and X cryogenic
- Azimuth speed : 40 degrees per minute
- Elevation speed : 40 degrees per minute
- PCFS version : 9.4.17
- VLBI equipment : Mk III and thick tape drive. S2 data acquisition and recording terminal.
- Time standard : NR Maser
- GPS receiver : Rogue

3. Antenna Improvements

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

Mechanical maintenance was performed in 1998 and the antenna has performed reasonably reliably since. The antenna control unit will be looked at in the spring of 2001 and may be replaced with one similar to that at Algonquin.

Yellowknife has had an S2 recording terminal and data acquisition system installed and a number of experiments have been performed using this new equipment.

4. Antenna Survey

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

5. Operations March 1999 - December 2000

In 1999 Yellowknife was involved in 5 CORE-B and 4 NEOS experiments. In addition, Yellowknife was involved in 2 CGLBI experiments (2 24-hour geodetic sessions).

In 2000 Yellowknife was involved in 1 CORE-B and 4 NEOS experiments. In addition, Yellowknife was involved in 8 CGLBI experiments (4 24-hour geodetic sessions).

In 2001 Yellowknife is currently scheduled to participate in 13 CORE and NEOS experiments. We anticipate that it will also participate in 5-10 CGLBI experiments.

OPERATION CENTERS

The Bonn Geodetic VLBI Operation Center

A. Nothnagel

Abstract

This report summarizes the activities of the IVS Bonn Operation Center.

1. Center Activities

The GIUB VLBI Operation Center is located at the Geodetic Institute of the University of Bonn, Nussallee 17, D-53115 Bonn, Germany. In the past year the activities of the GIUB VLBI Operation Center were concentrated on the preparation and organization of several different observing programs.

- **International Radio Interferometric Surveying - South (IRIS-S):**
  12 Sessions per year with the stations Wettzell, HartRAO, Fortaleza, Fairbanks, Hobart, O'Higgins and Westford
- **Measurement of Vertical Crustal Motion in Europe by VLBI (EUROPE)**
  6 sessions in 1999 and 7 sessions in 2000 with the stations NyÅlesund, Onsala, Wettzell, Simeiz, Madrid (DSS65), Yebes, Medicina, Matera and Noto. Effelsberg participated once per year, TIGO-WTZL participated occasionally.

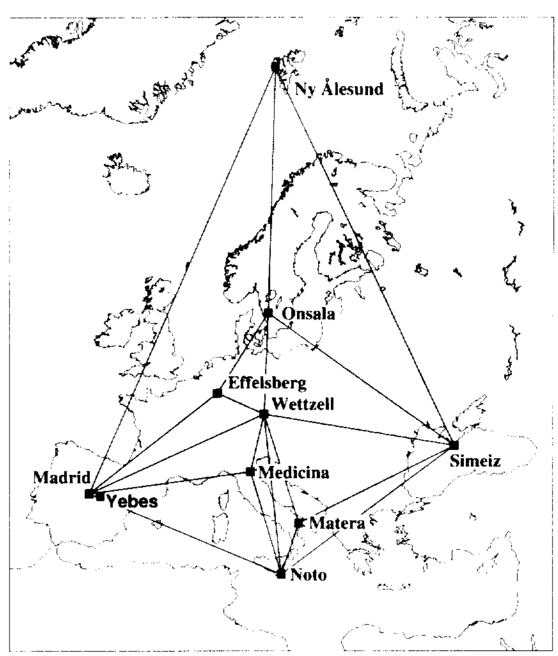

Figure 1. European VLBI network

- **Continuous Observations of the Rotation of the Earth (CORE-OHIG):** with stations HartRAO, O'Higgins, Fortaleza, Hobart, Kokee and DSS45 plus the Japanese Antarctic station Syowa

The operational tasks mainly consisted of preparing the detailed observing schedules for all sessions listed above. The schedules were prepared with the SKED software on HP-UX platforms. The work also involved sending of tapes, communication with stations, fault analysis, and arrangements for special sessions and testing schemes. Arno Müskens takes care of the IRIS-S and the CORE-OHIG sessions while Axel Nothnagel is responsible for the EUROPE project.

CORE Operation Center Report

Cynthia C. Thomas

Abstract

This report gives a synopsis of the activities of the CORE Operating Center from March 1999 to December 2000. The report forecasts activities planned for the year 2001. The outlook summarizes the evolution of the different CORE programs.

1. CORE Program Description

The continuous observations of the rotation of the Earth (CORE) program was initiated by the geodetic very long baseline interferometry (VLBI) community in 1997. The program is being carried out using geodetic VLBI stations for data acquisition and VLBI analysis centers for data processing and analysis. The CORE program will evolve over the period 1997-2003.

The goal of the CORE program is to generate a continuous high accuracy Earth rotation data set for Earth science and global change research. The program will produce basic observational data for studies of the continuous momentum exchange among the solid Earth, the atmosphere, and the hydrosphere, enabling exciting research areas that heretofore have been impossible.

The current Earth orientation parameter goal of the pre-CORE Mark III experiments is to attain precision of at least 3.5 μs for UT1 and 100 μas in pole position. The full CORE program has the potential for a typical precision of 2-2.5 μs in UT1 and 30-40 μas in pole position, for daily sessions with a 6-station network.

The availability of continuous, high accuracy Earth rotation data will be possible due to the Mark IV technology that became available during the third quarter of 2000. The Mark IV correlator became as efficient as the Mark III correlator during the last quarter of 2000. Improved sensitivity of the Mark IV data acquisition system together with the high playback efficiency of the Mark IV correlator are both necessary to produce the expected results for CORE.

CORE sessions were run with five basic network configurations: CORE-A, CORE-B1, CORE-B2, and CORE-B3 during 1997 and 1998. During 1999, the networks of the CORE-B sessions changed and the sessions were named CORE-B4, CORE-B5, and CORE-B6. The CORE-A sessions were simultaneous with NEOS sessions and CORE-B and NEOS sessions were on sequential days during both 1998 and 1999. During 2000, the CORE-3 sessions started in July and were performed in Mark IV mode. It was decided that the CORE-A/NEOS series of 76 sessions was sufficient for the analysis of EOP estimated from different networks and it was therefore ended. To start the process of filling in the observing week that will eventually be continuous in CORE, the CORE-A network was moved from Tuesdays to Mondays and renamed CORE-1.

2. CORE Sessions During April 1999 to December 2000

This section displays the purpose of the CORE-A, CORE-B, CORE-1 and CORE-3 sessions. It also lists other programs used by CORE.

- CORE-A/CORE-1: These experiments validated the CORE concept of measuring EOP continuously using different networks.

The network for CORE-A included Fairbanks, HartRAO, Hobart, Algonquin, Matera and Westford during 1998. During 1999 the network consisted of three constant stations: Fairbanks, HartRAO, and Algonquin. The other three stations consisted of Medicina, Westford, Tsukuba, Matera, and Hobart.

In 2000, the CORE-As were scheduled once per month until July. In July, the CORE-As were moved to Mondays and renamed CORE-1 because Algonquin was added to the NEOS weekly sessions. The network for the CORE-A and CORE-1 was Algonquin, Fairbanks, HartRAO, Matera, Tsukuba, and Hobart.

- CORE-B: The purpose of these sessions is to provide additional data for comparison of EOP measurements, to obtain long 48-hour data sets for geophysical studies and to provide observing sessions during which the stations can demonstrate their performance and their ability to participate in future regular CORE sessions.
- CORE-3: These sessions started in July of 2000 and were observed monthly. The CORE-3 series was named for the third day of the work week since it is scheduled for Wednesdays following the NEOS sessions. The CORE-3 sessions were the first of the regular, operational CORE sessions, recorded in a Mark IV mode.

There is data from other programs established by Bonn (IRIS-S, CORE-OHIGGINS, and EUROPE), USNO (NEOS, NAVEX, CRF), and GSI (APSG) that are used by the CORE program. Some of the data is used to help determine the direction of the CORE program during its evolution.

3. Current Analysis of CORE

Comparisons of daily EOP estimates made by the CORE-A and NEOS networks show that there are biases at the level of about 50 μas in polar motion and 2 μs in UT1 between simultaneous CORE-A and NEOS measurements. The wrms differences are 232 μas, 165 μas, 9.8 μs between X, Y, and UT1 estimates, respectively. The source of these differences is most likely unmodeled or mismodeled site motion, which we are currently investigating.

One of the measures of performance of the CORE experiments is the size of the formal EOP uncertainties. The uncertainties range from about 70-100 μas for X-pole, 50-100 μas for Y-pole, and 2.5-3.5 μs for UT1. Based on the observed differences between simultaneous CORE-A and NEOS sessions, the formal EOP precisions should be multiplied by about a factor of 1.5. The observed uncertainties are generally less than the minimal goal of 100 μas for PM and 3.5 μs for UT1.

4. The CORE Family

Table 1 lists the key technical personnel and their responsibilities so that everyone reading this report will know who to contact about their particular question.

5. Evolution of CORE

As of the end of 2000, the CORE observing program for 2001 and the Mark IV correlator plans were proceeding.

- The CORE-1 sessions have been scheduled monthly and will be observed in a Mark IV mode.

- The CORE-3 sessions have been scheduled bi-weekly during the year. In addition, a second CORE-3 network will begin bi-weekly starting July of 2001.
- The correlator has been operating as efficiently as the Mark III Correlator.

Table 1. Key Technical Staff of the CORE Operations Center

Name	Responsibility	Agency
Tom Buretta	Recorder and electronics maintenance	Haystack
Brian Corey	Analysis	Haystack
Irv Deigel	Maser maintenance	HTSI
Frank Gomez	Software engineer for the Web site	Raytheon/STX
David Gordon	Analysis	Raytheon/STX
Ed Himwich	Network Coordinator for CORE stations	NVI, Inc./GSFC
Chuck Kodak	Receiver maintenance	HTSI
Cindy Lonigro	Analysis	Raytheon/STX
Dan MacMillan	Analysis	NVI, Inc./GSFC
Leonid Petrov	Analysis	NVI, Inc./GSFC
David Shaffer	Sources and antenna parameter maintenance	Radiometrics/NVI, Inc.
Dan Smythe	Tape recorder maintenance	Haystack
Cynthia Thomas	Coordinate master observing schedule and prepare CORE experiments observing schedules	NVI, Inc./GSFC
Nancy Vandenberg	Organizer of CORE program and sked manager	NVI, Inc./GSFC
William Wildes	Procurement of materials necessary for CORE operations	GSFC/NASA

The tentative CORE evolution plan for the next few years is summarized in Table 2.

Table 2. Planned CORE Evolution

Start Date	Experiment Name	Avg Days per Week	Notes
1-Feb-2000	CORE-A monthly	2.0	Mark IV Correlator efficiency $<$ Mark III Correlator
1-Jul-2000	CORE-3 monthly	2.0	Discontinued CORE-A
1-Jan-2001	CORE-1 monthly	2.4	
1-Jan-2001	CORE-3 bi-weekly	2.4	
1-May-2001	CORE-C 8 sessions	2.5	
1-Jul-2001	CORE-3 weekly	2.8	two different CORE-3 networks

We are working on identifying the participating stations for each new CORE network. We will need more antenna observing to fulfill this plan. The goal for CORE is continuous observing but we recognize that it will be very difficult to fill in the weekend days for CORE-5, -6, and -7. Weekend observing is costly both in funding and in inconvenience to operators. We would appreciate any ideas you have about how to attack this problem. Volunteers for weekend observing would be very welcome!

6. CORE Review Panel

A panel, co-sponsored by NASA and IVS, met in early 2001 to review the CORE program and make recommendations about the best way VLBI can contribute to space geodesy programs. The report of the panel will be input to the master schedule planning for 2002 observing.

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U.S. Naval Observatory Operation Center

Kerry Kingham, M.S. Carter

Abstract

This report covers the activities of the NEOS Operation Center at USNO for 1999 and 2000.

1. VLBI Operations

NEOS operations in the period covered consisted of one 24-hour duration NEOS-A observing session, on Tuesday-Wednesday of each week, for Earth Orientation, together with daily one-hour duration "intensives" for UT1 determination. The operational NEOS-A network has included VLBI stations at Gilmore Creek (Alaska), Kokee Park (Hawaii), Wettzell (Germany), Fortaleza (Brazil), Ny-Ålesund (Norway), Algonquin Park (Canada), Westford (Massachusetts), Matera (Italy), Yellowknife (Canada) and Green Bank (West Virginia). No more than six stations were used in any given NEOS-A.

During the reporting period, the Green Bank station was closed and is no longer available. The daily intensive sessions switched from the Green Bank – Wettzell network to the Kokee Park – Wettzell network.

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

2. Staff Changes

During the reporting period, T.M. Eubanks left USNO to pursue opportunities in the private sector. B.A. Archinal left USNO for a job at the U.S. Geological Survey in Flagstaff, AZ. M.S. Carter has assumed the scheduling duties.

CORRELATORS

The Bonn Astro/Geo Mark IV Correlator

Arno Müskens, Walter Alef

Abstract

The Bonn MK IV VLBI correlator was officially opened on November 17th, 2000; it is operated jointly by the MPIfR (Bonn), the GIUB (Bonn) and the BKG (Frankfurt). The final installation will permit the simultaneous correlation of 16 channels of MK IV or VLBA formatted data for all baselines from 9 station playback units, in both cross- and parallel-hand polarizations.

1. History

Back in 1990 a "Prototype Next Generation Correlator" Project was initiated by a consortium of institutions on the East Coast of the United States. In 1993 the International Advanced Correlator Consortium (IACC) was founded and the construction of a completely newly-designed successor for the existing MK III(A) VLBI data acquisition and recording system was started at Haystack Observatory under the designation "MK IV Correlator Project". The aim of a working next generation VLBI correlator was achieved in 1999.

A MK IV correlator was installed by members of the Haystack Observatory at the *MPIfR* (Max-Planck-Institute for Radioastronomy, Bonn) in December 1999 [*Alef et al.*] shortly after the first operational correlator tests had been performed at the Washington VLBI correlation center at the *United States Naval Observatory (USNO)* [*Kingham and Martin*].

The Bonn MK IV correlator is jointly operated by the *MPIfR* for astronomical observations and by the *Bundesamt für Kartographie und Geodäsie (BKG)* in cooperation with the *Geodetic Institute of the University of Bonn (GIUB)* for geodetic applications.

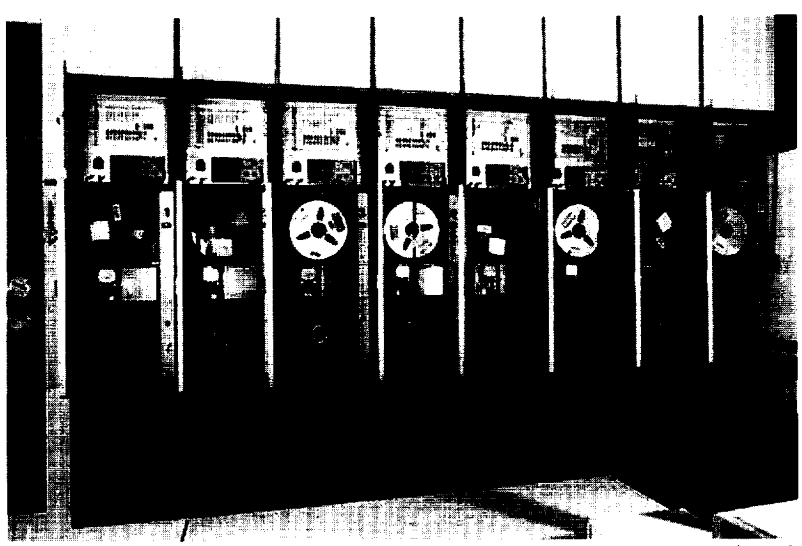

Figure 1. Present MK IV VLBI Correlator at Bonn (MPIfR/BKG).

2. Status and Capabilities of the Bonn MK IV VLBI correlator

At the time of this report 6 playback drives can be used simultaneously with 15 baselines, 16 channels, and 32 lags. This limitation is caused by the current software which can only handle 2 of the 16 correlator boards. Other modes with fewer stations but more lags are also possible. Multiple passes have to be done for observations with more than 6 stations: e.g. 7, 8 or 9 stations have to be done in 3 passes, 12 stations in 6 passes. The next release of the software will handle 9 playback units with some limited set of correlator modes.

All tape drives can play back thick and thin tape; the equalizers of 5 playback drives are optimized for thin tapes at present.

Supported playback speeds are 80 ips for thin tapes and 135 ips for thick tapes, which is due to the tape drives having only one set of equalizers. Due to another software limitation the playback speeds have to be the same as the recording speeds (speed-up factor has to be 1). One playback is equipped with a newly-designed switchable equalizer board which has 3 sets of equalizers; at present it can switch between 80/135/270 ips playback.

The supported formats are MK IIIA, MK IV and VLBA, both MK IV and VLBA with 1- or 2-bit sampling. Fan-in modes are not supported while all the fan-out modes 1:1 and 1:2 and 1:4 are possible. Any number of up to 16 frequency channels can be used, both upper and lower sidebands.

Multiple passes as needed for modes with more than 16 channels are not supported by the present software release. Channel bandwidths of 2, 4, 8 and 16 Mhz are usable.

The different playback modes are: MK III modes B and C, and those shown in Table 1.

	128-16-1	128-16-2	128-8-1
	128-8-2	128-4-1	128-4-2
thin tape only	128-2-2	256-16-1	256-16-2
thin tape only	256-8-1	256-8-2	256-4-2

Table 1. Overview MK IV correlator modes

The geometric correlator model is CALC 8.

Single-tone phase-cal extraction at 10 kHz is implemented. The possibility to extract other phase-cal frequencies as well as multi-tone phase-cal are planned. The pre-averaging time is flexible from 0.5 to 5 seconds.

Fringe-fitting is done off-line by the program fourfit. Dual frequency observations are done in a single execution of the program while dual/cross-polarization experiments have to be fringe-fitted in multiple executions.

The raw and fringe-fitted data is archived on DDS2 DAT cassettes. The archive contains the root, the raw correlator data (type 1 files), the fringe-fitted data (type 2), and the station-based files (type 3 files). All the processed geodetic data are also exported with the geodetic post-correlation software interface CALC/SOLVE.

3. Correlator Operations

Approximately 50% of the correlator time is allocated to IVS related tasks. It is used for setup and production processing of IRIS-S, EUROPE and CORE (Core-3, Core-OHIG) experiments.

The remaining 50% are used for astronomy correlation like the processing of millimeter-wave radio astronomy observations and other MPIfR-based VLBI observations. The total available processor time has to be reduced by 10% for such tasks as correlation fringe check, testing station performance, maintenance of processor software and playback recorder units and test experiments for geodesy and astronomy. Over the past year more than 25 geodesy sessions and test experiments were processed at Bonn MK IIIA / MK IV correlators.

4. Outlook

A new contract between GIUB and BKG was made to support IVS with the processing of about 50 experiments per year at the MPIfR/BKG correlator. At the end of 2001 it has to be reviewed if the commitment towards IVS can even be increased. This will also depend on further improvements of the MK IV processing software. Especially correlator post-processing software is still rudimentary and causes a lot of extra work.

5. References

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Haystack Observatory VLBI Correlator

Mike Titus, Brian Corey, Roger Cappallo, Arthur Niell

Abstract

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

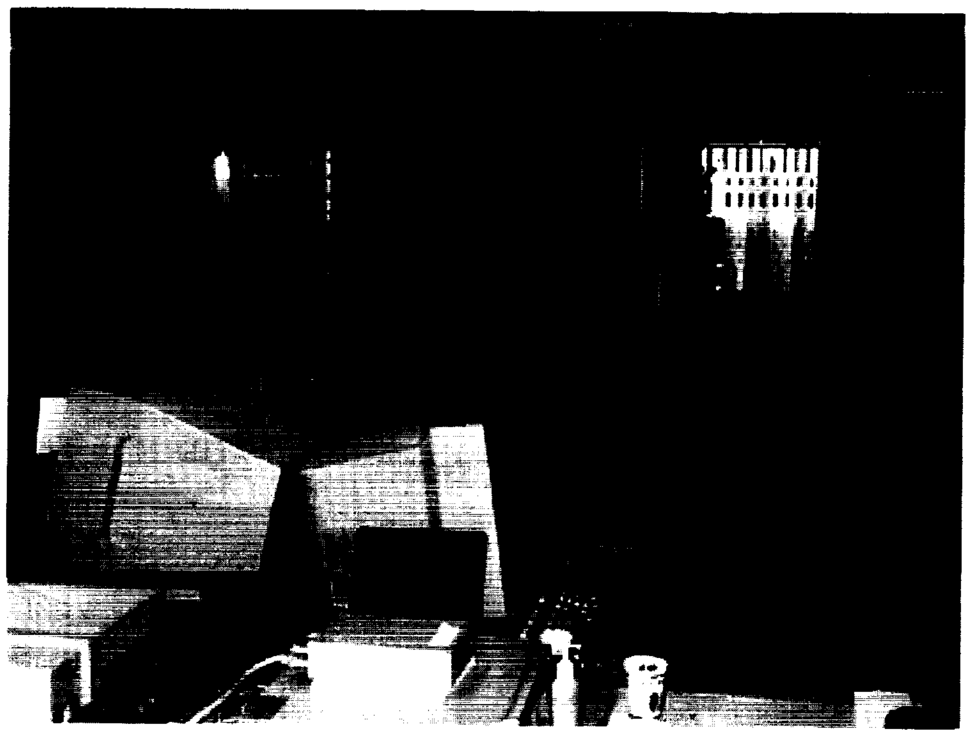

Figure 1. Haystack Mark IV Correlator

1. Introduction

The Haystack Observatory Mark IV VLBI correlator, located in Westford, Massachusetts, is supported by the NASA Space Geodesy Program and by the National Science Foundation. The available correlator time is divided approximately equally between processing geodetic VLBI observations for IVS and processing millimeter-wave radio astronomy observations for the Coordinated Millimeter VLBI Array. In addition to its role as an operational processor, the Haystack Correlator also serves as a development system for testing new correlation modes and hardware improvements and for diagnosing correlator problems encountered either at Haystack or one of the identical correlators at the U.S. Naval Observatory or at the Max Planck Institute for Radioastronomy. This flexibility is made possible by the presence on site of the team that designed the correlator hardware and software.

2. Summary of Activities

Since the last correlator report, major changes have occurred. As projected in the previous annual report, in December 1999 the Mark IIIA correlator was decommissioned and the Mark IV was brought on line. This transition, though difficult, has been a success. Geodetic production processing from Haystack experienced a short gap in service, and all correlation at Haystack is now done on the new Mark IV correlator. Since the transition, development efforts have focused on increasing the reliability and efficiency of operations and on enabling new modes of processing. Some examples of this development work include:

- Improve/repair capabilities of the Station Units (internal code and control software).
- Improve and increase capabilities, efficiency, accuracy and details of all aspects of the correlator control software (from tape drive control through operator interface).
- Examine and correct or enhance the quality, accuracy, and reporting of data.
- After testing, export software improvements to the Washington and Bonn sites.

3. Experiments done

Since the last report (July 99), 37 geodetic experiments have been processed, with 5 done on the Mark IIIA and 32 on the Mark IV. These are broken down into 4 CORE A's, 6 CORE 1's, 13 CORE B's and 5 CORE 3's (CORE 3's were all done on the Mark IV since they are recorded in a fanout mode that cannot be processed on a Mark IIIA). A collection of various test experiments comprise the remaining 9 (correlator tests, rack tests, station fringe tests, etc. ...).

4. Current/Future Hardware/Capabilities

Current hardware installed and functional on the new system are 6 tape units, 6 station units, 4 (operational) correlator boards, 1 crate, and miscellaneous other support hardware, with the ability to process all baselines for 6 stations at once in the standard geodetic modes. In the near future we plan to add two more tape and station units and fully enable the 2 crate mode, utilizing all 16 correlator boards. Other planned improvements:

- Add decoder as tool for examining recordings.
- Enable multiple streams and speedup factors in playback processing.
- Implement multiple speed parallel equalizers in playback drives.
- Address repeatability and reliability issues to reduce reprocessing requirements (mostly related to station unit).
- Improve capabilities and tools for examining correlator output and managing flow of data through system.

5. Staff:

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

5.1. Software Development Team:

- John Ball - operator interface, playback
- Roger Cappallo - leader, system integration
- Kevin Dudevoir - correlation
- Colin Lonsdale - post processing
- Alan Whitney - system architecture

5.2. Operations Team:

- Peter Bolis - correlator maintenance
- Tom Buretta - playback drive maintenance
- Brian Corey - experiment correlation oversight, station evaluation, technique development
- Dave Fields - playback drive maintenance
- Ellen Lautenschlager - correlator operator
- Glenn Millson - correlator operator
- Art Niell - experiment correlation oversight, technique development
- Don Sousa - correlator operator, experiment setup, tape library and shipping
- Mike Titus - correlator operations oversight, experiment setup, computer services
- Ken Wilson - correlator maintenance, playback drive maintenance

6. Conclusion/Outlook:

Operationally, we hope that these and other improvements will increase efficiency and throughput in the near future. The potential for additional improvements in this area, and the possibility to record and process many new types of experiments, should be realized in the next phase of development and production work. Over the next year the Mark IV system is expected to attain its full potential, which will greatly increase the sensitivity, flexibility, output, and power of the correlator as a tool for the IVS community.

KSP-VLBI Correlation Center Report

Mamoru Sekido, Hitoshi Kiuchi, Yasuhiro Koyama

Abstract

Communications Research Laboratory has been regularly operating Key Stone Project (KSP) VLBI experiments to monitor crustal deformation around the Tokyo metropolitan area. The KSP system detected crustal deformation in the south part of the Kanto region due to volcanic activities at Izu islands in 2000. Daily 23.5-hour VLBI experiments were performed to monitor the crustal motion. Such frequent experiments could not be performed without a real-time VLBI system. At beginning of 2001, Miura station was closed and the other three stations will continue monitoring of crustal movement. Optically linked real-time VLBI experiment with Usuda 64m antenna and Kashima 34m antenna was also performed several times.

1. Introduction

Communications Research Laboratory (CRL) has been doing regular geodetic VLBI experiments to monitor crustal deformation around the Tokyo metropolitan area. The name of the project is Key Stone Project (KSP) [1]. The KSP VLBI has two types of correlation processing systems. One is a tape-based VLBI correlation system [2][3] and the other is a real-time VLBI correlation system [4][5][6] (Figure 1). Both systems are operated at a data rate of 256 Mbps. KSP VLBI with four stations started in tape-based mode from fourth quarter of 1996 and 256 Mbps real-time VLBI observation started third quarter of 1997 by using Asynchronous Transfer Mode (ATM) network under collaboration with NTT (Nippon Telephone and Telegraph Corporation). Tape-based and real-time VLBI correlation processing is performed with 6 units of single baseline correlators, correlation controller and operation software with GUI interface designed for easy operation [7].

2. Correlation Center History of Routine KSP Operation

Real time VLBI experiments had been operated every other day with three stations (Kashima, Koganei, and Tateyama) for 23.5 hours, since optical fiber link of Miura station was closed in May 1999. The reason for the observation interval is to reduce abrasion of antenna system. Four-station tape-based VLBI observation had been performed once every 6 days. The reason for the low frequency of observation with the four-station tape-based system was that correlation processing of tape-based data took much time. Tape-based observations every other day is hard for both operator, tape recorder, and tape changer machine. Mechanical motion is the most frequent cause of the troubles in routine operation. From this point of view, real time VLBI was indispensable for daily VLBI observation as described in a later section.

In July 2000, shortening of the Kashima-Tateyama baseline was detected and the observation schedule was changed from every other day to every day with three stations and tape-based four-station VLBI observation every 6 days. The crustal deformation was found to be caused by volcanic activities in the Izu islands located about 100km south west of Tateyama. The daily VLBI observation continued to 11 November 2000, then the observation mode was changed to the same as before July, since rapid changing of the baseline length was finished and the change rate returned to the same state as before July. Miura station was closed after tape-based four-station

Figure 1. The KSP tape-based VLBI correlation system (left) and the KSP real-time VLBI correlation system (right) at Koganei, In the left figure, four racks at the left are automatic tape changer (DMS-24). The right three racks contain correlators, output interfaces, and correlation controller. All of these tape-based equipment will be transported to Kashima Space Research Center in near future.

VLBI observation on 4th January, because it had been planned before. After that date, routine KSP VLBI observations have been carried out by real-time VLBI with three stations.

Except for the routine KSP VLBI observation, domestic VLBI observation campaign has been performed for connection of KSP stations and Japanese geographical reference frame to international reference frame. The name of the campaign is JPNTI. The JPNTI VLBI experiments using KSP 4 stations, Kashima 34m antenna, Kashima 26m antenna, and Tsukuba 32m antenna were conducted in March, June, September, October, and November in 2000. The next JPNTI experiment is planned in February 2001. Most of these experiments were processed with the KSP correlation system.

KSP VLBI Kashima-Koganei baseline was also used for Giga-bit VLBI system performance check experiments, which were named GEX series. GEX-8 in May and GEX-9 in June 2000 were organized for delay measurement accuracy comparison between KSP and Giga-bit VLBI system.

3. Optically Connected VLBI Experiments

Optically linked VLBI experiments with large diameter antennas named GALAXY were performed several times under mutual collaboration among CRL, NTT, National Astronomical Observatory (NAO), and Institute of Space and Astronautical Science (ISAS). Kashima 34m antenna (CRL), Usuda 64m antenna (ISAS), KSP 11m antennas, and rarely Nobeyama 45m antenna (NAO) joined the observations. Currently the only established real-time VLBI correlation system is the KSP correlator in Japan. Thus all the real-time VLBI experiments are processed at Koganei Correlation center at present. Also distributed multi-baseline correlation processing was demonstrated with the KSP correlator by sending observed data via ATM network at NTT R&D Forum 2000. NAO's Mitaka FX correlator is under preparation for adapting to real time processing.

4. Technical Staff for the KSP VLBI Correlation Center

Technical staff members who are contributing to the KSP correlation center are listed below.

- Tetsuro Kondo, Responsible for overall operations and performance.
- Taizoh Yoshino, Leader of the Key Stone Project team in CRL.
- Hitoshi Kiuchi, Developments of correlation system and real-time VLBI interfaces.
- Jun Amagai, Responsible for management of correlation center.
- Mamoru Sekido, Development of correlation processing software.
- Naoki Goto and Muneo Takeda, Hiroyuki Shibata, Operator at the correlation center, Space Engineering Development Co., Ltd.

5. Current Status and Future Plans

After tape-based data processing including JPNTI experiments have finished, tape-based correlation system (Figure 1) will be transported to Kashima Space Research Center for data processing of experimental VLBI observation.

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Tsukuba VLBI Center

Kohei Miyagawa

Abstract

In this report, we present the summaries of the activities of correlator and related topics at the Geographical Survey Institute (GSI) from Mar. 1999 to Dec. 2000.

1. Correlator Processing

From Mar. 1999 to Dec. 2000, GSI K4 Correlator processed VLBI sessions as below.

- GSI domestic experiments (experiment code JADE, 9 times)
- Experiment between SYOWA and KASHIMA (Feb. 1999)
- Experiments between WETTZELL and TSUKUB32 (May and Jun. 1999)
- Remote controlled experiment between TSUKUB32 and AIRA (Dec. 2000)

Regarding GSI domestic experiments, we processed the data recorded with 64 Mbps before JADE-0002 in Jun. 2000. From this session, the data recorded with 128 Mbps was processed, and fringes were detected. Correlator summaries on domestic experiments are available on the GSI VLBI Web page from JADE-0002. URL is

`http://vldb.gsi.go.jp/sokuchi/vlbi/english`

From JADE-0003 in Sep. 2000, GIFU3 took part in JADE session. We processed and analyzed the data including GIFU3. In processing the data of the SYOWA experiment, fringes were detected for the first time with K4 correlator. The data of the WETTZELL experiments were processed with GSI correlator and analyzed at Bonn. For the remote controlled experiment, fringes were not detected, because Cesium, not H-maser, was used as a frequency standard at AIRA station.

2. Program Update for System Controller (CRC-9511-CNT1)

The problem that System Controller, which controls the correlator devices, incorrectly recognized record times was found. As system controller read the process time of each observation and station from temporary file generated from schedule file, system controller, in some cases, read the process times unrelated to the processing stations. As a consequence, correlation was not processed with the correct accumulation time. This error of the program for system controller was corrected and updated in Nov. 2000.

3. Y2K Problem

In application software for correlator, Kety KUS880419, Y2K problem occurred, and correlator processed incorrectly. The program was modified to fix the problem and now processing is correctly done.

4. Modification to Program for Bandwidth Synthesis

The program for bandwidth synthesis developed by CRL was modified. Length of data that could be processed by the program was originally less than 300 PP. Moreover parameter period was set to 1 sec, so the maximum data length was 300 sec. As a result of this modification and a change of PP to 2 sec., we can process the data of maximum 1024 sec. We are now reprocessing the data that is longer than 512 sec.

5. Staff

VLBI Staff at GSI are listed in the following table.

Table 1. Staff working at GSI VLBI group

Name	Position	Jobs
Shigeru MATSUZAKA	IVS Networks Representative	
Yoshihiro FUKUZAKI	Leader of VLBI group	
Tadayuki AKIYAMA	Collocation chief	Collocation, Operation
Kousei SHIBA	Operation chief	Experiments Coordination, Operation
Kazuhiro TAKASHIMA	Visiting scientist at GSFC	Improvement of software for VLBI analysis
Masaru YAZAWA	Analysis chief	Baseline Analysis, Operation
Shinobu KURIHARA	Operator	Baseline Analysis, Operation
Michiko ONOGAKI	Operator	Antenna and H-maser maint., Operation
Kohei MIYAGAWA	Correlation chief	Correlation, Operation
Kyoko KOBAYASHI	Assistant	Correlation, Operation

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Washington Correlator

James O. Martin, Kerry A. Kingham

Abstract

This report summarizes the activities of the Washington Correlator from the establishment of IVS to the end of 2000. The Washington Correlator provides 136 hours of processing per week, primarily supporting Earth orientation and astrometric observations.

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 spends more than 90 percent of its time on these experiments. All of the weekly NEOS-A sessions, all of the daily intensives, and most of the CORE-A sessions are processed at WACO. The remaining time is spent on reference frame and astrometry sessions. From March, 1999 until the end of December, 1999 the facility utilized a Mark IIIA correlator. Beginning in January, 2000 processing switched to the Mark IV correlator. The first data from the new correlator was published in the IERS Bulletin A for January 11, 2000.

2. Correlator Operations

During the reporting period, the remaining two Mark IIIA playbacks were upgraded to Mark IV. For all of the calendar year 2000, the correlator operated with 6 Mark IV, thin tape capable, playback tape drives. All are capable of processing high density recordings and all are equipped with dryer units to prolong head life.

The correlator facility operates 136 hours per week, and is fully loaded at this level. During the first part of the reporting period, the Mark IIIA correlator was used at its normal efficiency. By the end of 1999, some degradation of processing throughput occured due to the installation and checkout of the Mark IV processor.

After the introduction of the Mark IV correlator, correlator efficiency decreased due to training on the new correlator and also due to the primitive state of the whole operational system. Efficiency slowly improved, and by the end of 2000, the efficiency was beginning to approach Mark IIIA standards, although much more work needs to be done to fully realize the promise of the new correlator.

Due to the Mark IV startup period, NEOS-A and the Daily Intensives were the only sessions processed during the first few months of operations. As the correlator efficiency improved, more non-NEOS sessions, and some of the backlog were processed.

3. Staff

The Washington Correlator is under the management and scientific direction of the Earth Orientation Department of the U.S. Naval Observatory. USNO personnel continue to be responsible for overseeing the scheduling and processing. During the period covered by this report, a private contractor, AMSC, continued to supply a contract manager and correlator operators.

Dr. Kerry Kingham (USNO) VLBI Correlator Project Scientist, responsible for the scientific integrity of correlated data, hardware and software maintenance and upgrades.

James O. Martin (USNO) VLBI Correlator Project Manager, responsible for process scheduling and evaluation of correlated data. Oversees session setups and prepasses. Evaluates station performance.

Bruce Thornton (AMSC) Operations Manager, responsible for correlator operator scheduling, daily operations, and tape shipping.

Harvis Macon (AMSC) Correlator operator, NEOS-A setups.

Valerie Bockarie (AMSC) Correlator Operator

Steven Springer (AMSC) Correlator Operator

Lawrence Dorsey (AMSC) Correlator Operator

Joseph Granderson (AMSC) Correlator Operator

Roxanne Watkins (AMSC) Tape Librarian

4. Outlook

The Washington Correlator, at present, is able to process 6-station geodetic VLBI sessions in a single pass. As the Mark IV development continues, and at least two additional tape drives are added, the Correlator facility will be able to handle 8-station sessions in a single pass, or subdivide into as many as 4 simultaneous sessions. More of the Mark IV capabilities will become operational allowing new observation formats.

DATA CENTERS

BKG Data Center

Volkmar Thorandt, Reiner Wojdziak

Abstract

This report summarizes the activities and background information of the IVS Data Center from the establishment of IVS to the end of 2000. 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 file stock 6 times per day. The following sketch shows the principle of mirroring:

BKG <—> OPAR <—> CDDIS

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. These areas are protected and the users need to obtain username and password to get access.

An incoming script is watching this incoming area and checking the syntax of the files sent by IVS components every hour. If it is o.k. the script moves the files into the datacenter 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.

For public access to the BKG Data Center users can do it through FTP:

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

respectively WWW:

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

Structure of BKG IVS Data Center:

```
vlbi/            : root directory
ivs-iers/        : VLBI products for IERS
ivs-pilot2000/   : directory for special investigations
ivscontrol/      : controlfiles for data center
ivsdata/         : VLBI observation files
ivsdocuments/    : IVS documents
ivsproducts/     : analysis products
                   (earth orientation, terrestrial and celestial frames)
```

Aside from this IVS related data bank another data bank for analysis purposes exists. It contains about 7400 X-Band databases and 7300 superfiles.

2. Technical Equipment

HP 9000/D280/1 (HP UX 10.20 operating system)
disc space: 190 GBytes (Raid system)
internet rate: 2 MBit/sec
backup: tape library

3. Staff Members

Volkmar Thorandt (coordination, data analysis, vt@leipzig.ifag.de)
Gerald Engelhardt (data analysis, engelhardt@leipzig.ifag.de)
Dieter Ullrich (data analysis, dul@leipzig.ifag.de)
Reiner Wojdziak (data flow, web design, rw@leipzig.ifag.de)

Data Center at Communications Research Laboratory

Yasuhiro Koyama

Abstract

The Data Center at Communications Research Laboratory archives and releases the analysis results processed at the Analysis Center at Communications Research Laboratory. Regular VLBI sessions with the Key Stone Project VLBI Network are the primary objects of the Data Center. In addition, JPNTI and K4TIE series of geodetic VLBI sessions were processed and archived. Recent changes during the period between March 1999 and December 2000 will be reported and future plans of the Data Center will be described.

1. Introduction

The IVS Data Center at the Communications Research Laboratory (CRL) archives and releases the analysis results processed by the IVS Analysis Center at CRL. Major parts of the data are from the Key Stone Project (KSP) VLBI sessions [1] but other regional and international VLBI sessions are also archived and released. Such additional sessions include JPNTI series and K4TIE series. The former series have been repeatedly performed with Tsukuba 32m, Kashima 26m, Kashima 34m, and KSP stations to precisely determine site coordinates of the Tsukuba 32m and KSP stations on the International Terrestrial Reference Frame (ITRF) by using the site positions of Kashima 26m and 34m stations on the ITRF. The later series were performed twice with the Fairbanks, Kashima 26m, Kashima 34m, and KSP stations to demonstrate international geodetic VLBI observations with the K4 observation systems.

2. Data Products

The KSP VLBI sessions were performed with four KSP IVS Network Stations at Kashima, Koganei, Miura, and Tateyama in a daily or bi-daily (once every two days) basis until May 1999. Duration of each session is about 23.5 hours. Daily observations were performed from March 1 until April 1, 1999 to obtain continuous VLBI data series for various investigations such as studies about the atmospheric delay models and for the improvements of the data analysis technique. The high-speed ATM (Asynchronous Transfer Mode) network line to the Miura station became unavailable in May 1999 and the real-time VLBI observations with the Miura station became impossible. After this time, the real-time VLBI sessions were performed with three stations at Kashima, Koganei, and Tateyama. Once every six days (one session per three sessions), 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 to the Koganei station and the data were correlated. After the correlation processing completed, the data set produced with the real-time VLBI data processing was replaced by the new data set.

In July 2000, unusual site motion of the Tateyama station was detected from the KSP VLBI data series, and the frequency of the sessions was increased from bi-daily to daily since July 22,

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

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

Table 1. Number of sessions and observed delays used in the data analysis for each year up to December 2000.

Year	Number of sessions	Number of valid observed delays
1994	2	261
1995	171	15837
1996	345	66005
1997	308	287452
1998	183	474783
1999	198	351162
2000	235	339246
Total	1442	1534746

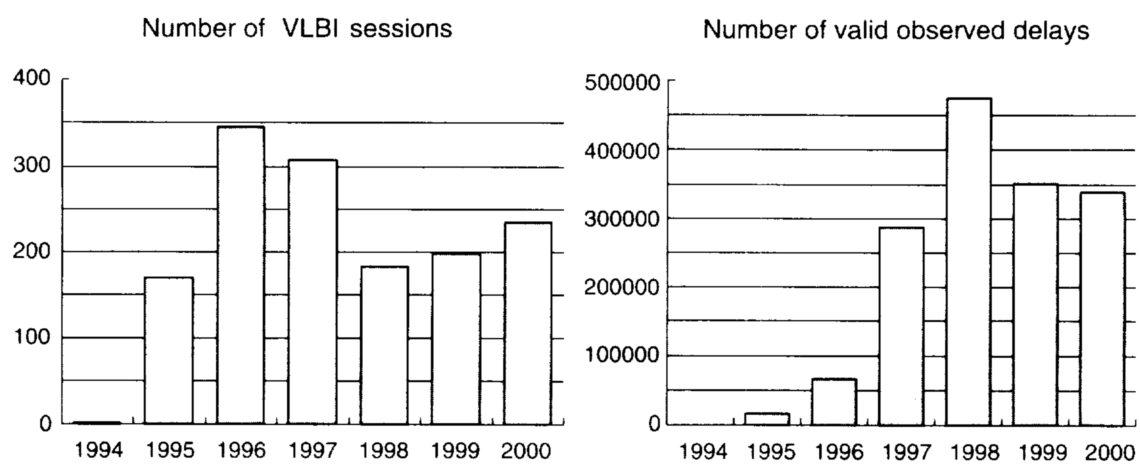

Figure 1. Number of sessions and observed delay used in the data analysis for each year as of March 1, 1999.

In December 2000, the server system for the WWW (World Wide Web) and FTP (File Transfer

Protocol) accesses was changed as shown in the Table 2. The URL (Unified Resource Locator) of the WWW service remained the same, but the URL for the FTP service was changed. Data analysis results are available in SINEX (Solution Independent Exchange) file format and in various formats including ASCII data and data plots.

Table 2. URL and IP address of the WWW and FTP server system.

Service	URL	IP address
WWW	http://ksp.crl.go.jp/	133.243.3.35
FTP	ftp://ksp.crl.go.jp/pub/j/j144/	133.243.3.35

3. Future Plans

The operation of the Miura KSP VLBI station was terminated in January 2001. The antenna and the observation facilities at the site will be transported to the Tomakomai Experimental Forest of Hokkaido University. The Tateyama station will also be closed in 2002, and the antenna and the observation facilities will be transported to the campus of the Gifu University. The tape-based correlator system at Koganei will be transported to the Kashima Space Research Center of CRL. In spite of these changes, the IVS Data Center at CRL will continue its service and will archive and release the analysis results produced by the IVS Analysis Center at CRL.

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CDDIS Data Center Report

Carey E. Noll

Abstract

This report summarizes activities for the year 2000 and future plans of the Crustal Dynamics Data Information System (CDDIS) with respect to the International VLBI Service for Geodesy and Astrometry (IVS). Included in this report are background information about the CDDIS, the computer architecture, staffing supporting the system, archive contents, and future plans for the CDDIS within the IVS.

1. Introduction

The Crustal Dynamics Data Information System (CDDIS) has supported the archive and distribution of Very Long Baseline Interferometry (VLBI) data since its inception in 1982. The current and future plans for the system's support of the International VLBI Service for Geodesy and Astrometry are discussed below.

2. Background

The CDDIS has been operational since September 1982, serving the international space geodesy and geodynamics community. This data archive was initially conceived to support NASA's Crustal Dynamics Project; since the end of this successful program in 1991, the CDDIS has continued to support the science community through the Solid Earth and Natural Hazards activity within NASA's Earth Science Enterprise. The main objectives of the CDDIS are to store all geodetic data products acquired by NASA programs in a central data bank, to maintain information about the archival of these data, and to disseminate these data and information in a timely manner to authorized investigators and cooperating institutions. Furthermore, science support groups analyzing these data submit their resulting data sets to the CDDIS on a regular basis. Thus, the CDDIS is a central facility providing users access to raw and analyzed data to facilitate scientific investigation. A large portion of the CDDIS holdings of GPS, GLONASS, laser ranging, VLBI, and DORIS data are stored on-line for remote access. Information about the system is available via the WWW at the URL *http://cddisa.gsfc.nasa.gov/cddis_welcome.html*.

The CDDIS successfully responded to the 1998 Call for Participation in the International VLBI Service for Geodesy and Astrometry (IVS). This response stated that the CDDIS would support data center activities by providing access to an archive of schedule files, log files, data bases, data products, and other auxiliary files.

3. System Description

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

3.1. Computer Architecture

The CDDIS is operational on a dedicated Compaq AlphaServer 4000 running the UNIX operating system. This facility currently has over 300 Gbytes of on-line magnetic disk storage; approximately 25 Gbytes will be devoted to VLBI activities. The CDDIS is located at NASA GSFC and is accessible to users 24 hours per day, seven days per week.

3.2. Staffing

Currently, a staff consisting of one NASA civil service employee and three contractor employees supports all CDDIS activities:

Table 1. CDDIS Staff

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

4. 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. In brief, an incoming data area has been established on the CDDIS host computer, *cddisa.gsfc.nasa.gov*. Operations and Analysis Centers deposit data files and analyzed results using specified file names to appropriate directories within this filesystem. Automated archiving routines, developed by GSFC VLBI staff, peruse the directories and migrate any new data to the appropriate public disk area. These routines migrate the data based on the file name to the appropriate directory as described in Table 2. Index files in the main subdirectories under *ftp://cddisa.gsfc.nasa.gov/pub/vlbi* are updated to reflect data archived in the filesystem. Furthermore, mirroring software has been installed on the CDDIS host computer, as well as all other IVS Data Centers, to facilitate equalization of data and product holdings among these Data Centers. At this time, mirroring is performed between the IVS Data Centers located at the CDDIS, the Bundesamt für Kartographie und Geodäsie (BKG) in Leipzig, and the Observatoire de Paris. Figure 1 illustrates the flow of information, data, and products between the various IVS components.

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.

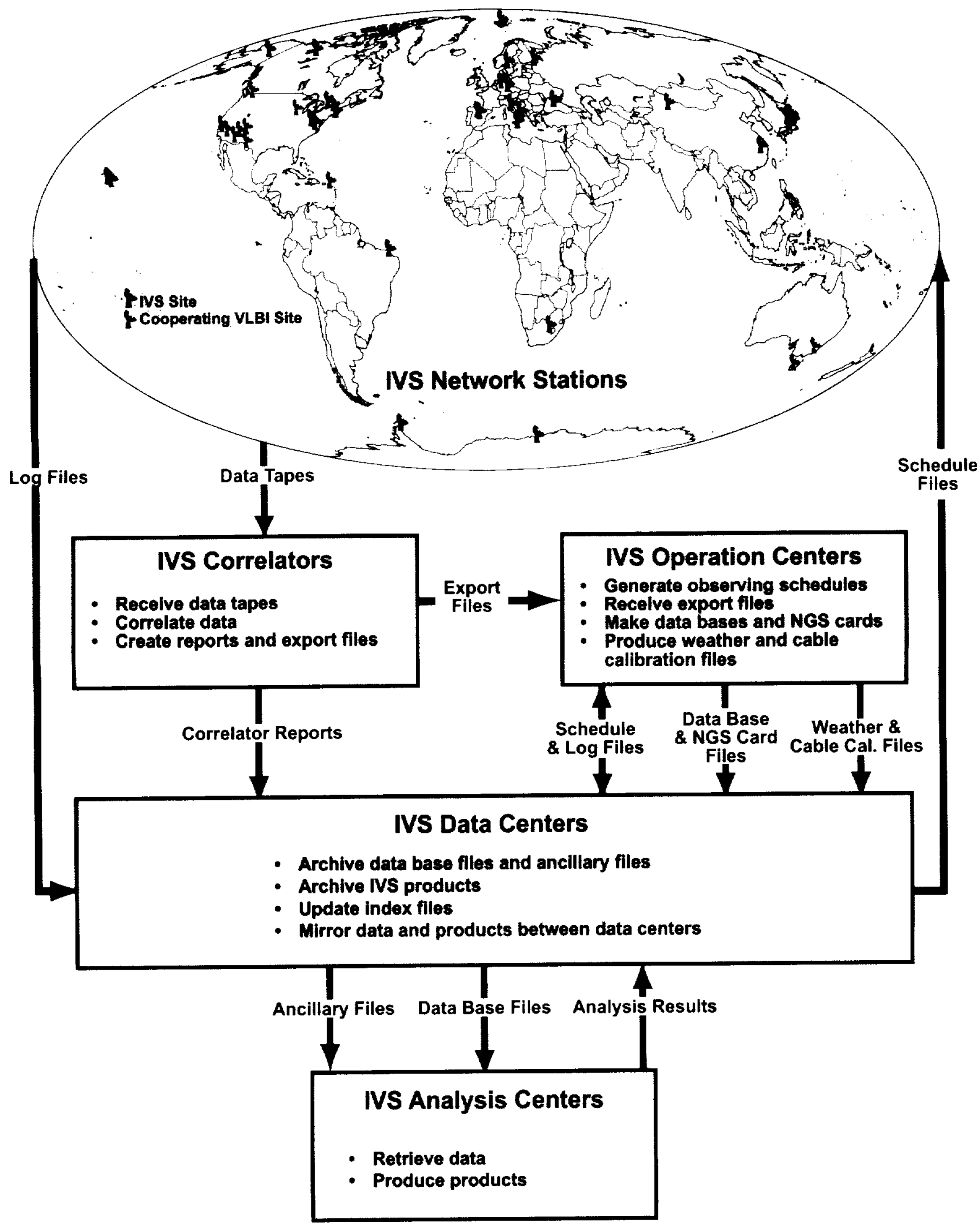


Figure 1. The flow of data, product, and log files from various IVS components to the IVS data centers.

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/sinex/*yyyy*	VLBI data files in SINEX format (future) 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
Product Directories	
vlbi/ivsproducts/crf	CRF solutions
vlbi/ivsproducts/eopi	EOP-I solutions
vlbi/ivsproducts/eops	EOP-S solutions
vlbi/ivsproducts/trf	TRF solutions
vlbi/ivs-iers	IVS contributions to the IERS
vlbi/ivs-pilot2000	IVS Analysis Center pilot project (2000)
Other Directories	
vlbi/ivscontrol	IVS control files (master schedule, IVS on-line directory and file information, etc.)
vlbi/ivsdocuments	IVS document files (analysis documentation, etc.)

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. The staff hopes to secure funding for some computer system enhancements, including a large RAID disk system.

Italy CNR Data Center Report

P. Tomasi

Abstract

This report summarises the situation of the Italian CNR VLBI data center. It will give the fundamental information about the structure of the center, its locations, and its activity.

1. Introduction

The Italy CNR VLBI data center is the joint effort of two Institutes of Consiglio Nazionale delle Ricerche (CNR) to improve, working together, the capability of VLBI data storage in Italy. The two Institute are:

a) the Istituto di Radioastronomia (Institute of Radio Astronomy IRA) located in Bologna, where the main research activity is carried out, both in radioastronomy and geodesy, but also managing the two VLBI antennas in Medicina (near Bologna) and Noto (in Sicily);

b) the Istituto di Tecnologia Informatica Spaziale (Institute of Informatica and Technology for Space ITIS), located in Matera at the Center of Spatial Geodesy (of the Italian Space Agency), where VLBI antenna, laser ranging telescope, permanent GPS receiver and PRARE antenna are located. Also a different data center is located here (GeoDAF). All these structures are properties of the Italian Space Agency and run by Telespazio.

However the two institutes mentioned above will become quite shortly a single institute, the "Istituto di Radioastronomia", with a section located in Matera. The new CNRs institute will carry on the same commitment to IVS as the previous two institutes. We have specialised the Bologna part to store and analyse single databases, using CALC/SOLVE software. In Bologna we have introduced CALC9.1 and all the databases stored here have been reCALCed. We are also using f-solve (release Nov. 2000) and that means a complete new series of superfiles have been produced, according to the new format introduced. This point is only of interest for CALC/SOLVE users. The IRA has started to store VLBI geodetic databases from 1989 but the databases archived in Bologna are mostly concerned with data including European antennas, starting from 1987. In particular most of the databases present here have VLBI data with at least three European antennas. However we are also storing all the databases with the Ny Ålesund antenna data. All the databases have been processed and saved with the best selection of the parameters for final arc solution.

In some cases we have introduced the wet delay coming from GPS in the European databases (at present only for EUROPE experiments for the year 1998), as if it was produced by WVR. Also these databases are available and stored with a different code from the original database. In Matera we have stored part of the databases and all the superfiles. In fact, we are using the faster computer there mostly for global solutions. However at the moment the f-solve version we are using there is the June 2000 version of f-solve, with superfiles format not compatible with the ones produced in Bologna. We will move quite soon to a new version of f-solve also in Matera and then also there we will have the superfiles in the new format.

2. Computer Available and Routing Access

In Bologna the main computer is HP715/80, the computer name is boira6.ira.bo.cnr.it and the databases are stored in different directories and in different disks as well. The complete list of directories where databases are stored is the following:

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

As you can see, comparing the previous annual report, a new big area (/GEO), has been added. At the moment this storing area is subdivided into three directories and its total storing area is about 35 Gbytes.

The username for accessing the database at the moment is geo. Password can be asked by sending a mail to tomasi@ira.bo.cnr.it. In the near future the database will be accessed by anonymous ftp.

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

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

The super files are stored in different directories:

/data2/super
/data10/super10
/data9/super9
/data14/super14

and the list of superfiles is stored in the file /data1/solvefiles/SUPCAT. The data can be accessed using the username geo, and the password can be asked of tomasi@ira.bo.cnr.it.

For the moment all the data are stored on magnetic disk, but we are planning to move the whole catalog of databases to optical disk. The area available on a jukebox (already installed in Matera) will be of 80 Gb on line.

Paris Observatory (OPAR) Data Center

Najat Essaïfi

Abstract

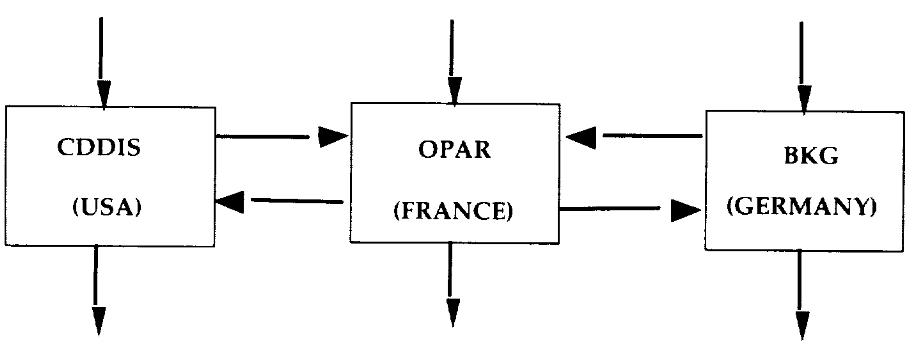
This report summarizes the OPAR Data Center activities over 2000. Included are information about functions, architecture, status, future plans, and staff members of OPAR Data Center.

1. OPAR Data Center Functions

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

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

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



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

2. Architecture

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

Structure of IVS Data Center has evolved since 1999, and has actually six primary directories:

```
ivscontrol/      : provides the control files needed by the data center
                   (session code, station code, solution code...)
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\\
ivs-iers/        : provides products for IERS Annual Report
ivs-pilot2000/   : provides products for special investigations
ivsdocuments/    : provides documents and descriptions about IVS products\\
```

3. Current Status

The OPAR Data Center is operational on a HEWLETT PACKARD 9000 Model 715 located at Paris Observatory and running the HP-UX 10.20 operating system. To make all IVS products available on-line, this server is equipped with a 20 Go disc storage for VLBI activities.

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

FTP access:

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

4. Future plans

The OPAR staff will continue to work with the IVS community. To ensure better access to the OPAR Data Center, a new enhanced computer system will replace the current one, within a few months. The disc space will also be increased with regards to IVS products.

5. Staff Members

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

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

6. Contact information

To obtain information about OPAR Data Center please contact:

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Analysis Center of Saint-Petersburg University

Oleg Titov, Maria Kudryashova, Veniamin Vityazev

Abstract

This report contains information about current and future activities of Analysis Center of Saint-Petersburg University.

1. Introduction

Our Analysis Center is located at the Astronomical Institute of Saint-Petersburg University. It began its activity in 1998. Initially we made an analysis of NEOS-Intensives VLBI sessions only. Since 2000 year we have started to process the weekly NEOS-A experiments.

2. Staff

The staff and their responsibilities are:

V.Vitayzev – Director of Astronomical Institute of Saint-Petersburg University, PhD, General coordination and support of activity at the Astronomical Institute.

O.Titov – Assistant Professor of Saint-Petersburg University, PhD. Current processing of VLBI data.

M.Kudryashova – Postgraduate student of Saint-Petersburg University. Current processing of VLBI data.

3. Data Analysis

The Analysis Center participates in regular submission of EOP from both NEOS-Intensives and NEOS-A observational programs. We use OCCAM (version 3.4) package to get the solutions. VLBI data files are downloaded in NGS format from Paris Observatory database (IVS component). Almost all reductional calculations are in accordance with IERS Convention 1996 and later modifications (Explanatory Supplement). Relativistic corrections are from IERS Recommendations 1992. Secular polar motion for pole tide correction is given by formulae from The Explanatory Supplement. Station coordinates are referred to ITRF97. The celestial reference frame was fixed to Reference Frame Navy 1997-8.

Values of UT1-UTC are estimated within the scope of EOP's operative service. For the purpose we use short (1-2 hours) VLBI sessions obtained by NEOS-Intensive program. Data are processed by OCCAM software using weighted least squares method. Wettzell is used as reference station for all sessions. Its wet delay, clock offsets and clock rates for other stations are regularly estimated. The solution SPU00001.EOPI contains 778 estimates of the UT1-UTC since 01 September 1997.

As to processing of NEOS-A VLBI sessions, five parameters of Earth Rotation (pole coordinates, UT1-UTC, nutation offsets) are estimated by Kalman filter technique. For the reference station (Wettzell on default) only wet delay is estimated. Wet delay, clock offsets are also estimated for other stations. A random walk model has been chosen to adjust the stochastic behaviour of the wet delay and clock offset. Usually clock rate is a constant parameter. For the last years clock behaviour for WETTZELL is not perfect sometimes. In this case we use another suitable VLBI site as reference. Moreover, in this case we have to use a random walk model to adjust the clock rate for WETTZELL as well. The solution SPU00001.EOPS contains 987 estimates of all five EOPs since 07 February 1983. Fig.1-3 demonstrate the residuals between the solution and IERS C04 system for 1996-2000.

4. Outlook

During the year 2001 we are planning:

- to make weekly comparison and combination of Intensive Series EOP.
- to upgrade OCCAM software jointly with groups from DGFI and Vienna Technical University.

5. Acknowledgments

The Analysis Center activity is supported financially by Russian Foundation of Basic Research (grant 99-02-18059) and Federal program "Integration".

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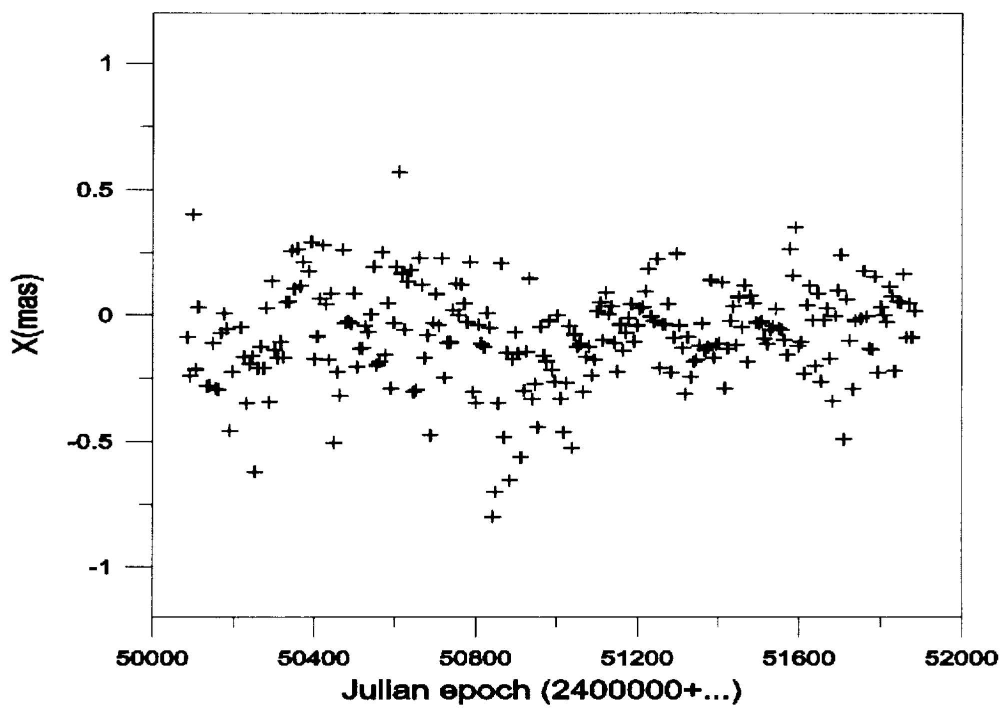

Figure 1. Residuals SPU00001 - IERS C04 for X-coordinates.

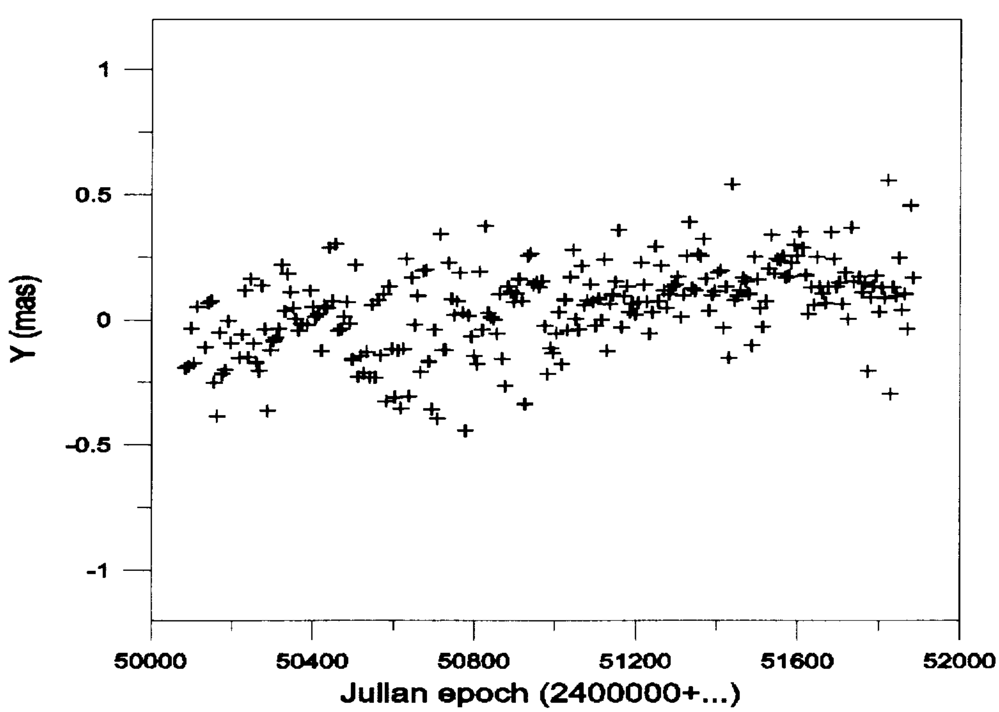

Figure 2. Residuals SPU00001 - IERS C04 for Y-coordinates.

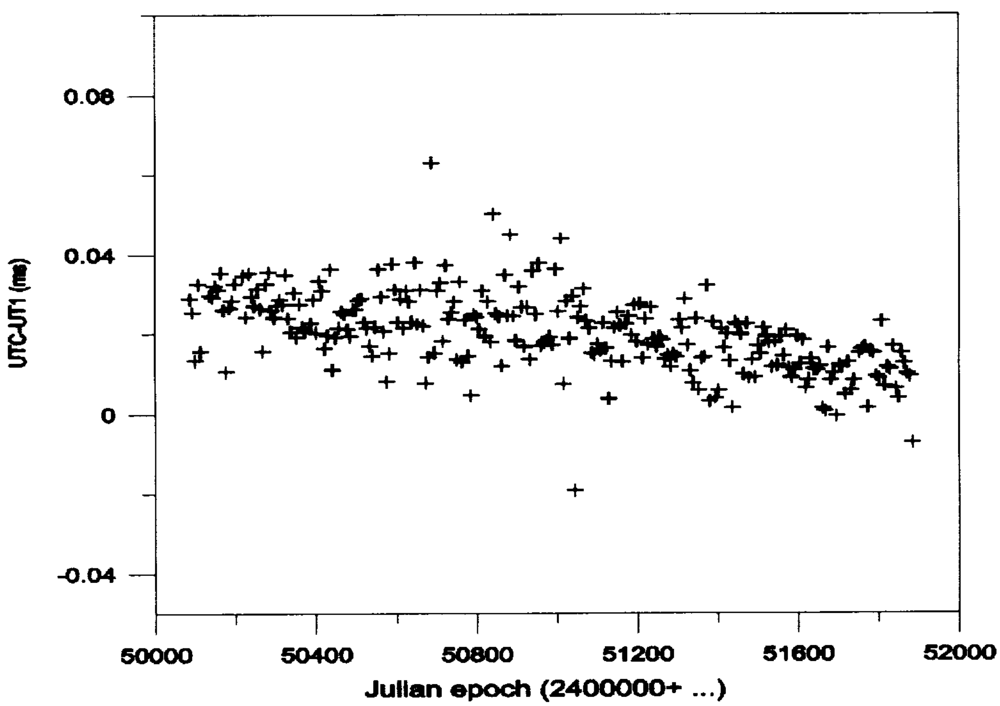

Figure 3. Residuals SPU00001 - IERS C04 for UT1-UTC.

Bordeaux Observatory Analysis Center Report

Patrick Charlot, Bruno Viateau, Alain Baudry

Abstract

This report summarizes the activities of the Bordeaux Observatory Analysis Center from the establishment of IVS to the end of 2000. During this period, most of our efforts have been devoted to the development of an astrometric project on the European VLBI Network for densifying the International Celestial Reference Frame (ICRF). Another achievement is the evaluation of the astrometric quality of the ICRF sources based on their observed structures, and the diffusion of this information through a web page. Additionally, we have contributed to the implementation of a geodetic VLBI model in a multi-technique software, GINS, developed by the GRGS group in Toulouse. Changes in staff and equipment are also described, and the outlook for 2001 is given.

1. Celestial Frame Activities

As mentioned in our initial IVS report [1], our major scientific interest is the celestial frame, especially the maintenance and extension of the International Celestial Reference Frame (ICRF). The main achievements in this area since the establishment of IVS are reviewed below.

1.1. ICRF Densification

Along the lines described in [2], we have initiated an astrometric project on the European VLBI Network (EVN) for densifying the ICRF in the northern hemisphere. The aim of this project is to add 150 new sources at carefully selected sky locations to fill the "empty" regions of the frame and improve the overall source distribution. Most notably, the addition of these new sources will reduce the distance to the nearest ICRF source for any randomly-chosen location in the northern sky from a maximum of 13° (as it is now for the current ICRF-Ext. 1 frame) to a maximum of 6°. Further details on the source selection strategy are given in [2].

Table 1. Network used in ICRF densification experiment.

EVN telescopes	Non-EVN telescopes
Effelsberg	Algonquin Park
Medicina	Goldstone (DSS 13)
Noto	Green Bank (NRAO 20)
Onsala	Hartebeestoek
Wettzell	Ny-Ålesund
Urumqi	
Shanghai	

As a first step, a proposal was submitted to the EVN for observing 50 of these new sources. This proposal was approved and the subsequent experiment was carried out on May 31, 2000, using seven EVN telescopes along with five external non-EVN geodetic stations that agreed to participate in this project. The participating telescopes are listed in Table 1. The new sources were scheduled jointly with a set of 10 highly-accurate ICRF sources so that their positions can be linked directly to the ICRF. Correlation of these data has just been carried out with the Bonn Mark IV correlator. A quick look at the correlation results indicates that all 50 new sources have been detected.

1.2. Source Classification Based on Observed Structure

Another achievement is the completion of source structure effect evaluation for most of the ICRF sources north of −20° declination [3]. For possible use by IVS operational and analysis centers, we have created a web page with false color images showing the magnitude of these effects at X band and S band as a function of baseline length and orientation. The current web page[1] provides such an evaluation for 392 ICRF sources and contains a total of 784 images. It also provides "structure indices" which reflect the astrometric suitability of each source according to the median structure effect in the bandwidth synthesis delay, as defined in Table 2.

Table 2. Structure index and astrometric quality.

structure index	astrometric quality	median effect (ps)	observed structure
1	very good	0–3	point-like
2	good	3–10	resolved
3	use with caution	10–30	extended
4	not acceptable	> 30	very extended

Based on the above evaluation, we have searched for correlations between the observed radio structure and the ICRF source position accuracy and stability. Such correlations have been found and they indicate that the more extended sources have larger position uncertainties and are less positionally stable than the more compact sources [3]. This study also revealed that 16 ICRF defining sources have a structure index of 4, indicating that they are spatially extended and thus are not appropriate for defining the celestial frame with the highest level of accuracy [3].

2. Software Development

A collaboration has been established with the GRGS group (Groupe de Recherches de Géodésie Spatiale) in Toulouse (France) to implement a geodetic VLBI model in the GRGS space-geodesy software GINS for analysis of both Earth-based and space VLBI observations. The major goal of this project is to process space VLBI delay and delay rate measurements from the HALCA satellite to test the concept of space VLBI geodesy. Ultimately, the software will also be able to process standard Earth-based geodetic VLBI data and to combine them with other space geodetic measurements (SLR, GPS, DORIS) for multi-technique Earth orientation estimation and reference frame unification.

Progress on this project has been reported in [4]. Our contribution in Bordeaux has been especially to test the implemented geodetic VLBI model by carefully comparing results obtained with GINS to those obtained with the MODEST VLBI analysis software [5]. This comparison showed a very good agreement and indicates that the VLBI model in GINS is currently accurate

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

at the few millimeter level. The new VLBI capability of GINS has also been used to process the space VLBI delay data acquired during a HALCA experiment carried out on December 4, 1997. The results of this analysis, although preliminary, suggest that the reconstructed HALCA orbit at the time of the experiment is accurate at the few meter level, somewhat better than the 10 m nominal accuracy given for this satellite [4] .

3. Staff and Equipment

- One member of our team (Bruno Viateau) spent 10 months (June 1999–April 2000) as a post-doc fellow in the VLBI group at the Jet Propulsion laboratory. Unfortunately, despite the experience gained there, he did not obtain a permanent research position after his return in Bordeaux. He left the Observatory in July 2000 and now works for a private company.
- One of us (Patrick Charlot) spent a few days at NASA/GSFC in April 2000 to learn the basics of the SKED scheduling software. This software was then successfully installed in Bordeaux and used for scheduling the ICRF densification experiment described above.
- Computer equipment has been significantly upgraded with two new Unix workstations, a Compaq DS20 acquired in September 1999, and a Compaq ES40 acquired in September 2000. The MODEST analysis software has been installed on these workstations, while the Goddard data base system and related software like SKED remain on our old HP workstation.

4. Outlook

- Starting next fall, we expect to have a new engineer for IVS analysis activities. This should allow us to increase our level of activity and develop regular analyses related to the celestial frame. Our goal is to produce time series of source positions and study the ICRF source position stability as initially proposed [1].
- In the immediate future, our aim will be to process the data of the ICRF densification experiment described above and to assess the results. This analysis will be carried out with the MODEST VLBI analysis software [5]. Once we have these results, a new proposal will be submitted to the EVN for observing the remaining 100 sources.
- Additionally, we will continue to evaluate the astrometric quality of the ICRF sources as new maps are available, and make structure indices and false color images available through our web page. Future work will also be targeted at incorporating source structure corrections to actual observations. Progress toward this goal has been reported in [6].

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Matera CGS VLBI Analysis Center

Roberto Lanotte, Giuseppe Bianco

Abstract

This paper reports the VLBI data analysis activities at the Space Geodesy Center (CGS) at Matera from March 1999 through December 2000 and the contributions that the CGS intends to provide for the future as an IVS Data Analysis Center.

1. Introduction

The VLBI data analysis activities at the CGS in the year 2000 are mainly dominated by the unavailability of the workstation used to process the VLBI solutions due to a power supply failure. In spite of that some activities related to the VLBI analysis have been carried out.

2. Combination of Velocity Fields from SLR, GPS and VLBI for the Italian Region

We combined four space geodetic solutions produced at the CGS analysis center in Matera:

1. a daily GPS network solution of the European area
2. a daily GPS precise point positioning solution that recovers single station coordinates for some stations in the European area
3. a VLBI solution for the European area
4. a global SLR solution

Since each single-technique solution realizes its own reference frame, it is necessary to define a common reference frame in which to perform the combined solution. We chose to transform and combine the velocity fields within the ITRF97 reference frame by determining the time derivatives of rotation, translation and scale parameters that transform each solution in the common frame. For small rotations and velocities, typically on the order of a few mas and mm/yr respectively, the approximated equations defining the roto-translations of the velocities fields are:

$$\dot{\mathbf{X}}_{solution} - \dot{\mathbf{X}}_{ITRF} = (\dot{\mathbf{d}} + \dot{\varepsilon})\mathbf{X}_{ITRF} + \dot{\mathbf{T}} \tag{1}$$

where $\mathbf{X}$ are the site cartesian coordinates (x,y,z) and $\dot{\mathbf{X}}$ their corresponding velocities. The unknowns are respectively the scale factor $\dot{d}$, the three rotations and three translation time derivatives $\dot{\varepsilon}_x$, $\dot{\varepsilon}_y$, $\dot{\varepsilon}_z$, $\dot{T}_x$, $\dot{T}_y$, $\dot{T}_z$.

The covariance matrix $\mathbf{C}_{solution}$ of each velocity solution has been propagated accordingly:

$$\mathbf{C}_{ITRF} = \mathbf{C}_{solution} + \mathbf{\Gamma}^T \mathbf{C}_H \mathbf{\Gamma} \tag{2}$$

where $\mathbf{C}_{ITRF}$ is the covariance matrix transformed in the ITRF97 reference frame, $\mathbf{C}_H$ is the covariance matrix of the roto-translation parameters and $\mathbf{\Gamma}$ is the matrix of the partials w.r.t. the roto-translation parameters.

Once each velocity field was expressed in the common reference system, the combined 3-D velocity field has been estimated in a least squares sense, minimizing the velocity residuals:

$$\dot{\mathbf{X}}_C = (\mathbf{A}^T\mathbf{W}\mathbf{A})^{-1}\mathbf{A}^T\mathbf{W}\mathbf{Y} \tag{3}$$

Where $\dot{\mathbf{X}}_C$ is the combined velocity solution, **A** is the matrix of the partials w.r.t. the estimated parameters and has the form:

$\mathbf{A} = \begin{pmatrix} \mathbf{I} \\ \vdots \\ \mathbf{I} \end{pmatrix}$ with **I** identity matrix,

W is the total weight matrix:

$\mathbf{W} = \begin{pmatrix} \mathbf{\Sigma}_1^{-1} & & \mathbf{0} \\ & \ddots & \\ \mathbf{0} & & \mathbf{\Sigma}_n^{-1} \end{pmatrix}$ with $\mathbf{\Sigma}_i^{-1}$ covariance matrix of each single velocity solution

and

$\mathbf{Y} = \begin{pmatrix} \mathbf{X}_1 \\ \vdots \\ \mathbf{X}_n \end{pmatrix}$ with $\mathbf{X}_i$ single velocity solution.

More details and the results of this work can be found in Devoti et al. 2000 [1].

3. Spectral Analysis of Time Series

The estimated geodetic time series could be affected by non-tectonic signals such as: mismodeling in the data analysis models, local phenomena induced by human activities and local geophysical or geological phenomena. It is expected that some of these phenomena have a periodical behavior and a spectral analysis should highlight their presence. We developed some tools for the spectral analysis of the time series. Our initial target is to recover the stationary part of a signal; this is obtained using a wavelets approach that is able to distinguish the stationary part of the signal from the non-stationary one. After that a least-squares procedure is used to characterize frequency, amplitude and phase of the stationary part in the form: $\sum_i A_i \cos(\omega_i t + \phi_i)$. These tools are based on the Lomb-Scargle periodogram that is suitable for time series with unevenly sampled data. At the present the tools have been developed and we shall use them in the near future.

4. Contribution to IVS for 2001

The following items represent the contribution that the CGS intends to provide to the IVS for the year 2001:

- Global analysis using all geodetic sessions to estimate TRF and EOP
- Dedicated analysis for the VLBI experiments from the EUROPE campaign
- Combination of TRF and EOP solutions available from IVS and IERS
- Comparisons of tropospheric parameters derived by VLBI and GPS

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Analysis Center at Communications Research Laboratory

Ryuichi Ichikawa

Abstract

The aim of the Key Stone Project is to obtain precise relative positions of four stations using VLBI, SLR, and GPS on a daily basis by the Communications Research Laboratory. VLBI results spanning the last three and half years indicate that the Miura and Tateyama KSP sites are moving NNW with respect to Kashima at velocities of 17.0 and 20.9 mm/year, respectively. For two months after June 2000, the baseline length between Kashima and Tateyama was shortened by about 5 cm caused by a dike intrusion and co-seismic offsets between the Izu islands. We also carried out research and development such as evaluations of tropospheric path delay and ionospheric electron content, monitoring of flux-density variations of radio sources using the KSP network. This report summarizes the results from these research fields using the KSP network of CRL to the end of 2000.

1. Introduction

The KSP has been carried out around the Tokyo metropolitan area, Japan by the Communications Research Laboratory (CRL), using VLBI, SLR, and GPS. One of the main objectives of the KSP is to monitor regional deformation and strain accumulation at the plate boundary region of the Kanto district. The KSP is not only aimed at monitoring crustal deformation but also utilized for research and technical development of space geodesy. It is designed to make frequent observations possible with a minimum of human operations and to provide analyzed results as fast as possible. In particular, its automated design allows frequent VLBI experiments. By placing the three above-mentioned techniques close together at each site, the different and independently obtained results can be compared. We describe some analysis results using the KSP network in this report.

2. Analysis Results using the KSP Network

2.1. Crustal deformation

Figure 1a plots the estimated lengths of the baseline between Kashima and Tateyama stations using VLBI. This figure shows gradual improvements in VLBI data quality which are evident based on the scattering of plots and their formal errors. The results after September 30, 1997 are remarkable, reflecting the extended duration of each experiment.

Figure 1b shows the observed horizontal site velocities (millimeters per year) using VLBI and GPS at three KSP sites (Koganei, Miura, and Tateyama) relative to Kashima from January 1997 to June 2000. These VLBI measurements span the last three and half years and indicate that the Miura and Tateyama sites are moving with respect to Kashima at velocities of 17.0 and 20.9 mm/year toward the NNW, respectively. The velocities moving toward NNW at Miura and Tateyama suggest the effect of the subducting Philippine Sea plate beneath northern Honshu along the Sagami Trough.

Figures 1a and 2a show extraordinary drifts in both VLBI and GPS measurements after the end of June 2000, namely the baseline length between Kashima and Tateyama is shortened by about 5 cm in two months. Accumulated displacement at KSP sites toward north-east are presented in figure 2b. Similar displacement at four GPS sites (Katsuura, Kyonan, Miura, and Tateyama) of GEONET by Geographical Survey Institute (GSI) are also shown in the figure.

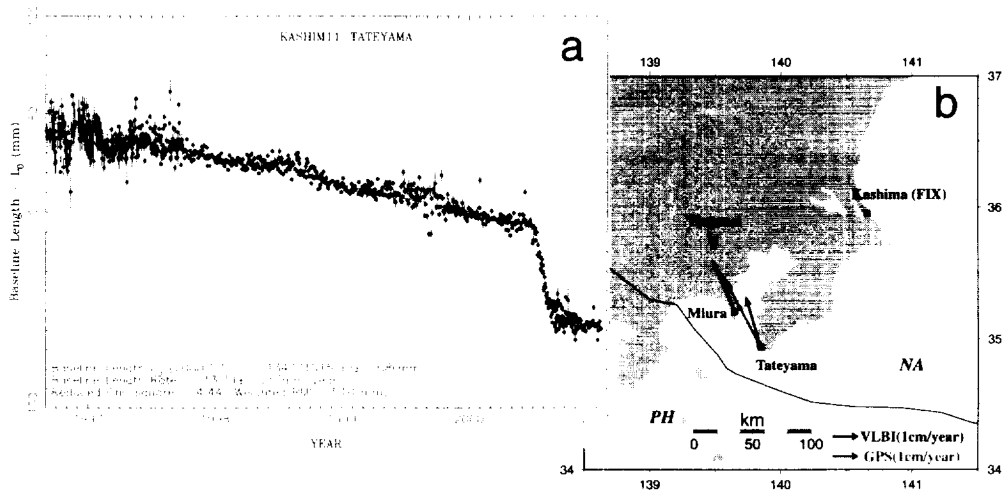

Figure 1. (a) Estimated baseline length between Kashima and Tateyama using VLBI. The formal error of each estimation is shown by a vertical bar in both figures. The variations in baseline length are fitted by linear lines and the best fit line is shown by straight solid lines. (b) Observed horizontal site velocities (centimeter per year) relative to Kashima site. The velocities from VLBI and KSP GPS from January 1997 to June 2000 are shown.

Following the magma intrusion in the Izu Islands (about 150 km south of Tokyo), during June 26 and 27, 2000, crater subsidence and volcanic eruptions continued in July and August at one of the islands, Miyakejima. In addition, high seismic activity and significant crustal deformation has continued around Miyakejima and Niijima-Kodushima since the end of June. According to the inversion using half-infinite elastic model, the crustal deformation at Tateyama, located about 100 km north-east of Kodushima island, is caused by a dike intrusion at about 3 km depth and co-seismic offsets between the islands [1]. The strike of the simulated dike is N140E, which is almost perpendicular to the azimuth from Kodushima toward Tateyama. This geometrical configuration can move the Tateyama site toward the north-east by the deformation due to the simulated dike.

2.2. Evaluation of tropospheric path delay

The repeatability of the baseline length of KSP VLBI measurements tends to be degraded in summertime. A correlation analysis between measured baseline lengths and surface temperature data was made, and it suggested that an apparent position change of the Kashima site occurred [2].

In June 1998, we initiated a field experiment for detecting and characterizing water vapor variations using water vapor radiometers (WVRs) at KSP Kashima site and Tsukuba. A WVR at Tsukuba is deployed by the Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA). Time series of atmospheric gradients estimated by WVR slant delays at Tsukuba and Kashima are compared.

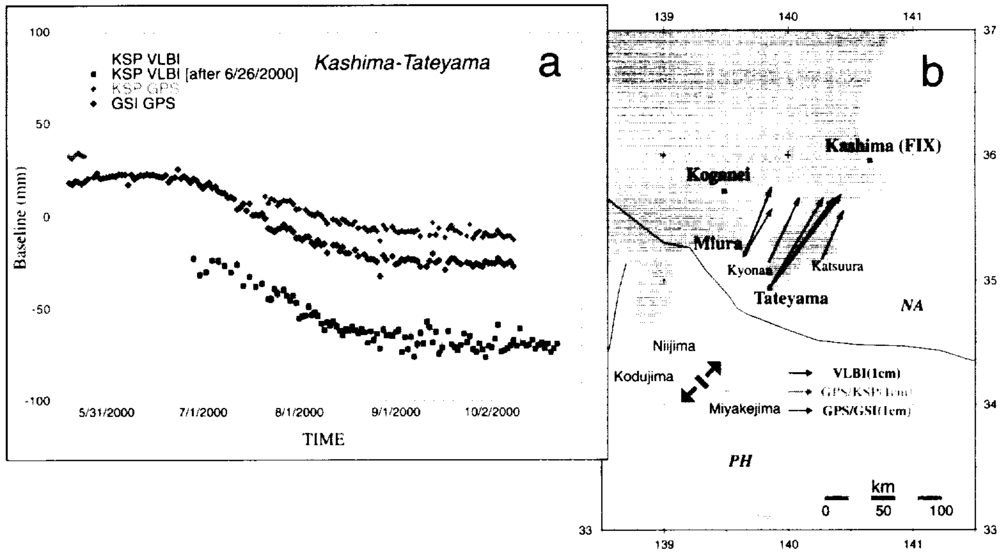

Figure 2. (a) Estimated baseline length between Kashima and Tateyama using VLBI and GPS of the KSP network. GPS results of the GEONET by Geographical Survey Institute (GSI) are also shown. (b) Accumulated displacements from VLBI, KSP GPS and GEONET GPS sites from July to September 2000.

In spite of relatively short distance between Tsukuba and Kashima (about 54 km) the atmospheric gradients solutions are significantly different. This result suggests that the mesoscale weather pattern caused large differences. We are now analyzing the output of high resolution numerical weather prediction models in order to investigate these results more deeply.

2.3. Evaluation of ionospheric electron content

Ionospheric delay correction with GPS-based Earth ionosphere total electron content (TEC) measurement is useful for single band VLBI application; for example, pulsar astrometry and geodetic VLBI with a single band receiver. To investigate the accuracy of GPS-based ionospheric TEC measurement, three cases of TEC estimation methods were compared with those from dual band VLBI observations of the Kashima-Koganei baseline [3]. The comparison study indicated the GPS-based TEC measurement can correct ionospheric delay in VLBI observations in almost the same accuracy with S/X dual band VLBI observation. This result is encouraging to apply GPS derived TEC to single band astrometric VLBI observation. Also realizing single band geodetic VLBI benefit at lower cost single band receiver instead of dual band receiver and more data channels can be used for X band signal.

2.4. Monitoring flux density variations of radio sources

Compact and strong radio sources are repeatedly observed in regular geodetic VLBI experiments under the KSP [4]. The two main purposes of the KSP VLBI network are to precisely measure relative site positions and to monitor their variations with a minimum delay of processing time. For these purposes, time delays between signals received at two sites and their rates of change are obtained through data correlation and bandwidth synthesis processing performed in real-time. The five years of the observed data show irregular variations in the flux densities were detected for several radio sources using the source 2134+004 as the calibrator.

3. Staff

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

- Kondo Tetsuro, Responsible for overall operations and performance.
- Koyama Yasuhiro, Development of data analysis software.
- Ichikawa Ryuichi, Research for crustal deformation and atmospheric modeling.
- Amagai Jun, Maintenance of data analysis system.

4. Current Status and Future Plans

As of mid-September 2000, the crustal deformation around Izu islands almost decayed according to the results from continuous GPS measurements of GEONET at the Izu islands by GSI. However, it is very important to monitor a postseismic stage in order to understand the tectonic process of the recent event around the islands. Thus, we made a decision to continue the KSP observations at least for one year regularly though we had a plan to close the KSP in spring 2001.

At present, the atmospheric gradient models [5][6] are not used in the operational analysis of the KSP VLBI. We are now modifying the VLBI analysis software to improve the accuracy of the position determination using atmospheric gradient model.

The web server for the Analysis Center is provided by CRL. The URL address is

`http://ksp.crl.go.jp/index.html`

The KSP web site holds all the data obtained by the KSP VLBI network. Baseline lengths, site positions, flux densities of observed radio sources, estimated earth orientation parameters are available on our web site. Our analysis results of the site positions have been generated using SINEX format.

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DGFI Analysis Center Annual Report 2000

Volker Tesmer, Hansjörg Kutterer, Hermann Drewes

Abstract

This report summarizes the activities of the DGFI Analysis Center from March 1999 to the end of 2000. The report contains planned activities for the year 2001, too.

1. Special Analysis Center Operation

The Deutsches Geodätisches Forschungsinstitut (DGFI) is a non-governmental research institute under the auspices of the Deutsche Geodätische Kommission (DGK). It is housed at the Bavarian Academy of Sciences (BAdW) in Munich. DGFI is financed by the State of Bavaria.

The general task of the IVS Analysis Center at DGFI is to support and to improve the VLBI data analysis and to generate VLBI products, in particular Earth rotation parameters (see DGFI web server `http://www.dgfi.badw.de`).

2. Initial Activities

Since the beginning of IVS, DGFI has carried out following activities:

1. Modification of the OCCAM VLBI software
   - correction of the station coordinates due to atmospheric loading, published by H.G. Scherneck (www.oso.chalmers.se/~hgs);
   - correction of thermal antenna deformation, according to Haas et al. (1999);
   - implementation of the new model of solid Earth tides, which will be included in the next IERS Conventions (2000);
   - extension of OCCAM by a least-squares approach following the Gauss-Markov model (in cooperation with J. Böhm from the University of Technology, Vienna).
2. Analysis of all NEOS-A, CORE-A, CORE-B and IRIS-S sessions between 1997 and 1999
   Systematic differences between the series were detected. The offsets between results from different networks reach 190 mas (Tesmer and Schuh, 2000).
3. Analysis of the 58 simultaneous NEOS-A and CORE-A sessions between 1997 and 1999
   Differences were found between EOP derived from the two completely independent networks observing simultaneously, which were occasionally two times greater than their formal errors (Tesmer and Schuh, 2000). They are very similar to those obtained by MacMillan et al. (1999) who used the CALC/SOLVE software package.
4. Considering a-priori correlations in VLBI data analysis
   Comparisons between solutions with a full variance-covariance matrix of the observables and 'usual' solutions with the off-diagonal elements set to zero showed that taking a-priori correlations into account yields formal errors of the results of a single session which are greater and hence more realistic than those from an 'uncorrelated' solution. Additionally, the repeatability of the parameters improved significantly (Schuh and Tesmer, 2000).

5. Development of a Knowledge-Based System for the automation of VLBI data analysis by SOLVE (Schwegmann and Schuh, 1999, Schwegmann and Schuh, 2000).

3. Staff

DGFI personnel involved in the IVS Analysis Center are the following (status January 2001):

Hermann Drewes, Hansjörg Kutterer and Volker Tesmer.

Changes in personnel:

In April 2000, Harald Schuh, Head of the Earth Rotation Section, left the DGFI to become a full professor at the University of Technology Vienna. His successor is Hansjörg Kutterer, formerly at the University of Technology Karlsruhe.

In May 2000, Wolfgang Schwegmann left the DGFI for a position at the Istituto di Radioastronomia, Bologna.

4. Plans

For 2001 the plans of DGFI Analysis Center are:

- Further improvement of OCCAM:

  OCCAM will be updated to be in full agreement with the IERS Conventions (2000). The parameterisation will be extended. All changes will be done in cooperation with the VLBI groups of Saint-Petersburg University (O. Titov) and the University of Technology Vienna (J. Böhm).
- Contribution to the VLBI terrestrial reference frame:

  It is planned to compute a terrestrial reference frame with OCCAM, accumulating normal equations of all usable VLBI sessions from 1979 till present.
- Further investigations of offsets between EOP series which depend on the particular VLBI network.
- Further investigations on the stochastical model used in VLBI data analysis.
- Investigations of subdiurnal variations of Earth orientation parameters.
- Generation of IVS products (EOP and TRF) and contribution to the IVS Working Group on data analysis.

Due to the move of W. Schwegmann to Bologna, the work on the development of a Knowledge-Based System for the automation of VLBI data analysis will not be continued at DGFI, but at the Istituto di Radioastronomia, Bologna.

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Combination of VLBI, GPS and SLR Data Analysis at FFI

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an Analysis Center will focus primarily on a combined analysis at the observation level of data from VLBI, GPS and SLR using the GEOSAT software. This report briefly summarises the current status of analyses performed with the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. Introduction

Recently, a number of colocated stations with more than one observation technique have been established. In principle, all instruments at a given colocated station move with the same velocity and it should be possible to determine one set of coordinates and velocities for each colocated site. In addition, a constant eccentricity vector from the reference point of the colocated station to each of the individual phase centers of the colocated antennas is estimated using constraints in accordance with a priori information given by the ground surveys. One set of Earth orientation parameters (EOP) and geocenter coordinates can be estimated from all involved data types. The present dominating error source of VLBI is the water content of the atmosphere which must be estimated. The inclusion of SLR data, which is independent of water vapour, gives new information which will help in the de-correlation of atmospheric and other solve-for parameters and lead to more accurate parameter estimates. These, and many more advantages with the combination of independent and complementary space geodetic data at the observation level, are fully accounted for with the GEOSAT software [2] developed by FFI during the last 15 years.

2. Data Analysis

A set of VLBI data from January 1993 to September 1999 has been analyzed. This analysis will be referred to as the VLBI-alone analysis. A second analysis referred to as the combined analysis was performed where SLR data for Lageos I and Lageos II from the same period was combined with the VLBI data at the observation level using exactly the same strategy as for the VLBI-alone analysis. The two analyses were performed in arcs of 24 hours using the GEOSAT software. The arc-results were combined into a multi-year VLBI-alone and a combined VLBI and SLR solution using the CSRIFS software [1]. The VLBI analysis model and analysis strategy are described in Andersen [3]. Station coordinates and velocities were estimated simultaneously with the Earth orientation parameters.

The results show that the use of SLR data in addition to VLBI data improves the precision of the estimated polar motion parameters from 0.2 mas to 0.1 mas, it improves the precision of the estimated UT1 parameters from 10 to 5 microseconds, and it improves the precision of the estimated nutation parameters from 0.2-0.3 mas to 0.15 mas. The formal precision of the nutation parameters indicates that the precision of these parameters in principle could be improved to the level of 0.05-0.08 mas. The analyses show that the applied VLBI and SLR models are consistent to a few mm.

The results indicate that as long as SLR tracking of two Lageos satellites is available on a daily basis it might be better to have, say 3-4 VLBI sessions a week, with many participating stations rather than daily VLBI sessions with a small number of participating stations. The SLR data are fully capable of producing high precision estimates of these parameters for days where VLBI data are not available. Further investigations are necessary in order to determine the consequence of enlarging (or reducing) the periods with no VLBI data on the precision of the estimates of the Earth orientation parameters.

It is observed from the solutions for the radio source positions that the inclusion of SLR data can lead to changes up to 0.3 mas in the estimated source coordinates. This is not unexpected since the two Lageos satellites used in the present analysis are physical objects in addition to the radio sources being used for the realization of CRF. It is a general trend in the formal uncertainties that the standard deviation in the right ascension is slightly improved with the inclusion of SLR data while the standard deviation in declination is significantly improved in some cases by as much as a factor of four. This will be further investigated.

The results show that for the first time VLBI and SLR tracking data have been successfully combined at the observation level. Furthermore, it is the first time satellite tracking data successfully have been used for the direct determination of nutation parameters. Based on the analysis and preliminary experience with the combination of VLBI, SLR and GPS data the author is convinced that the direct combination of high precision space geodetic data at the observation level within ten years will be the primary method for the realization of terrestrial and celestial reference frames and their interrelations.

More details of the analysis can be found in Andersen [4].

3. Prospects

In the near future GPS data for selected days will be incorporated in the analysis and combined with the VLBI and the SLR data at the observation level.

4. Technical Staff

Table 1 lists the FFI staff involved in IVS activities.

Table 1. Staff working at the FFI AC and TDC

Name	Background	Dedication	Agency
Per Helge Andersen	geodesy	40%	FFI

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The GIUB/BKG VLBI Analysis Center

Axel Nothnagel, Volkmar Thorandt, Gerald Engelhardt

Abstract

This report describes the activities of the GIUB/BKG VLBI Analysis Center during the reporting period. Data analysis activities and the development of data analysis technology are described. Past and on-going research topics are reported. Finally, center personnel are listed.

1. Overview

The GIUB/BKG VLBI Analysis Center has been estabished jointly by the Bundesamt für Kartographie und Geodäsie (BKG), Leipzig, and by the Geodetic Institute of the University of Bonn (GIUB). Both institutions closely cooperate in the field of geodetic VLBI maintaining their own analysis groups in Leipzig and Bonn. The responsibilities include data analysis and software development.

Both groups use the Mark III/IV data analysis software CALC/SOLVE/GLOBL which originated at NASA/GSFC. At GIUB the basic SOLVE/GLOBL software has been modified extensively to increase its computational speed and to add several new features.

2. Data Analysis Activities

At BKG the CALC9.11/f-SOLVE package is being used for routine VLBI data processing. The software has been installed on a HP 9000/D280/1 computer (HP UX 10.20 operating system) with about 190 GByte disc space.

The following sessions have been analysed jointly at GIUB and BKG since the beginning of March 1999:

- **Measurement of Vertical Crustal Motion in Europe by VLBI (EUROPE sessions)** (EU Project FMRX-CT960071)
  Six sessions in 1999 and 7 sessions in 2000 with the stations NyÅlesund, Onsala, Wettzell, Simeiz, Madrid (DSS65), Yebes, Medicina, Matera and Noto have been processed. Effelsberg participated once per year and the mobile unit TIGO-WTZL participated at several occasions during its testing phase.
- **Polarization tests**
  In order to investigate polarization impurities two regular EUROPE sessions were extended in which several stations swapped polarization from right circular polarization (RCP) to left circular polarization (LCP) while other stations continued to observe RCP. Fringes at all cross-polarization scans were detected and the analysis was completed.
- **International Radio Interferometric Surveying - South (IRIS-S):**
  Twelve sessions per year with the stations Wettzell, HartRAO, Fortaleza, Fairbanks and Westford were processed.
- **Continuous Observations of the Rotation of the Earth - O'Higgins (CORE-OHIG)**

Nine sessions with stations HartRAO, O'Higgins, Fortaleza, Hobart, Kokee and DSS45 have been analyzed in 1999 and 2000.

- **Annual Solution for Submission to IERS**
  In addition to the session by session analysis one combined solution is computed cooperatively each year which comprises most of the dual frequency fixed station Mark III data available worldwide. This solution is the basis for the annual submission to the IERS. Station coordinates and velocities, radio source positions and Earth orientation parameters (EOP) are estimated in one global solution. The solution types are bkgtra99 for the Terrestrial Reference Frame and bkgira99 for the Celestial Reference Frame and the Earth orientation parameters are available from the IVS Data Centers. Station coordinates, velocities and covariances of the TRF solution were converted into SINEX format and submitted to the ITRF Section of IERS as a contribution to the ITRF2000 realization.

- **Processing of correlator output**
  The BKG group generated calibrated databases for most of the sessions correlated at the Bonn Astro/Geo Mark III/IV Correlator and subsequently submitted them to the IVS Data Centers for distribution.

- **IVS EOP time series**
  After the preprocessing of the individual VLBI sessions which includes inspection of the residuals and procedures for outlier elimination the databases and related files are uploaded to the incoming area of the BKG IVS Data Center and into the local data area.

  The final processing of individual VLBI sessions (IRIS-S, EUROPE, COHIG, NEOS, CORE) at BKG is the basis for producing two EOP time series regularly submitted to the IVS Data Centers:

  - bkg00001.eops generated from 2360 24h VLBI sessions between 1984 and 2000
  - bkgint01.eopi generated from UT1 intensive sessions between 1999 and 2000

Table 1. Mean formal errors for 24 h sessions

Component	1984-2000	1999-2000
σ_{xwob}	0.618 mas	0.223 mas
σ_{ywob}	0.641 mas	0.213 mas
σ_{ut1}	33.8 μs	13.6 μs
$\sigma_{d\psi}$	0.764 mas	0.212 mas
$\sigma_{d\epsilon}$	0.256 mas	0.085 mas

The corresponding values for the time span from 1999 to 2000 have improved by a factor of approximately three. The mean formal error for the intensive experiments between 1999 and 2000 is 22.0 μs. The features of the solutions are described in the respective technical descriptions which are available in the IVS Data Centers in the directory ivsdocuments.

3. Development of VLBI Data Analysis Technology

- One of the responsibilities of the GIUB analysis group is the preparation of correlator data for export in the form of Mark III data analysis system databases for the sessions correlated at the Bonn Astro/Geo correlator center. In most cases this task is straightforward but sometimes it requires some extra efforts. The main reason for additional interaction is radio frequency interference which may saturate individual channels causing some of the delay observables to be corrupted. In this case the fringe fitting process may select the wrong peak of the delay resolution function and produce an incorrect delay observable. However, this fact can only be detected when a least squares solution is computed with the program SOLVE. In a subsequent step the residuals of the SOLVE run can be used to narrow the search window in a repeated fringe fitting process. A semi-automatic procedure for this task is available at GIUB.
- Semi-automatic Web-presentation of data analysis results is being developed. Detailed reports of all VLBI data processed at the GIUB/BKG Analysis Center have been displayed on the Web between 1998 and the middle of 2000. This task will be resumed when additional man-power becomes available.
- Internal logic of the software SOLVE was updated in order to reduce overhead, to speed up data processing and to expand the capabilities of the analysis system.
- In order to make the analysis processes more effective the BKG group developed its own program environment around the CALC/SOLVE software automating the post interactive part for establishing the two EOP series mentioned above.

4. Research Topics

- **Determination of telescope displacements by local engineering work at Medicina**
  The Medicina telescope has been displaced slightly in 1996 due to track repairs. The local surveys before and after the displacements were analysed (NOTHNAGEL AND BINNENBRUCK 2000).
- **Footprint measurements at Ny Ålesund**
  In the framework of a footprint project local measurements were carried out at Ny Ålesund in order to determine the coordinates of the antenna's VLBI reference point relative to a local network of concrete pillars. Preliminary analysis of the measurements has occurred, and local eccentricities between the VLBI antenna and the IGS GPS antennas will be computed when the Norwegian Mapping Authority will have completed its GPS analysis.
- **Joint least squares adjustment of GPS and VLBI observations**
  At DGFI a combination of space geodetic measurements at the level of observables is being carried out. Special VLBI data preprocessing and solutions are performed at GIUB in support of this research.
- **Investigation of the feasibility of using phase delays in geodetic VLBI**
  An extended set of VLBI sessions has been re-analyzed for resolving phase delay ambiguities. Conditions when ambiguities can be resolved as well as differences between group delay and phase delay solutions were investigated.

- **Correlator comparison**
  In order to investigate in greater detail the MK III/MK IV correlator performance, a 4-station IRIS-S session has been correlated both at the old MK IIIa and at the new MK IV correlator. In fact, before the definitive closing down of the MK IIIa correlator, two complete and fully independent correlations of the same IRIS-S sessions were carried out to establish the noise floor of the old system. First results of the comparison have been published (MÜSKENS et al. 2000).

5. Personnel

Table 2. Personnel at GIUB/BKG Analysus Center

Klaus Börger	GIUB	until 11/2000
Gerald Engelhardt	BKG	
Axel Nothnagel	GIUB	
Leonid Petrov	GIUB	until 4/2000
Christoph Steinforth	GIUB	
Volkmar Thorandt	BKG	
Dieter Ullrich	BKG	

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GSFC VLBI Analysis Center

David Gordon, Chopo Ma, Leonid Petrov, Dan MacMillan

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during the period from March 1, 1999 through December 31, 2000. The center's primary software development, analysis and research activities are reported, and the responsible staff members are described. Plans for 2001 are also presented.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, MD. GSFC analyzes all geodetic and astrometric VLBI sessions and submits databases to IVS for all NASA/GSFC and USNO sessions within 24 hours or less of their correlation. The group's main thrust is the operation and analysis of the CORE experiments and the gradual expansion of CORE into a full time EOP monitoring program. The group processes all 24-hour sessions from the Mark 4 correlators and submits EOP values derived from each session within 24 hours of correlation. The group also analyzes NEOS Intensive experiments and submits the UT1 values within 2 hours of correlator release. Additionally, GSFC periodically submits station positions and velocities as well as source coordinates from global solutions using all available VLBI observations. The analysis group also processes all VLBA RDV sessions using the NRAO AIPS program.

GSFC uses, maintains, develops, and distributes the Calc/Solve analysis system. The group also engages in research and analysis activities aimed at improving the measurement and understanding of Earth rotation, improving VLBI analysis techniques and modeling, improving troposphere modeling, and maintaining and refining the celestial and terrestrial reference frames.

2. Activities

The primary software development activities from March 1, 1999 - Dec. 31, 2000 included:

- Program Calc was upgraded to versions 9.1 and 9.11 to add the permanent tide option and to fix a minor error.
- F-Solve development was moved from GIUB/BKG to GSFC in April 2000, and the two groups' Solve versions were consolidated.
- Extensive changes in programs Dbedit and Solve were made to support the processing of data from the new Mark 4 correlators.
- Developed an automated system for data transmission between correlators, the IVS Data Centers and the IVS Analysis Centers (programs dserver, dclient, geo_export and geo_import).
- Developed an automated system for generating EOP and submitting EOP series and databases to IVS (program opa).
- Began bimonthly Calc/Solve system updates, in the form of an easy-installation distribution kit. Considerably increased the Calc/Solve system documentation. Currently 44

Calc/Solve documents are available from http://gemini.gsfc.nasa.gov/solve. (An activity begun at GIUB/BKG and moved to GSFC in April 2000.)

- Developed software for analysis of phase calibration errors and for correction of spurious phase cal signals. (Begun at GIUB/BKG and moved to GSFC in April 2000.)

The primary analysis activities during the period included:

- ICRF-Ext.1, the first extension of the ICRF, was produced in mid 1999 to include additional data from July 1995 to April 1999. This solution added 59 new sources to the catalog and introduced small modeling improvements consistent with the stated uncertainties of the ICRF.
- Two solutions were generated as input to ITRF2000. The first submission, gsf1122, in the Spring of 2000 (CALC 8.2/S-Solve) included data through the end of 1999. Based on the discussions at the ITRF2000 workshop, a second solution, gsf2000b, was made at the end of 2000 (CALC 9.1/F-Solve) which incorporated additional Asian stations as well as data through October 2000.
- Began manual database submissions within 24 hours to IVS in June 1999. Upgraded to automated submissions in October 2000.
- Began manual EOP-S weekly IVS submissions (polar motion, UT1, and nutation) in September 1999. Upgraded in October 2000 to automated submissions within 24 hours of correlator release.
- Began NEOS-Intensive session analysis and automated EOP-I (UT1) series IVS submissions in November 2000.
- Analysis activities were shifted from Calc8.2/S-Solve analysis to Calc9.1/F-Solve analysis in June 2000.
- Assumed the initial analysis and data submission responsibilities for NEOS-A and NEOS-Intensive experiments from the USNO in December 2000.
- Submitting all old (1979-1998) databases to IVS, approximately two-thirds completed.

The primary research activities during the period included the following:

- Investigated the precision and accuracy of daily VLBI EOP estimates. Two EOP series derived from simultaneous CORE and NEOS sessions were compared with an IGS GPS series for the period 1997-2000. The level of bias between the VLBI networks is greater than expected and is most likely due to an error in the underlying TRF. Based on 3-corner hat comparisons between the two simultaneous VLBI series and the GPS series, the observed precision of polar motion (80-120 μas) from the three series is similar, although GPS is somewhat better. Several sources of unmodeled or mismodeled station position error that contribute to the EOP error are being examined, for example, tidal ocean loading, atmospheric pressure loading, and hydrology loading.
- Continued investigations using meteorological data assimilation models to improve VLBI tropospheric delay modeling. Use of a priori mean site gradients reduces systematic error in both the CRF and the TRF. Use of a priori 6-hour gradients yields some improvement in repeatabilities. Mapping functions based on raytracing of model profiles yield improvement in repeatabilities.

- Examined signatures in corresponding VLBI and GPS baseline length and site time series. An error budget summarizing the remaining unmodeled error was developed. Spectral analysis indicates that there are annual and semi-annual signatures in many of the VLBI and GPS series, but the VLBI and GPS signatures are only similar for some sites.
- Investigated the determination of high frequency tidal amplitudes from hourly EOP VLBI estimates. Collaborated with Markus Rothacher (Technical University of Munich) to compare VLBI and GPS tidal amplitudes and to determine tidal amplitudes from a combination of VLBI and GPS hourly series.
- Developing methods for the direct estimation of nutation expansion coefficients, precession parameters, and high frequency EOP amplitudes and phases in a single combined solution. Examined the differences between a combined solution versus a two-step approach, in which a nutation time series and the nutation expansion coefficients are estimated separately, neglecting their mutual correlations.
- Estimated Love numbers for long period tides from VLBI observations.
- Investigated the feasibility of an arc-length approach for the selection of primary and secondary sources.
- Made a correlator comparison study of Mark 3 versus VLBA/AIPS processing in the RDV11 experiment. Results indicated an error source on the VLBA/AIPS side. Preparing for a larger comparison of Mark 4 versus VLBA/AIPS in RDV22.
- Began collaboration with NRAO on astrometric analysis of the VLBA calibrator survey experiments.

3. Staff

The GSFC analysis group is part of a larger VLBI group of civil servant and contractor personnel, led by Dr. Thomas A. Clark, which also includes a Technology Development Center, three Network Stations, the CORE Operation Center, and the Coordinating Center. The analysis group is composed of the following six individuals who are involved full time, or nearly so, in analysis activities.

Dr. Chopo Ma leads the analysis group. His interests include astrometry, the celestial and terrestrial reference frames, extension and improvement of EOP measurement, and the improvement of analysis and modeling. He is a member of the IAU working group on the Celestial Reference System and heads the subgroup for the maintenance and extension of the ICRS. As such he has particular interest in improving the modeling and optimization of ICRF analysis as well as providing better information about source position variations. He is also one of the VLBI representatives on the IERS directing board, and is responsible for generating ITRF and ICRF products for IVS and IERS use and for improvement of consistency between them.

Dr. Dan MacMillan (NVI, Inc.) is involved in VLBI technique improvement and analysis system software development (Solve), particularly in the area of tropospheric delay modeling. His interests include improving the modeling of atmospheric delay gradients, deriving better mapping functions from meteorological assimilation data, and various TRF and CRF studies. He is also working on improving or adding modeling for atmospheric pressure loading, ocean loading, and hydrology loading. He is also studying differences in EOP derived from different simultaneous

VLBI networks and GPS EOP in order to assess the observed accuracy and precision of the VLBI and GPS estimates.

Dr. David Gordon (Raytheon ITSS) manages all initial data processing and analysis activities, performs the AIPS geodetic processing of VLBA experiments, and maintains and develops program Calc. His research interests include astrometry, global and regional tectonic motions, improving VLBI modeling, improving VLBA/AIPS processing, correlator support, correlator comparisons, and phase delay development.

Dr. Leonid Petrov (NVI, Inc.) moved from the GIUB/BKG analysis group to the GSFC analysis group in April 2000. He maintains and develops the Mark 4 VLBI analysis software Calc/Solve and the suite of programs for automated data transmission and processing. He conducts research in the fields of optimal estimation of EOP, estimation of Love numbers, improvements in the modeling of ocean loading, and investigation of instrumental errors in VLBI.

Ms. Karen Baver (Raytheon ITSS) maintains and develops a wide range of software, including the database and solution archive catalog systems, the SNOOP reporting programs, and various analysis graphics programs. She also supports the group's web page activities, assists in generating all types of TRF and CRF reports, generates site and velocity plots, assists in generating IVS publications, and provides assistance to new and current users of the analysis package.

Ms. Cindy Lonigro (Raytheon ITSS) works on initial experiment preparation and data archiving and provides analysis support, web page support, and miscellaneous support.

4. Outlook

Plans for 2001 include:

- Calc/Solve: Develop source structure correction capabilities. Add the Niell isobaric mapping function (IMF). Incorporate mapping functions derived by raytracing atmospheric profiles and compare with the Niell IMF mapping function. Test effects of hydrology loading series and three dimensional atmospheric pressure loading (from loading convolution method) series. Implement new schemes for estimating EOP. Update as necessary for compliance with IERS 2000 Conventions. Modify as necessary for HPUX11.0 on an HP9000/785 workstation.
- Collaborate on the development of a new database format.
- Make a comparison study of Mark 4/Fourfit versus VLBA/AIPS correlating/fringing in the RDV22 experiment. Also compare and study Mark 3 versus Mark 4, and K4 versus Mark 4 processing.
- Complete the astrometric analysis of the VLBA Calibrator survey experiments.

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Analysis and Research at the Haystack Observatory

Arthur Niell, Brian Corey

Abstract

New mapping functions that incorporate easily accessible *in situ* atmospheric information have been incorporated in the *solvk* analysis package at Haystack. For middle and high latitudes the mapping function contribution to the vertical error budget is significantly reduced.

A study has been initiated on how to utilize VLBI to better understand the antenna characteristics of the GPS satellites. A better model for the GPS satellite phase center will help resolve possible discrepancies between the VLBI and GPS terrestrial reference frame scales.

1. Geodetic Research at the Haystack Observatory

The primary objectives of analysis activities at Haystack Observatory are to improve the underlying models in order to obtain better accuracy and precision and to better understand the uncertainties that limit the space geodetic techniques. Since there are many similarities between VLBI and GPS, it is natural to investigate both common error sources and and those that are unique in order to obtain the best results from both techniques. This has led us to study the atmosphere model, which can be applied to either, and the characteristics of both satellite and receiver antennas of GPS.

Atmosphere models

Gridded global numerical weather models provide *in situ* meteorological information. The geopotential heights of an isobaric surface, for example the 200 hPa surface, serve as a useful parameter for the hydrostatic component of the mapping function [3]. The improvement relative to the widely used NMFh [2] is shown in Figure 1 for a mid-latitude site; the scatter of the mapping function at 5° is an indication of the error that will be introduced in the vertical. The improvement in modeling precision, interpreted as approximate vertical error as a function of latitude, is illustrated in Figure 2.

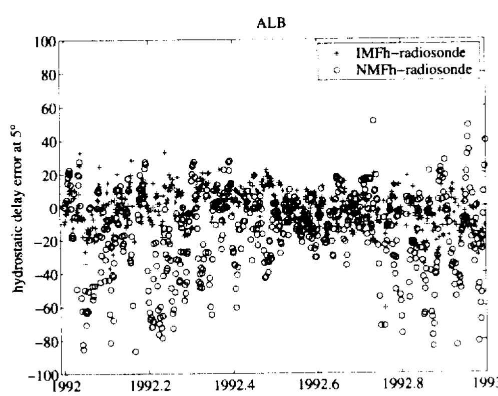

Figure 1. Temporal errors of hydrostatic mapping functions. The difference with respect to raytracing of radiosonde profiles for the IMF and NMF hydrostatic mapping functions at 5° elevation.

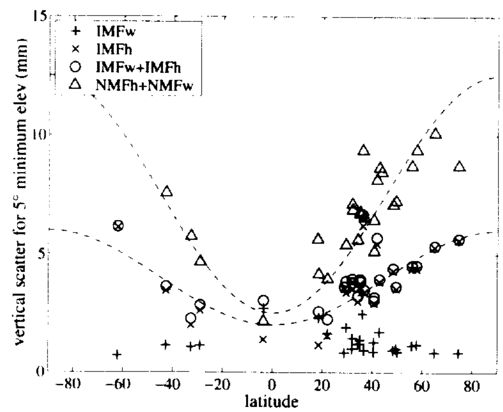

Figure 2. Vertical error induced by hydrostatic mapping functions. The approximate contribution of the hydrostatic and wet mapping functions to the vertical error for VLBI or GPS experiments with a minimum elevation of 5°. The dashed lines are of the form cos(2*latitude) and are intended only to guide the eye to the expected height uncertainties for the combined hydrostatic and wet mapping function errors for IMF and for NMF.

The relative value of the two hydrostatic mapping functions has been tested by comparison of the variation of the baseline lengths for the CONT94 VLBI data, assuming that they are constant over the short period of that campaign. The standard deviation of the lengths is slightly smaller using IMFh than using NMFh. No correction was made for atmospheric pressure loading, and, since this effect may have a comparable contribution to the scatter, this may account for the marginal improvement.

VLBI, GPS, and the Terrestrial Reference Frame

The direction-specific instrumental delay (phase center variation) of GPS ground antennas differs by antenna model. The Dorne-Margolin choke ring antenna has been assumed to be uniform, but measurement of the phase pattern in anechoic chambers and by a rapid cycling among satellites by a "robot" [4] suggest a large elevation-dependent error. For this error to be reasonable the GPS satellites must have a compensating phase error to avoid a large discrepancy between GPS and VLBI in the scale of the terrestrial reference frame. A joint working group composed of representatives from the IVS, IGS, and ILRS and chaired by Brian Corey has been studying the feasibility of using differential VLBI observations of GPS satellites and nearby extragalactic sources to measure the phase pattern of the transmitted L1/L2 GPS signals. The aim is both to measure the phase center locations of the GPS phased array transmitters and to "map" the relative magnitudes and phases of the drive voltages of the individual phased array elements. The required accuracy on the VLBI fringe phase is $< 10°$, or < 5 mm in differential range, after correction for propagation media effects, extragalactic source position uncertainty, etc.; this level of accuracy will likely be difficult to achieve.

2. Outlook

Both of these projects will continue. For the evaluation of the atmosphere models, *solvk* [1] will be updated with atmospheric pressure loading and with an improved ocean loading model. The amount of data will be extended to cover at least a full year in order to evaluate any annual components in the results.

Upon completion of the study to determine the feasibility of using VLBI to characterize the GPS satellite antennas, a decision willl be made on whether to proceed, and, if the project looks promising, funding will be sought.

References

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[3] Niell, A.E.: Improved atmospheric mapping functions for VLBI and GPS, Earth, Planets, and Space (accepted), 2001.

[4] Wubbena, G. Schmitz, M., Menge, F., Boder, V. and Seeber, G.: Automated Absolute Field Calibration of GPS Antennas in Real-Time, Proceedings of the ION Meeting 2000, Salt Lake City, Utah.

IAA VLBI Analysis Center Report for 2000

Zinovy Malkin, Elena Skurikhina, Maria Sokolskaya, George Krasinsky, Vadim Gubanov, Igor Surkis, Iraida Kozlova, Yuriy Rusinov

1. Introduction

The IAA Analysis Center (IAA AC) is located at the Institute of Applied Astronomy of the Russian Academy of Sciences. The main fields of the activity include EOP service, computation of station and radio source coordinates, geodynamical investigations, comparison and combination of EOP, TRF and CRF realizations, development and comparison of algorithms and software for processing VLBI observations. IAA AC works in close cooperation with IERS and IVS.

2. Staff

Three VLBI groups of IAA contribute to IAA AC activity:

1. Lab of Space Geodesy and Earth Rotation: Dr. Zinovy Malkin (head), Elena Skurikhina, Dr. Maria Sokolskaya. The main tasks of this group related to IVS activity are: management of the IAA EOP Service, determination of EOP, station and radio source coordinates, comparison and combination of VLBI, GPS, and SLR products. The group explores two program packages: OCCAM for EOP and TRF computation, and ERA for EOP and (mainly) CRF computation.

2. Lab of Ephemeris Astronomy: Prof. George Krasinsky (head). The main IVS related activity of this group is development of program package ERA for investigations in Earth sciences and dynamical astronomy based on processing VLBI observations including combining VLBI, SLR, LLR, and optical observations. In particular, determination of EOP from combination of VLBI and SLR observations is under development.

3. Lab of New Methods in Astrometry and Geodynamics: Prof. Vadim Gubanov (head), Igor Surkis, Iraida Kozlova, Yuriy Rusinov. The main task of this group related to IVS activity is determination of EOP, station and source coordinates using new package QUASAR with emphasis on investigation of stochastic parameters (EOP, troposphere, clocks).

3. Analysis Activities

3.1. EOP service

IAA EOP Service based on regular processing of SLR and VLBI observations has been operating since 1994. Regular processing of VLBI observations started in 1996. Both operative and yearly final EOP series are regularly contributed to both the IERS and the IVS. Accuracy of these series is presented in Table 1. Along with EOP, station coordinates for every 24h session are computed. In 2000 we started operative processing of the NEOS Intensives series.

In 2000 two EOP final solutions EOP(IAA)00R01 (1984–1999) obtained with OCCAM package and EOP(IAA)00R02 (1994–1999) obtained with ERA package have been submitted to the IERS 1999 Annual Report. For all solutions the model of reduction and the method of parameter estimation were practically analogous to those described in the IVS 1999 Annual Report.

Table 1. Accuracy of EOP series obtained with the OCCAM package for 1999–2000.

Series (program)	X_p, mas	Y_p, mas	$UT1$, 0.1 ms	$\Delta\psi \sin\varepsilon$, mas	$\Delta\varepsilon$, mas
IAAo9907 (NEOS-A+CORE)	0.19	0.15	0.09	0.13	0.15
IAAo9907 (NEOS-A)	0.14	0.14	0.07	0.12	0.14
IAAi0011 (NEOS-I)	—	—	0.22	—	—

3.2. Radio source coordinates

The computation of radio source catalogues from global processing VLBI observations using ERA package was continued in 2000. Two catalogs of 312 radio sources have been submitted to the IERS 1999 Annual Report. Moreover, the first version of software for comparison and combination of catalogs is advanced. The latest radio source catalog was transformed to the ICRF system and compared with ICRF-Ext.1. Result of comparison is presented in Figure 1.

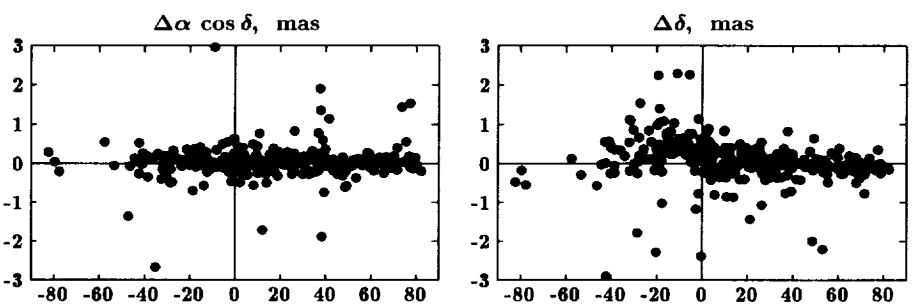

Figure 1. Differences of radio source coordinates RSC(IAA)–ICRF-Ext.1.

A special study was performed to investigate possible dependence of radio source coordinates on observational programs (NEOS-A – CORE-A).

3.3. Processing long time series VLBI observations

All available 24h VLBI sessions were processed to obtain session station coordinates and troposphere zenith delay time series. An example of wet troposphere delay time series is presented in Figure 2.

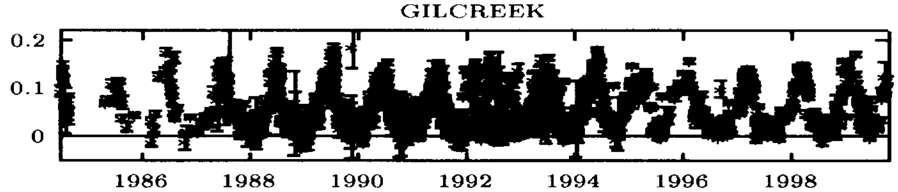

Figure 2. Time series of wet zenith troposphere delay for station Gilmore Creek.

A series of UT1 based for period 1984–2000 has been also obtained and submitted to the IVS.

3.4. Comparison and combination of EOP series

The basic software for comparison of EOP series is developed. This software allows us to compute and investigate systematic differences of EOP and TRF series and related statistics. It is in every-day use in the EOP service. Software for combining EOP series including those obtained from different observational techniques is also advanced.

In 2000 we performed intensive study of systematic differences between EOP series and CRF realizations obtained from NEOS-A and CORE programs with OCCAM and ERA packages. It was found, in particular, that EOP results substantially depend on software and CRF used for computation. The differences between EOP series contain significant systematic components. Table 2 presents some obtained results.

Table 2. Wrms of differences between EOP series obtained from different observational programs using two program packages and two radio source catalogues with EOP(IERS)C04 before/after removing linear trend.

Program / catalog / package	X_p, μas	Y_p, μas	UT1, 0.1 μs	$\Delta\psi$, μas	$\Delta\varepsilon$, μas
NEOS-A / IAA / ERA	323/271	287/246	170/105	570 /531	254/201
NEOS-A / WGRF / ERA	273/265	268/232	140/97	550 /521	206/192
NEOS-A / IAA / OCCAM	219/200	202/165	103/93	328 /306	142/133
NEOS-A / WGRF / OCCAM	219/201	202/165	103/93	328 /305	142/134
CORE-A / IAA / ERA	453/389	448/320	261/229	808 /619	325/252
CORE-A / WGRF / ERA	398/361	343/306	238/214	737 /630	241/228
CORE-A / IAA / OCCAM	213/194	247/170	114/107	467 /420	180/174
CORE-A / WGRF / OCCAM	204/194	219/173	124/114	489 /426	188/184
CORE-B / IAA / ERA	357/313	298/287	247/192	763 /725	268/203
CORE-B / WGRF / ERA	374/322	317/294	270/207	764 /729	240/226
CORE-B / IAA / OCCAM	273/207	250/218	158/140	545 /521	185/170
CORE-B / WGRF / OCCAM	273/208	258/225	159/141	550 /526	190/176

3.5. First results of program package QUASAR

The multi-functional package QUASAR is aimed at processing observations of global VLBI networks with the purpose of studying Earth rotation and improving coordinate systems accuracy. The package runs under Windows 9x. Main features of the package are:

1. Flexible parameterization.
2. Different methods of parameter estimation: multi-parameter least squares (MPLS) (realized); multi-group least squares (MGLS) (realized); moving least squares filter (MLSF) (planned); optimal Kalman filter (OKF) (realized); moving Kalman filter (MKF) (planned); least squares collocation (LSC) (realized).
3. Multi-window control system which allows the user to select and tune the reduction model, to correct or reject outliers, and organize input-output database control.

Package QUASAR was applied to processing NEOS-A observations for period 1997–1998. Data were processed using LSC techniques. The accuracy of EOP determination in comparison with

EOP(IERS)C04 series is presented in Table 3. Comparative analysis of EOP results obtained with different estimation techniques is underway.

Table 3. Accuracy of EOP series obtained with the QUASAR package for 1997–1998.

X_p, mas	Y_p, mas	$UT1$, 0.1 ms	$\Delta\psi \sin\varepsilon$, mas	$\Delta\varepsilon$, mas
0.16	0.17	0.09	0.14	0.20

NEOS Intensives observations for 1998–2000 were processed using MPLS, OKF and LSC techniques. The most accurate estimations were obtained by MPLS with use of stochastic regularization.

Twelve sessions carried out during CONT94 experiment were processed using LSC technique and estimates of intraday stochastic components were obtained as follows:

- wet component of zenith troposphere delay for all stations (for station Onsala result is in good agreement with independent WVR measurements); significant horizontal gradients of wet troposphere zenith delay were found for some stations.
- residual variations of PM and UT with reference to Ray's and Gipson's models that are consistent within ±0.1–0.3 mas.

The same observations were used for determination of global nominal and secular Love and Shida numbers. The following values were obtained: $h^{(0)}$=0.579±0.003, $l^{(0)}$=0.087±0.001, h_s=0.795±0.009, l_s=0.129±0.002. Secular numbers are related to total permanent tide in the reference frame ITRF'97. Moreover, nominal Love and Shida numbers were estimated from 12 daily sessions. These results show some instability of local number h that may be caused by insufficient modelling of vertical motion of Earth crust.

LSC technique has been also applied to processing observations of programs IRIS (1984–1992) and NEOS-A (1993–1999). Estimates of all stochastic parameters and their autocovariance functions were obtained. Significant instability of these functions was detected; therefore further LSC evaluation will be carried out by use of iteration process.

4. Outlook

We plan for the coming year:

- Regular computation of combined `eops` and `eopi` series and submission of results to the IVS Analysis Coordinator for further investigation.
- Development of algorithms and software for analysis, comparison and combination of radio source catalogs.
- Regular computation of session station coordinates in SINEX format.
- Comparison of weekly station coordinates and troposphere delay solutions obtained from VLBI and GPS.
- Beginning of regular submission of EOP computed from NEOS-A and NEOS-I sessions with QUASAR package.

Italy CNR Analysis Center Report

P. Tomasi

Abstract

This report summarises the work of the Italian CNR VLBI Analysis Center. It will give the fundamental information about the structure of the center, its locations, and its activity.

1. Introduction

The Italy CNR VLBI Analysis Center is the joint effort of two Institutes of Consiglio Nazionale delle Ricerche (CNR) to improve the quality of the geodetic VLBI results, in particular in the European area. The two institutes are:

a) the Istituto di Radioastronomia (Institute of Radio Astronomy, IRA) located in Bologna, where the main research activity is carried out, both in radioastronomy and geodesy;

b) the Istituto di Tecnologia Informatica Spaziale (Institute of Informatica and Technology for Space, ITIS), located in Matera at the Center of Spatial Geodesy (of the Italian Space Agency), where VLBI antenna, laser ranging telescope, permanent GPS receiver and PRARE antenna are located. Also a different analysis center is located here. All these structures are properties of the Italian Space Agency and run by Telespazio.

However the two institutes mentioned above will become quite shortly a single institute, the "Istituto di Radioastronomia", with a section located in Matera. The new CNR's institute will carry on the same commitment to IVS as the previous two intitutes.

The IRA have started to analyze VLBI geodetic database from 1989, using CALC/SOLVE package at the HP1000 at the Medicina station. In the following years that software was installed on an HP360 workstation and later on on an HP715/50 workstation. We have analyzed here mostly databases with some European baselines, generally at least three. Most of the databases have been reprocessed here in Bologna (using CALC and SOLVE). We are now using CALC9.1 and the November 2000 version of f-solve, for data analysis. We will soon move to the updated version of f-solve (February 2001).

From 1997 also ITIS have installed the CALC/SOLVE software and after some tests we have specialized the Bologna section to analyze single databases, in order to produce the final database. The global solutions have been computed in Matera at the ITIS. In Matera we are also using f-solve but with a previous version with respect to the one installed in Bologna.

2. Data Analysis and Results

In Bologna the main computer is HP715/80; the computer name is boira6.ira.bo.cnr.it. On it we are now analysing single experiments (interactive solve); the global solutions are run mostly on Matera computer.

We are continuing to work on the possibility of using tropospheric zenith path delay from GPS in order to improve the repeatability of the VLBI geodetic results. We have inserted the wet zenith path delay in the VLBI database as if this information was derived using a water vapour radiometer. The tropospheric data have been collected at the Berna site of the IGS. However the IGS data, with an hour interval, are the total tropospheric delay. For that we have subtracted the dry delay, from the VLBI data, in order to produce the "wet" zenith delay. These data have been inserted into the VLBI database using an updated version of DBCAL. In this new version the Niell mapping function was implemented and also some other errors present in the program have been corrected.

In Matera the main computer is an HP282 computer with internet name hp-j.itis.mt.cnr.it. Also here we have installed f-solve (the center name is ITISCNR) and we are using it mostly for global solutions in order to compute the positions and velocities of European stations.

The use of GPS tropospheric zenith path delay have produced some interesting results. On the European database of 1998, the use of the new way of analysing VLBI data seems to produce a better repeatability on the European baseline length (Rioja at al. 2000).

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Vienna IGG Special Analysis Center Annual Report 2000

Harald Schuh, Johannes Böhm, Thomas Hobiger

Abstract

A short overview about the Institute of Geodesy and Geophysics (IGG) at the Vienna University of Technology is given and its activities as IVS Special Analysis Center are described. Topics currently worked on and future plans are described.

1. Introduction

The Institute of Geodesy and Geophysics (IGG) at the University of Technology in Vienna, Austria, was officially appointed as an IVS Special Analysis Center on December 4, 2000. Already since 1999 the VLBI group at IGG has worked on the modification of the VLBI software package OCCAM and on investigations concerning the modeling of tropospheric path delays.

2. Staff at IGG associated with the IVS Special Analysis Center

Personnel at IGG associated with the IVS Special Analysis Center in Vienna are Harald Schuh (Head of the Department of Advanced Geodesy) and the research assistants Johannes Böhm (allocation 100%) and Thomas Hobiger (50%).

3. Special Analyses at IGG

- Modification of the VLBI software package OCCAM
  Together with Oleg Titov (Astronomical Institute of St. Petersburg University) and Volker Tesmer (Deutsches Geodätisches Forschungsinstitut DGFI, Munich) a group was set up in summer 2000 to test, develop and further enhance the OCCAM software. At IGG, we extended the classical least-squares approach of the Gauss-Markov model in OCCAM by allowing the estimation of piecewise linear functions for the clocks, the zenith path delays and horizontal tropospheric gradients (Böhm et al., 2000).
- Modeling of tropospheric refraction
  Based on the classical least-squares estimation procedure we compared tropospheric gradients determined by GPS and VLBI. Different software packages for the two techniques were applied (OCCAM and SOLVE for VLBI, BERNESE and GIPSY for GPS). Moreover several constraints were used for the piecewise linear functions to check their impact on the estimation of gradients. The results are described in Böhm et al. (2000) and Böhm et al. (2001) and one example of good agreement between gradients derived by GIPSY and OCCAM is shown in Figure 1.

4. Outlook

During the year 2001 the plans of the IVS Special Analysis Center at IGG include:

- Further development of OCCAM, e.g. the implementation of a free network solution and its datum definition.

- Contributions to the IVS working group on geophysical models.
- Research on new tropospheric models which correspond to the traditional usage of mapping functions and gradients.
- Comparisons of tropospheric parameters derived by VLBI, GPS and WVR data based on NEOS-A, IRIS-S and EUROPE sessions.
- Contributions to special IVS projects, e.g. the pilot project 2000 by delivering EOP estimates for 1999.

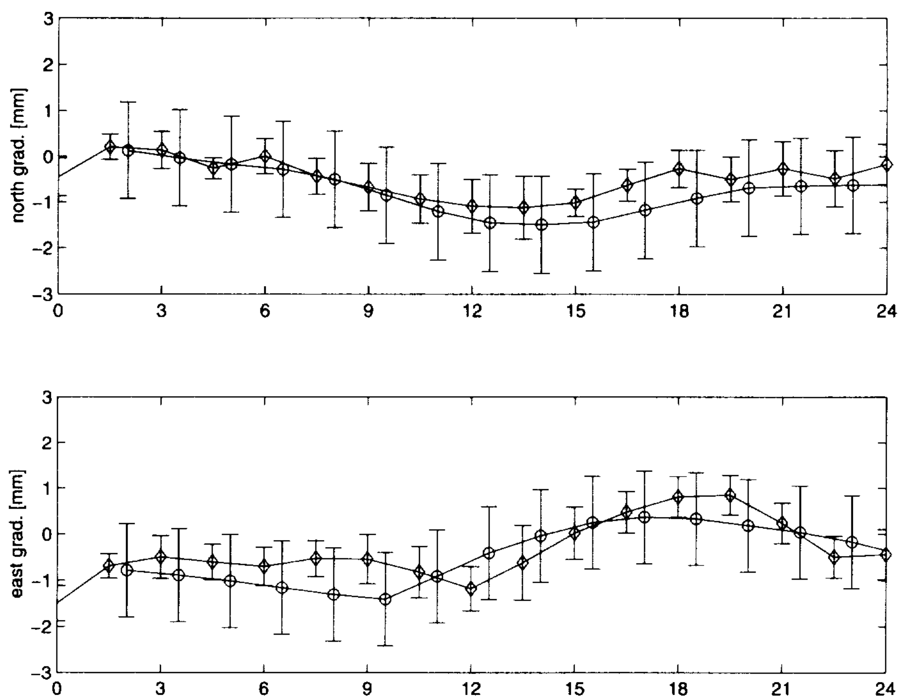

Figure 1. North and east gradients at Wettzell station for the VLBI session IRIS-S 136 on 15 March 1999 and simultaneous GPS measurements. For the estimation of tropospheric parameters a 3 hours' time interval was chosen and the constraints for the gradients were set to 0.6 mm/sqrt(h). Diamonds are used as markers for GPS (GIPSY), circles for VLBI (OCCAM). Acknowledgement: Ruediger Haas from Onsala Space Observatory, Chalmers University of Technology, Sweden, provided the gradients obtained by GIPSY for this comparison.

5. References

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Paris Observatory Analysis Center OPAR: Report on Activities, March 1999 - December 2000

A.-M. Gontier, M. Feissel, N. Essaïfi, D. Jean-Alexis, K. Le Bail

Abstract

The OPAR Analysis Center activities over March 1999 - December 2000 focused on analyses of the time stability of the celestial reference frame. The routine analysis of the intensive and 24-hour sessions was continued. The team was not changed, except for the help of one student (six months in 2000).

1. Activities

1.1. Stability of ICRF

The capability of the VLBI geodetic and astrometric programs to maintain stable directions in space was evaluated [1] on the basis of time series of session-per-session source coordinates computed at USNO using the CALC-SOLVE software [2].

The systematic and random characteristics of several hundreds of source apparent motions were investigated in order to derive a set of qualifiers that would be helpful in selecting sources to maintain a precise and stable celestial reference frame. We developed a selection process based on the density of observations over 1987-1999 and on the time stability of averaged yearly coordinates. The stability considered is that along the maximum variability direction in a source-fixed frame. 242 sources were thus selected. The rotation angles of the corresponding differential celestial reference frames are shown on Figure 1.

The results of this selection process are compared to the current ICRF qualifiers [3], i.e. "defining", "candidate" and "other" sources, and structure index, is shown in Table 1. The following comments can be made.

1. ICRF categories. The stability test keeps practically all "defining" and "candidate" sources that were preselected on the basis of their observational history, and most of the "others". When considering the complete ICRF-Ext.1, one can note first that only 1/3 of the "candidate" sources were selected on the basis of long and dense observational history. In fact we know that a number of "candidate" sources are considered so because their time span of observation is still too short. We also know that a number of sources were qualified as "other" although they had a dense observational history, explaining the selection of 3/4 of them. The selection rate of the "defining" sources is between the other two (1/2). Already at this first level, the first part of our selection scheme (based on the observational history of the source) provides a pre-qualification of sources which is quite different from the current ICRF one. Once this first selection is performed, the second one, based on the internal consistency of the time series of coordinates in the direction of the maximum variability, keeps nearly all "defining" and "candidate" sources, thus confirming their current ICRF status. Meanwhile, 7/10 of the "other" sources are still kept. This seems to indicate that using time series information might bring in more sources that would contribute to stabilize the celestial reference frame.

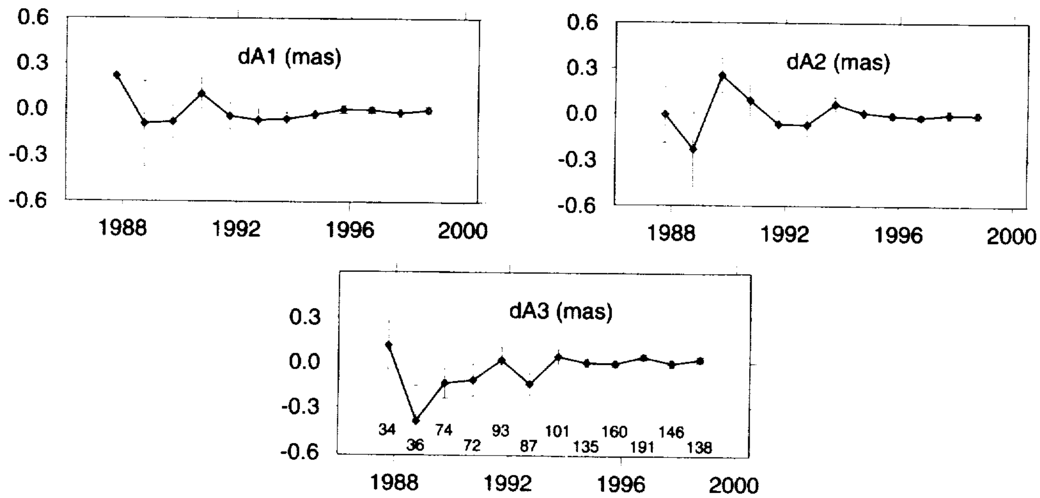

Figure 1. Rotation angles of 12 yearly differential CRFs relative to a mean one, using 242 sources selected on the basis of dense observational history and time stability over 1987-1999. The numbers of sources whose coordinates were available in a given year are listed (dA3 graph). The double horizontal line corresponds to the stated uncertainty of the ICRF axes directions (± 20 μas).

Table 1. Match of the source selection with the ICRF source qualifiers. The sources are first selected on the basis of a dense observation history, then a percentage of them is recognized as stable.

	Number presel.	% stable	All sources	% stable		Number presel.	% stable
1. ICRF categories					2. Structure index		
Defining	108	95%	212	49%	1	49	86%
Candidates	98	88%	294	29%	2	87	80%
Other	73	67%	102	48%	3	63	87%
					4	26	85%

2. The structure index for each source [4] qualifies the level of position disturbance expected from the irregularity of the source emission structure (1 for the less disturbed, 4 for the most disturbed). The lack of correlation between this index and our stability criterion suggests that, for the data set used in this study, the observational and analysis errors due to other factors tend to dominate the source structure effect.

This study also highlights the usefulness of considering the time evolution of radiosource directions, not only for internal purposes such as the ICRF quality control or applications like differential VLBI, but also to enhance the support of VLBI to scientific research, as in the understanding of the physical properties of the non-rigid Earth through analysis of precession and nutation observations, or for realistic studies of source structure or microlensing effects.

In another study [5], using a set of 16 well observed radio sources (north of +20 degrees), it was shown that reliable information can be obtained on the local motions in the sources since the end of the 1980's, with a 0.5-year time resolution. The analysis showed that the variability of these objects have varied spectral characteristics, that could possibly be related to diverse physical processes taking place in the sources.

1.2. OPAR time series of source coordinates

Computation of time series of source coordinates referred to the ICRF was initiated. Preliminary results were obtained for 52 sources over 1999. Figure 2 shows the average coordinates of 37 of them, for which the 1998 coordinates could also be derived from the USNO [2] series. The weighted standard deviations of the yearly position differences between the USNO and OPAR analyses are 0.13 mas in R.A.cos(Dec) and 0.18 mas in Declination.

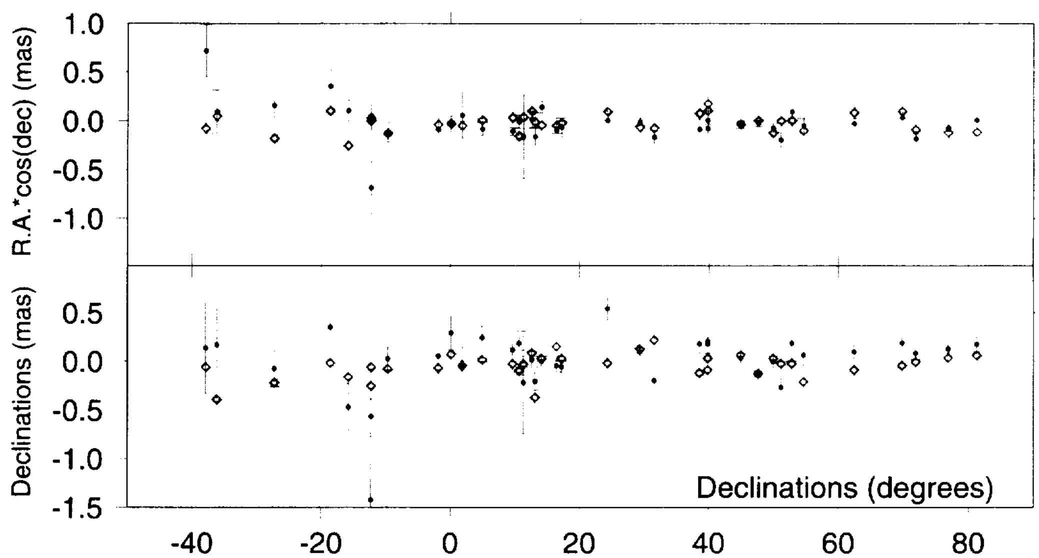

Figure 2. Average coordinates for 37 common sources: USNO 1998 (brown/light) and OPAR 1999 (blue/heavy)

1.3. Operational analyses

The analysis of the intensive one-baseline sessions was continued and that of the 24-hour sessions was initiated. Results were provided to IERS and IVS. The results obtained are illustrated in Figure 3. The standard deviation of the differences of the OPAR solutions with the IERS series C04 over 1999 is ±20 μs on UT1-UTC for the intensive sessions; for the 24-hour sessions: ±0.28 mas on polar motion, ±12 μs on UT1-UTC and ±0.22 mas on celestial pole offsets.

2. Prospects

Our plan is to continue developing reference frame studies and applications. Most of these studies will contribute to the work of the IERS ICRS Product Center, with which the OPAR IVS

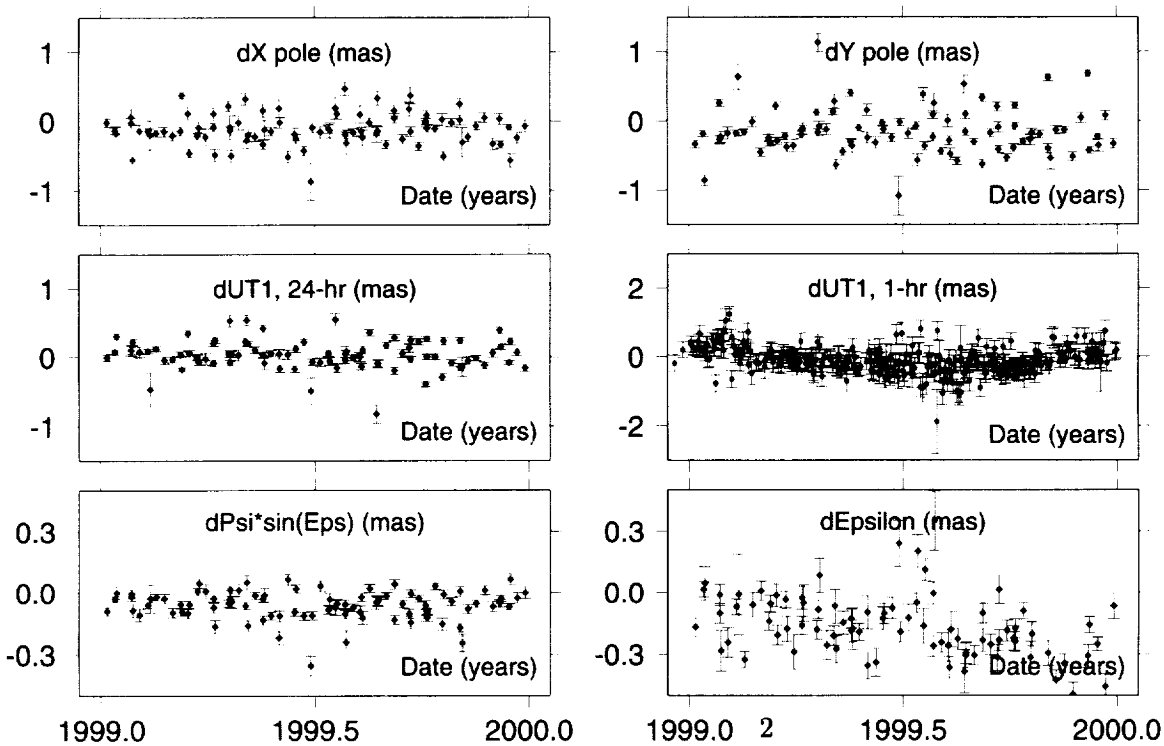

Figure 3. OPAR EOP results in 1999. Difference with EOP(IERS) C04.

Analysis center is closely associated.

1. Time series of source coordinates referred to the ICRF. These time series can be used in several research and operational applications, e.g. the astrophysical interpretation of observed apparent motions, the accurate use of the sources in differential VLBI, the scheduling of IVS observing sessions, the optimization of future revisions of ICRF. The time series will be available on the ICRS-PC website (http://hpiers.obspm.fr/icrs-pc).
2. Global celestial reference frame analyses.
3. Time series of terrestrial reference frames.

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The IVS Special Analysis Center at the Onsala Space Observatory

Rüdiger Haas, Hans-Georg Scherneck, Gunnar Elgered, Jan M. Johansson, Lubomir P. Gradinarsky, Boris Stoew, and Sten Bergstrand

Abstract

We give a short overview on the activities of the IVS Special Analysis Center at the Onsala Space Observatory. Current topics of analysis and research are ocean tide and atmospheric loading, crustal deformation in Europe, atmospheric radio wave propagation, thermal deformation of VLBI radio telescopes, combining and integrating VLBI and GPS and earth rotation. Future plans are briefly described.

1. Introduction

The IVS Special Analysis Center at the Onsala Space Observatory (OSO) concentrates on a number of particular problems which can be investigated using and developing VLBI databases and analysis programs, and providing ancillary parameters. No routine analysis of global VLBI data in a service sense is performed or planned at OSO for the next few years.

2. Ocean Tide Loading

The studies performed at OSO cover theoretical modelling and empirical determination of ocean tide loading effects. New ocean tide loading coefficients based on recent ocean tide models have been calculated and made available for a global set of VLBI stations [1]. The ocean loading web site http://www.oso.chalmers.se/~hgs/README.html includes loading parameters computed on the basis of the recent GOT99.2 tide model [2].

A case study for the IVS station Westford showed that the refinement of the tidal modelling at the continental shelves leads to an improved agreement between modelled ocean tide loading and three-dimensional ocean tide loading effects derived from the analysis of VLBI data [1].

3. Atmospheric Loading

A data base with time series of atmospheric loading predictions based on global pressure fields has been generated for most of the VLBI databases since 1990 [1] and is available from our http server http://www.oso.chalmers.se/~hgs/apload/apload.html.

4. Crustal Deformation in Europe

The pure geodetic European VLBI experiments observed since 1990 have been analysed applying the two-step analysis strategy described in [3]. Crustal motion results and the corresponding large-scale strain-rate field in Europe have been determined [4].

5. Atmospheric Radio Wave Propagation

Atmospheric studies have been performed using the collocated techniques VLBI, GPS and microwave radiometry at Onsala [5]. Simultaneous observations with these three techniques during 1993 to 1998 showed correlation coefficients for the zenith wet delay between 0.74 and 0.87 and for the horizontal delay gradients between 0.27 and 0.51 [6]. Equivalent zenith wet delay values derived from VLBI and GPS have also been compared to values from Numerical Weather Prediction (NWP) models [7]. The agreement is promising with correlations at the level of 0.8.

6. Thermal Deformation of VLBI Radio Telescopes

The simple model describing the deformation of radio telescopes due to thermal influences [8] has been used to model the effects and to compare them to the vertical height changes measured at Onsala and Wettzell with the respective invar measurement devices (see Fig. 1).

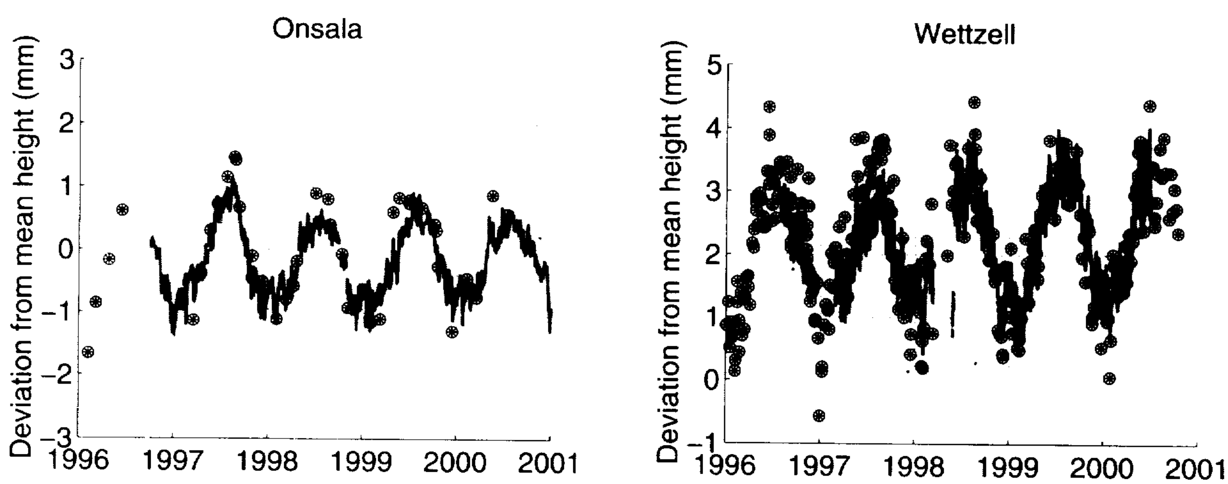

Figure 1. Vertical height changes of the VLBI radio telescopes at Onsala and Wettzell: solid lines - measured by the invar rod measuring systems; stars in circles - modelled with a simple model based on daily mean temperature from the VLBI data base, thermal expansion coefficient, and the telescope dimensions.

7. Combining and Integrating VLBI and GPS

Since each space geodetic technique has specific advantages and disadvantages, the combined and integrated use of several space geodetic techniques seems to be a useful approach. This is especially true for investigations concerning the crustal strain-rate fields and for the determination of absolute sea level changes. Therefore we started first investigations to combine and integrate VLBI and GPS in Europe [9]. The continuously growing data set of daily GPS solutions since 1993 available at OSO and in particular the GPS data from the BIFROST project [10] offer an excellent basis to continue these investigations.

8. Earth Rotation

The IVS Special Analysis Center at the Onsala Space Observatory participated in the First IVS Analysis Pilot Project and submitted an earth orientation parameter (EOP) solution obtained from the 52 NEOS-A sessions in 1999 (see Fig. 2).

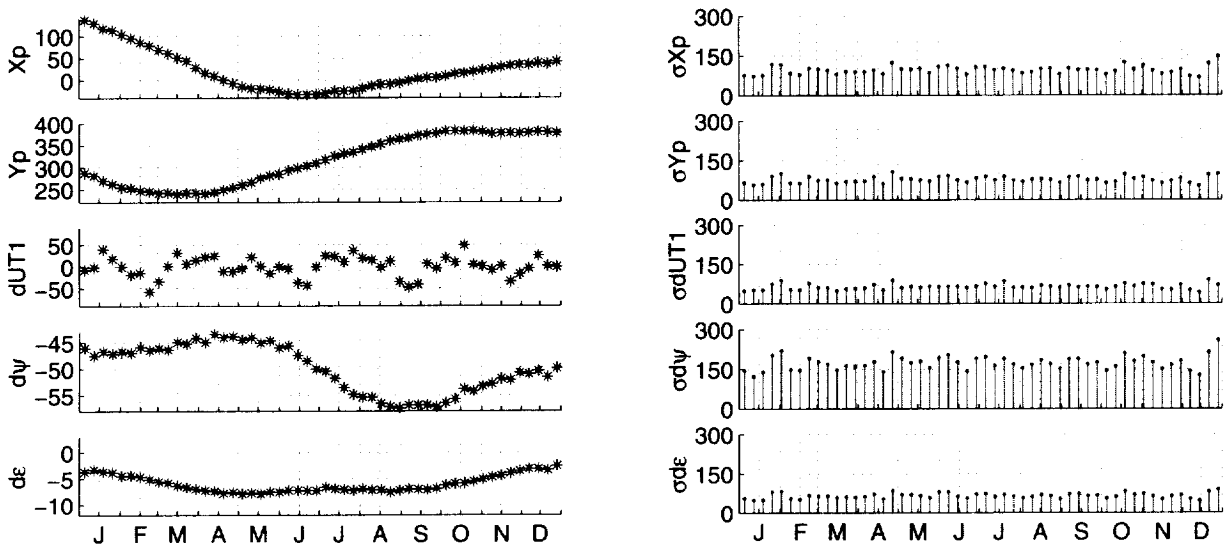

Figure 2. OSO's submission of earth orientation parameters derived from the 52 NEOS-A experiments in 1999 for the First IVS Analysis Pilot Project. The left column shows the earth orientation parameters in milliarcseconds, the right column shows the respective standard deviations in microarcseconds. For UT1-UTC (dUT1) an offset, a drift, an annual and a semi-annual term are subtracted.

9. Outlook

The IVS Special Analysis Center at the Onsala Space Observatory will continue to work on crustal loading and deformation effects. Special focus will be ocean tide loading and atmospheric loading but we will also work in the field of solid Earth tides. Parameter estimation and the covariances with EOP determinations will be of main interest. Eventually we will also contribute to IVS by submitting EOP solutions.

We will continue to analyze the European VLBI data with the aim to derive the most robust and reliable results for crustal motion and strain-rates. Our investigations will include also combination strategies with other space geodetic techniques like GPS, especially to achieve a more detailed view on the strain-rate field in Europe and to investigate changes in absolute sea level. We will also work on the geophysical interpretation of the results.

Our research concerning atmospheric properties will continue and we will use especially the collocated space geodetic and remote sensing techniques available at the Onsala Space Observatory. The investigations will reach from small scale structures in the atmosphere that can be detected with the new microwave radiometer [11] to climatological studies.

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Analysis Center Report from Shanghai Astronomical Observatory for 1999.03—2000.12

Jinling Li, Guangli Wang

Abstract

Here we summarize the activities of the astrometric and geodetic VLBI group of Shanghai Astronomical Observatory during the period from March 1999 to the end of 2000. Our activities are involved in the coordination of the VLBI observations for Asia-Pacific Space Geodynamics (APSG) program and several Chinese national geodetic projects, the data archives and reduction, the astrometric and geodetic application studies of VLBI. We also describe our plans for the year 2001 and finally show our thanks to all IVS colleagues and others giving us help.

1. Observation Coordination

Outstanding characteristics such as high precision repeatability for long baseline length measurements and providing high precision observations in the quasi-inertial deep space background, make VLBI one of the key supporting techniques of the Asia-Pacific Space Geodynamics (APSG) program and several Chinese national geodetic projects, for instance, the Chinese Observation Network of Crustal Movement, the Mechanism and Prediction of Continental Intensive Earthquakes. In January and October of 2000, our group organized in total four 24-hour Chinese national VLBI experiments. The antennas are one fixed at Sheshan and one 3-m mobile at Kumning. In November of 1999 two international VLBI sessions were coordinated and in October of 2000 one session. All are for the APSG program. The stations are Sheshan and Urumqi of China, Gilcreek and Kokee of USA, Kashima of Japan and Hobart of Australia. These observations are important to the studies of contemporary crustal motions within the China mainland as well as in the Asia-Pacific region.

2. Data Archives and Reduction

The original HP C180 workstation was updated by extending the memory capacity to 260 Mb and the hard disk to 54 Gb. The originally installed CALC8.2 was replaced by CALC9.1. The observations were archived in personal computer disk, which is cheaper, faster and more convenient than originally used 4-mm tape and its tape driver.

As a milestone in our group's history of data reduction, Mark III VLBI observations between August 1979 and December 1998 were successfully analyzed in 1999. It was the first time for our group to perform a full time span global VLBI data reduction. We compared our solution with ITRF96, RSC (WGRF) 95 R01 and EOP (IERS) 97 C04. The three orientation angles for the Celestial Reference Frame are not significant at the level of precision of $0.1mas$. Though no significant values are found for the three deformation parameters, coordinate drifts up to $0.5mas$ are identifiable for some sources in the southern hemisphere. The relative rotation angles and their rates of change for the Terrestrial Reference Frame are not significant respectively at the precision level of $0.2mas$ and $0.1mas/yr$. Detailed comparisons however show that the differences in the velocity field are obvious for the eastern part of Eurasian plate and Australian plate. About Earth

Orientation Parameter series, the systematic differences and the relative drifts are not significant respectively at the level of $0.4mas$ and $0.1mas/yr$.

In the year 2000, our global VLBI solution was adopted as one of the three input solutions of the latest version International Terrestrial Reference Frame (ITRF2000), which is really encouragement to the whole group and also to the supervisors of our work unit.

3. Application Studies

3.1. Temporary crustal movement

Based on our global VLBI solution, we analyzed the motion of Sheshan VLBI station using two different methods. One is based on the prediction of plate motion model. The other is based on the absolute angular velocity of plate. In the first method, the VLBI measurement of Eurasia plate motion was compared with the prediction of the plate motion model NNR-Nuvel1a by the following equation,

$$\begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix}_{NNR-NUVEL1A} - \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix}_{VLBI} = \begin{pmatrix} T_1 \\ T_2 \\ T_3 \end{pmatrix} + \begin{pmatrix} D & R_3 & -R_2 \\ -R_3 & D & R_1 \\ R_2 & -R_1 & D \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{VLBI} \quad (1)$$

where D, $T_{1,2,3}$ and $R_{1,2,3}$ are respectively the scaling factor, the translation and rotation parameters between the measurement and prediction. These parameters are solved for by a least-squares adjustment in a re-processing procedure. Only stations with post-fit residuals in horizontal velocity less than the analysis formal error (1σ) were finally used to contribute to the solution. Then after the removal of the effects of systematic transformation parameters and the prediction of plate motion model from the VLBI measurement, the motion of Sheshan station relative to the stable part of Eurasia plate is found to be 8.4 ± 0.4mm/yr in the direction N$122.4 \pm 2.8°$E.

In the second method, the absolute angular velocity of Eurasia plate, $\vec{\Omega}(\Omega_x, \Omega_y, \Omega_z)$, was solved for from the following equation,

$$\vec{v}(v_x, v_y, v_z) = \vec{\Omega} \times \vec{r} \quad (2)$$

where $\vec{v}$ and $\vec{r}$ are the geocentric velocity and position of a station from VLBI measurement. Again, only stations with post-fit residuals in horizontal velocities less than the analysis formal error were used to solve for the absolute angular velocity. The motion of Sheshan station relative to the Eurasia plate was found in this way to be 7.4 ± 0.3mm/yr in the direction N$117.4 \pm 2.0°$E. By comparing this with that from the first method, the difference between them is obvious. However, if we neglect the effect of the scaling factor and the translation parameters in $Eq.(1)$, the motion will be 7.3 ± 0.4mm/yr in the direction N$113.5 \pm 3.0°$E, which becomes consistent with that from the second method within the error budgets. Since D, T and R are independent parameters from each other and modeling possible real systematic effects, the motion determined from the first method should be more reliable than from the second one.

In Table 1 some results about the motion of Sheshan station relative to the Eurasia plate determined by various authors are shown for comparison. From this one can only say that the motion is eastward about 1 cm/yr. An efficient way to improve the precision of this determination would be to improve the temporal coverage of data rather than solely the accumulation of observations.

Table 1. The motion of Sheshan station relative to Eurasia plate

Author	Technique	Rate mm/yr	Azimuth N°E
Heki, 1996	VLBI	11.1±1.2	112.1±6.2
Molnar & Gipson, 1996	VLBI	8.0±0.5	116.5±4.1
Zhu Wenyao et al., 1997	GPS	11.2	75.7
Zhu Wenyao et al., 1999	GPS	10.8	87.3
Yu & Kuo, 1999	GPS	11.2±1.0	112.3±6.4
This paper (based on absolutely angular motion)	VLBI	7.4±0.3	117.4±2.0
This paper (based on plate motion model)	VLBI	8.4±0.4	122.4±2.8

The relative motion between Eurasia and North America was also analyzed based on our global VLBI solution. In Table 2 several determinations are listed for comparison. Various authors provided generally consistent results. The rotational velocity is about $0.2°/Myr$ with a slightly faster rotation for the modern space technique determination compared with the past millions of years' geophysical records. The positions of the rotational pole and the azimuths of major semiaxis given by various authors are obviously different from each other, so again the coverage and amount of observations must be improved.

Table 2. Angular motion between Eurasia and North America plates

Author	Technique	Angular velocity: Latitude °N	Longitude °E	ω °/Myr	Pole error ellipse: σ_{max} °	σ_{min} °	A N°E
DeMets et al., 1994	NUVEL1A	62.4	135.8	0.21 ±0.01	4.1	1.3	−11
Cook et al., 1986	Earthquake	71.2	132.0				
Argus & Heflin, 1995	GPS	78.5	122.0	0.23 ±0.03	4.1	2.4	−8
Larson et al., 1997	GPS	68.1	126.6	0.24 ±0.02	3.2	2.0	−30
Kogan et al, 2000	GPS	74.3	123.0	0.231±0.008	1.8	1.4	16
This paper	VLBI	74.34	137.98	0.242±0.007	3.5	2.1	−9

ω: rotational velocity.
σ_{max}, σ_{min}: major and minor semiaxes of the 1σ error ellipse.
A: azimuth of major semiaxis reckoned clockwise from north.

3.2. Polar motion

In a spectrum and wavelet analysis of the VLBI determined polar motion series for the time span from August 1979 to December 1998, it is shown that (1) during the VLBI data span the Markowitz wobble does not appear, (2) the amplitudes of both annual and Chandler wobble show temporal variations, with the former being more obvious than the latter within the observation period, (3) all the signals in polar motion series are characterized by temporal variation in amplitudes, which means that it is almost impossible to separate signals by a least-squares fit and (4) by applying a low-pass filter the secular polar motion is found to be 2.74±0.01 mas/yr towards 83.9±0.3 °W longitude, which is smaller in rate and more westward in direction compared with those determined from optical observations (Li & Wang, 2000).

3.3. Optical astrometry

Image restoration has been shown to be a very useful tool for many kinds of research, such as in the reduction of Hubble Space Telescope images, gamma ray data and in monitoring the gravitational lenses of AGNs. Members of our group used image restoration to remove the influence of tracking error in astrometric CCD images. As shown in Fig.1, (a) is the two-dimensional Gaussian distribution of an ideal image, (b) is the image of the standard star degraded by tracking error in a CCD frame, (c) shows the blended images of two nearby stars and (d) shows that after the image restoration the two nearby stars are well separated. By applying image restoration, the precision of the center of star image can be improved, the images of nearby stars too (Tang et al., 2001). The optical counterparts of 23 extragalactic radio sources, of which 13 are in the southern hemisphere, are observed with CCD. The positions have been determined with mean standard errors in right ascension and declination better than 0.2 arcsec (Tang et al., 2000).

4. Plans for the Year 2001

Most important, try our best to provide analysis products to IVS data center quarterly. Continuously coordinate VLBI experiments for Chinese national geodetic projects and for the APSG program. Make some analysis of the effects of various constraints on the global solution. Precisely determine the positions of the optical counterparts of two dozen extragalactic radio sources. Improve our ability in VLBI data reduction and application studies.

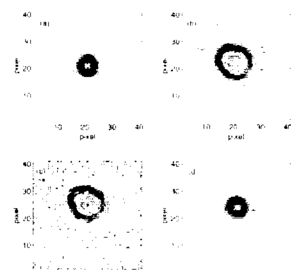

Figure 1. Separating nearby images degraded by tracking error with image restoration.

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USNO Analysis Center for Source Structure Report

Alan L. Fey, David A. Boboltz, Ralph A. Gaume, Kerry A. Kingham

Abstract

This report summarizes the activities of the United States Naval Observatory Analysis Center for Source Structure from its inception in January 2000 to the end of the calendar year 2000. The report forecasts activities planned for the year 2001.

1. Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO).

The main mission of the Analysis Center is to analyze VLBI data to extract intrinsic source structure information for use in maintaining the International Celestial Reference Frame (ICRF). Source structure information is provided in the form of synthesis images and source models suitable for evaluating sources for astrometric and/or geodetic use and for long term monitoring of sources. Research into the effects of source structure on astrometric position determination is also carried out with emphasis on improving the long-term stability of the ICRF.

The web server for the Analysis Center is provided by the USNO. The temporary address is:

`http://www.usno.navy.mil/RRFID/`

The Radio Reference Frame Image Database (RRFID) web site holds information on the radio frequency intrinsic structure of most ICRF sources with declination greater than −30 degrees. Both the raw data and processed images (with their associated source models) can be obtained from this site. Links to the astrometric suitability of the sources, as derived by Fey & Charlot (2000, Astrophysical Journal Supplement Series, Vol. 128, pp. 17–83 and references therein), are also provided. A new web site devoted exclusively to the Analysis Center for Source Structure is planned.

2. Initial Activities

In December 1999, the USNO proposed to become an IVS Analysis Center. The USNO Analysis Center for Source Structure was accepted by the IVS as a Special Associate Analysis Center in January 2000.

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 USNO has, since mid–1996, hosted the Radio Reference Frame Image Database (RRFID), a web accessible database of radio frequency images of most ICRF sources with declination greater than −30 degrees. Images are available at both S–band (13 cm) and X–band (3.6 cm), the standard frequencies used for VLBI astrometric and geodetic observations. Observations are taken from both the geodetic/astrometric database and from RDV observations. The RDV experiments are a joint collaboration between the USNO, Goddard Space Flight Center and the National Radio

Astronomy Observatory (NRAO). During each 24 hour RDV session, about 70 ICRF sources are observed at S/X band using the NRAO Very Long Baseline Array (VLBA) antennas together with up to 10 additional geodetic antennas. The resulting intrinsic source structure information provides a valuable resource for evaluating the astrometric suitability of the extragalactic sources used to define the ICRF.

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.

3. Current Activities

Since the inception of the USNO Analysis Center, three VLBA RDV experiments have been processed and imaged. These include the RDV07, RDV08 and RDV09 sessions. Processing of RDV10 is under way.

The RRFID has contributed data to the structure analysis of Fey & Charlot (2000). The resultant "Structure Index" is available from Patrick Charlot at

`http://www.observ.u-bordeaux.fr/public/radio/PCharlot/structure.html`

The USNO and the Australia Telescope National Facility (ATNF) are collaborating in a VLBI research program in Southern Hemisphere source imaging and astrometry using USNO, ATNF and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the Southern Hemisphere. Plans include strengthening the ICRF in the Southern Hemisphere by a) increasing the reference source density with additional S/X band (2.3/8.4 GHz) bandwidth-synthesis astrometric VLBI observations, and b) VLBI imaging at 8.4 GHz of ICRF sources south of $\delta = -20°$. These observations will provide a strong tie between the Northern and Southern Hemisphere through the overlap with common sources measured from the north. One 48 hour imaging session has been carried out and is awaiting correlation.

Several summer students contributed to the Analysis Center. Sarah Zelechosky used geodetic VLBI observations to image 3C418, finding evidence of superluminal motion. Ginger Leonard used RRFID data to classify ICRF sources according to the variability of their intrinsic structure.

4. Staff

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

Name	Responsibilities
Alan L. Fey	Primary scientific contact, Web and data base design and content, Webmaster, Web server administration, VLBA data analysis (imaging), structure analysis
David A. Boboltz	VLBA data analysis (imaging), structure analysis
Ralph A. Gaume	Liaison to the ICRF Product Center of the IERS
Kerry A. Kingham	Web and data base design and content, Webmaster, Web server administration, geodetic data analysis (imaging), Mark 4 interface to imaging software, structure analysis

5. Future Activities

The following activities are planned:

- Continue imaging of VLBA RDV experiments
- Make additional astrometric and imaging observations in the Southern Hemisphere in collaboration with ATNF partners
- Continue research into the effects of intrinsic source structure on astrometric position determination
- Continue development of an interface between the Mark 4 correlator output and the imaging software
- Establish a new web site devoted exclusively to the Analysis Center for Source Structure

6. Relevant Publications

Analysis Center products of relevance which are currently available can be found in the scientific literature, e.g.:

- "VLBA Observations of Radio Reference Frame Sources. I.," Astrophysical Journal Supplement Series, August 1996 issue (Vol. 105, No. 2, Pages 299-330).
- "VLBA Observations of Radio Reference Frame Sources. II. Astrometric Suitability Based on Observed Structure," Astrophysical Journal Supplement Series, July 1997 issue (Vol. 111, No. 1, Pages 95-142).
- "The Proper Motion of 4C 39.25," Astronomical Journal, December 1997, (Vol. 114, No. 6, Pages 2284-2291).
- "Geodetic VLBI Observations of EGRET Blazars," Astrophysical Journal, November 1998, (Vol. 507, No. 2, Pages 706-725).
- "VLBA Observations of Radio Reference Frame Sources. III. Astrometric Suitability of an Additional 225 Sources," Astrophysical Journal Supplement Series, May 2000 (Vol. 128, No 1, Pages 17-83).

TECHNOLOGY DEVELOPMENT CENTERS

Canadian VLBI Technology Development Center

Wayne Cannon, Calvin Klatt

Abstract

The Canadian VLBI Technology Development Center has been active in a number of areas during the 22 month reporting period.

The S2 Geodetic VLBI program continues to make significant advances on many fronts, including development of the frequency switched S2 VLBI data acquisition system, enhancement of the S2 correlator capabilities to process frequency switched VLBI observations, utilization of a transportable antenna and the expansion of capabilities for scheduling, data processing and analysis. A number of experiments have been conducted using the Algonquin, Yellowknife and the Canadian Transportable VLBI Antenna (CTVA).

The next-generation, S3, VLBI system continues to be under active development at the Space Geodynamics Laboratory. It is capable of 1 Gbit/sec recording with unattended record times as long as 160 hours (depending on system configuration) using robotic tape changers.

1. Introduction

The Canadian VLBI Technology Development Center is a collaborative effort of the Space Geodynamics Laboratory of the Center for Research in Earth and Space Technology, (SGL/CRESTech), the Geodetic Survey Division of Natural Resources Canada (GSD/NRCan) and the Dominion Radio Astrophysical Observatory (DRAO) of the Herzberg Institute for Astrophysics of the National Research Council of Canada, (DRAO/HIA/NRC).

2. S2 VLBI Geodesy

Introduction

The Canadian S2 geodetic VLBI program is developing a complete "end-to-end" geodetic VLBI system and operational capability. This effort involves a wide range of activities including development of the frequency switched S2 VLBI data acquisition system, enhancement of the S2 correlator capabilities to process frequency switched VLBI observations, utilization of a transportable antenna and the expansion of capabilities for scheduling, data processing and analysis.

S2 VLBI Data Acquisition System (S2-DAS)

The S2 VLBI data acquisition system is being jointly developed by SGL and the GSD. The S2-DAS is designed to accomodate up to four VLBA/MkIV-type single sideband baseband converters (BBCs), each with a local oscillator (LO) independently frequency switchable under computer control. The objective of the development of the S2-DAS is to enable high sensitivity group delay measurements without appealing to a more costly parallel IF/baseband sub-system.

There are currently four S2 DASs in use. An additional three are in production: two for GSD and one for BKG. These should be available for operational testing within the first half of 2001.

The DAS Operating System (DASOS) has seen extensive development in the past 22 months. Much effort has gone into frequency switching with automatic gain control (1999) and automated self tests (2000). The official release of DASOS is planned to occur in April 2001.

DAS-PCFS communication requirements are being established. Development of a station wavefront clock model is also underway.

S2 VLBI Correlator

The Canadian S2 Correlator is a six station correlator using S2 playback terminals and is designed to handle S2 frequency switched bandwidth synthesis data. Recent activity has focussed on the development of post processing software to enhance system performance monitoring.

Canadian Transportable VLBI Antenna (CTVA)

The CTVA is a 3.6m radio telescope acquired to facilitate densification of the terrestrial reference frame in remote regions. The antenna will be colocated with GPS elements of the Canadian Active Control System (CACS) to provide fiducial station positions. The GSD is responsible for CTVA system development.

Since 1997 the antenna has been located at DRAO near Penticton, B.C. Recent work focusses on antenna sensitivity and system stability and reliability. Extensive testing through CGLBI (S2) experiments has occurred. We anticipate that the antenna will be moved to a new site in 2001.

S2 Geodetic Experiment Scheduling, Operations and Analysis

The Canadian Geodetic VLBI program involves all aspects of Geodetic VLBI operations, from experiment design through analysis. Anthony Searle has recently joined the GSD VLBI group. He has taken on many scheduling and analysis tasks and has assisted with experiment operations.

The CGLBI experiment scheduling was improved as a result of the introduction of S2 support in the SKED software. The CGLBI scheduling (and drudging) process is approaching full automation through use of scripts. The analysis software was updated to f-SOLVE and we have both CALC 8.2 and 9.1 available. Minor software changes to SOLVE remain necessary for CGLBI data to be analyzed. Software to create Mk3-type databases from (S2) frequency-switched experiments (CGLBIDB) was written and has been used on a regular basis.

A number of S2 VLBI experiments have taken place in the reporting period (see below). A significant amount of simulation work (using SKED and SOLVE) has taken place to investigate the system performance and possible future directions (S2 CORE?) for S2-based geodesy. An investigation into multi-beam VLBI (several small antennas co-observing with large ones) is underway.

The GSD has produced a CGLBI website which is regularly updated to reflect experiment activity (www.vlbi.ca). An analysis web site was created as a contribution to the IVS. This website documents SOLVE: f-SOLVE is documented elsewhere.

Interferometric Experiments

In the reporting period 23 developmental experiments (CG006/June 1999 through CG028/ December 2000) have been performed using the S2 VLBI system, ALGOPARK and the CTVA. Of these, 17 were 24-hour geodetic experiments and the remainder were system tests. Yellowknife participated in 10 of these experiments, 6 being 24-hour geodetic.

Fringes have been obtained in each S2 interferometric experiment. The measured baseline length between ALGOPARK and PENTICTN using the S2 system has been repeatable within 1 cm.

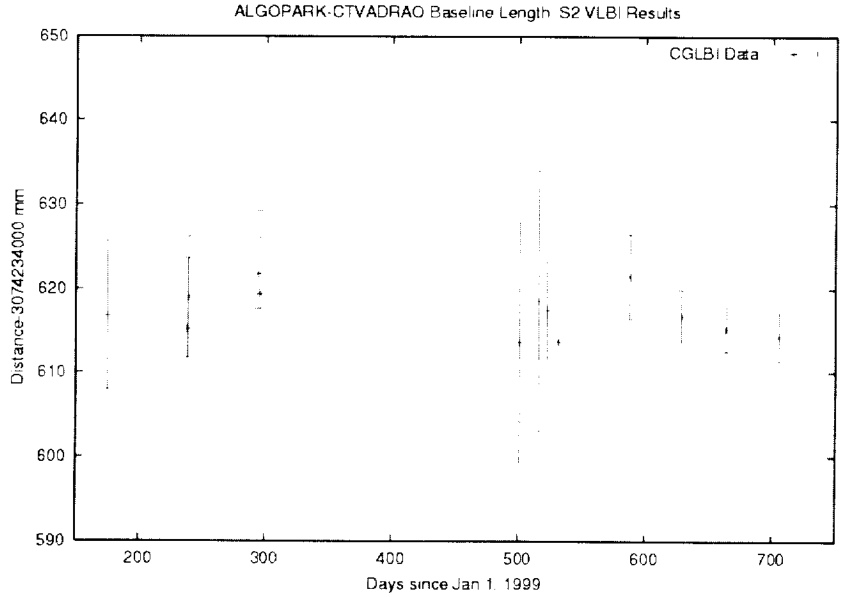

Figure 1. Penticton - Algonquin S2 Baseline Length Measurements

3. S3 Wide Bandwidth VLBI Data Record/Playback System Development

VLBI applications to geodesy and astrophysics can benefit from higher signal to noise ratio observations. The most attractive means of achieving large factor improvements in SNR in geodetic VLBI observations is by developing wide bandwidth VLBI data record/playback/correlation systems.

The Space Geodynamics Laboratory (SGL) located on the campus of York University in Toronto, Canada is developing a family of wide bandwidth VLBI data record/playback systems designated "S3", as a next generation follow-on to the "S2".

The S2 VLBI data record/playback system is a 128 Mbit/sec, Mostly-Off-The-Shelf (MOTS) VLBI data record/playback system based on an array of eight video tape transports together with custom designed signal channel cards and a single board control computer housed in a standard VME enclosure. The S2 is specified to operate without error correction coding at a Bit Error Rate (BER) of the order of 10^{-4}; however typical BER performance in the S2 is of the order of 10^{-5}. The extensive use of MOTS hardware in the S2 design resulted in a low cost, high performance, VLBI data record/playback system of which more than 50 have been fabricated at SGL and are now in use in a variety of radio astronomy and VLBI applications in more than a dozen countries around the world.

The S3 VLBI data record/playback system is the next generation MOTS VLBI system. It has inherited a significant amount of its architecture from the S2 although the VME backplane has been replaced with a wide bandwidth Compact PCI backplane. In addition the interface for the S3 will be compatible with the VLBI Standard Interface (VSI) specification. The S3 is constructed as an array of eight JVC "Digital-S" (now designated "D9") digital video tape transports, each of which is able to record/playback VLBI data at a rate of 150 Mbit/sec, of which 128 Mbit/sec is "user data", for an overall user data rate of 1024 Mbit/sec (1 Gbit/sec). Recent S3 system tests at SGL in which pseudorandom digital data was written to and read from the S3 tape transport indicate that the signal to noise ratio on the S3 eye pattern is comparable to that of the S2. The S3 is expected to provide a BER performance that is comparable to the S2.

The tape change interval for the S3 tape array is 2.5 hours at a data rate of 1024 Mbit/sec (1 Gbit/sec) with longer tape change intervals being possible when operating the S3 at reduced data rates. The cost of recording media for the S3 is expected to be $150 (US) per hour at a data rate of 1024 Mbit/sec (1 Gbit/sec).

The S3 VLBI data record/playback system is designed for system upgrades based on the recently introduced JVC High Definition TV "D9-HD" tape transport, which in the S3 context will record/playback VLBI data at a rate of 300 Mbit/sec. The D9-HD will enable the fabrication of the "Compact" version of the S3 system, the "S3-C", which will record/playback VLBI data at a rate of 1024 Mbit/sec (1 Gbit/sec) on a compact array of only four tape transports.

The D9-HD will also enable the fabrication of the "Extended" version of the S3 system, the "S3-E", which will record/playback VLBI data at a rate of 2048 Mbit/sec (2 Gbit/sec) on an array of eight tape transports. Dual operation of the S3-E will provide for VLBI data record/playback at data rates as high as 4096 Mbit/sec (4 Gbit/sec).

SGL has implemented a TiltRac robotic tape changer for the S3 family of VLBI data record/playback systems. The tape changer is a true Commercial-Off-The-Shelf (COTS) system developed especially for use with the JVC D9 and D9-HD tape transports. The robotic tape changer is available in single-bay, dual-bay, and triple-bay configurations. SGL has implemented a dual-bay configuration in its development system. The robotic tape changer provides the option of long unattended operation intervals with the S3 family of VLBI data record/playback systems.

			Unattended Operation (Hrs)		
System Config	Data Rate (Mbps)	Tape Duration (Hrs)	Single Bay Robot	Double Bay Robot	Triple Bay Robot
S3	1024	2.5	-	65	130
	512	5	-	130	260
	256	10	-	260	520
	128	20	-	520	1040
S3-C	1024	1.25	32.5	97.5	162.5
	512	2.5	65	195	325
	256	5	130	390	650
S3-E	2048	1.25	-	32.5	65
	1024	2.5	-	65	130
	512	5	-	130	260
	256	10	-	260	520
Dual S3-E	4096	1.25	-	32.5	65
	2048	2.5	-	65	130
	1024	5	-	130	260
	512	10	-	260	520

Table 1. S3 Tape Durations and Unattended Operating Times with Robotic Tape Changer

Technology Development Center at CRL

Tetsuro Kondo

Abstract

Communications Research Laboratory (CRL) has led the development of the VLBI technique in Japan and has been keeping high activities in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at CRL and summarizes recent activities.

1. Introduction

Communications Research Laboratory (CRL) has been leading the development of the VLBI system in Japan since the development of the K3 VLBI system in 1979 which is compatible with the Mark III VLBI system developed by the US group. CRL then developed the K4 VLBI system, which facilitated ease in both operation and transportation. In October 1990, the International Earth Rotation Service (IERS) designated the Communications Research Laboratory (CRL) and Haystack Observatory (in the United States) as Technical Development Centers (TDC). In September 1996, the IERS directing board designated CRL as TDC again. The function of the IERS VLBI Technical Development Center was taken over by the IVS Technology Development Center after its establishment on March 1, 1999. Since then CRL has participated in IVS as one of its Technology Development Centers. The CRL-TDC newsletter is published biannually to inform the VLBI community of its current activities. The newsletter is also available through the Internet at the following URL **http://www.crl.go.jp/ka/radioastro/tdc/index.html**.

2. Recent Activities

2.1. Real-Time VLBI

The Keystone (KSP) real-time VLBI [1] system observed extraordinary crustal deformation of over 2 cm/month on the Kashima-Tateyama baseline during July-August 2000 (Fig.1). It occurred just after the volcanic eruption event at Miyake Island about 150 km south of Tokyo at the end of June. To provide data to the Headquarters for Earthquake Research Promotion more frequently, we changed a 24-hour session frequency from every two days to every day. Every-day observation continued till November when the crustal deformation seemed to be well settled. During this period we had no technical problems in real-time VLBI operation. Although it was planned to terminate the Keystone project at the end of March, 2001, it was decided from the importance of KSP observation to extend the term of the project for one more year with three stations, Kashima, Koganei, and Tateyama.

This real-time VLBI technique is also used to connect a 64-m antenna at USUDA and a 34-m antenna at Kashima so as to realize a large virtual radio telescope. A test observation was successfully carried out in December 1998, then this project was named GALAXY and has carried out radio astronomical observations once every several months. The GALAXY has been carried out in collaboration with the Institute of Space and Astronautical Science (ISAS), National Astronomical Observatory (NAO), and Nippon Telegraph and Telephone Corporation (NTT)[2].

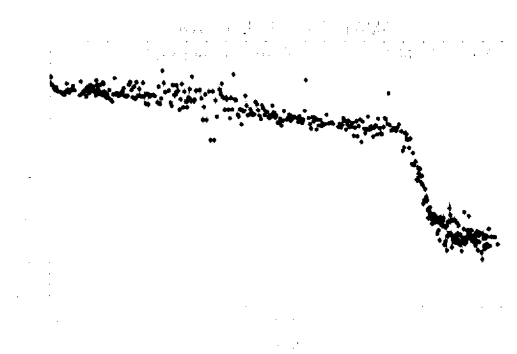

Figure 1. Kashima-Tateyama baseline length change. Extraordinary crustal deformation over 2 cm/month was observed during July-August 2000.

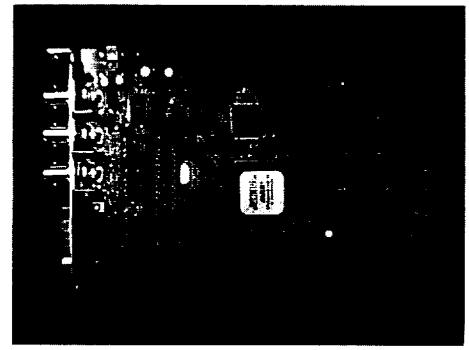

Figure 2. PCI sampler board for the IP-VLBI system.

In the KSP real-time VLBI system, data are transmitted through the high-speed ATM network. However, network cost is still expensive and connection sites are still limited, so that ATM-VLBI is not yet well generalized. We therefore aimed to develop a new real-time VLBI system using IP (Internet protocol) technology that has already spread widely, to reduce network cost and to expand the connection sites of network. We call this system "IP-VLBI" or "VLBI over IP", and started the development in late 1999. We have been developing the PC-based IP-VLBI system consisting of a PCI-bus sampler board (Fig.2) and PC software to make real-time data transmission and reception. We also intend to carry out real-time correlation by PC software. One sampler board has 4 video signal inputs and is designed to be able to sample each signal with a frequency of up to 16 MHz for 1 bit A/D. The sampler board has been tested by using actual signals from radio sources. Real-time characteristics have been evaluated by using the LAN at the Kashima Space Research Center. So far we can confirm the sufficient performance of "coherent sampling" up to 8 MHz sampling. Although the performance of 16 MHz sampling has not yet been confirmed, it will be checked soon. Regarding the "real-time correlation processing" by using PC software, we can process 2 MHz sampling data in real-time at present time. An improvement in the algorithm to make correlation processing faster is in progress[3].

2.2. Giga-bit VLBI System

The developments of the giga-bit VLBI system at the Communications Research Laboratory started in 1996. The system consists of the A/D sampler unit (TDS580D/TDS784A), the recorder system (GBR1000), the correlator (GICO), sampler interface unit, the timing control unit (DRA1000), and the data buffer unit (DRA2000). In 1998, first fringes were successfully detected on the Kashima-Koganei baseline using this system.

During 1999 - 2000, four geodetic VLBI experiments were performed using the giga-bit VLBI system. Two of them are on the Kashima-Koganei baseline and others are on the Kashima-Gifu baseline (about 360 km). In each experiment, observations were performed with K4 VLBI system in parallel to compare the results. As the sampling frequency of giga-bit system (1024MHz) is much higher than that of K4 system (16 MHz), performance of the giga-bit system is influenced by the stability of the sampling frequency. By developing a method to compensate for the sampling jitter using a superimposed tone signal, data quality and estimation errors have been improved to a level comparable to the K4 VLBI system [4].

A new compact VSI Gbps sampler, ADS-1000, has been developed. A design of ADS-1000 started to provide a simple portable Gbps sampler. Antenna front-end mounted with AD samplers will eliminate long analog transmission in near future. Although, the current AD packages weigh 50 kg and occupy 6U in the system, the ADS-1000 weigh less than 10 kg and occupies 1/2U (Fig.3). Sampling jitter is expected to be reduced by using a high purity-sampling signal which is directly supplied from a PLO. As a remarkable feature, the sampler output is VSI-H (VLBI Standard Hardware Interface) compatible. According to the endorsed document VSI-H proposal, LVDS devices have been examined and this is CRL's first VSI-H instrument. The ADS-1000 is manufactured by DigitalLink Co.Ltd. and Venetex corporation. They are venture companies which are distinguished by advanced digital technology [5].

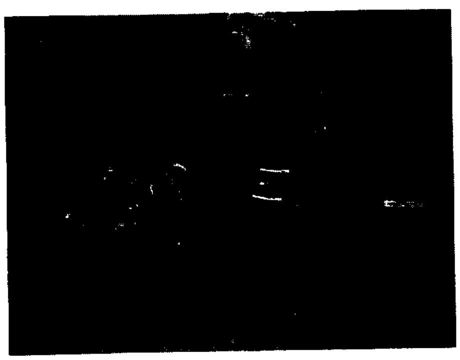

Figure 3. ADS-1000, the new compact VSI Gbps sampler under test.

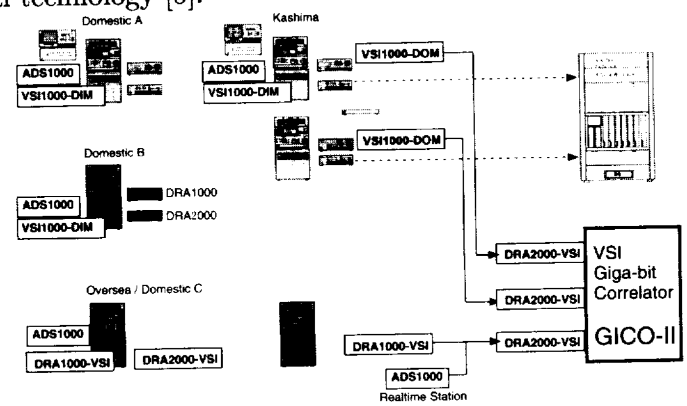

Figure 4. Proposed Gbit VLBI system enhancement for the global baseline.

2.3. VLBI Standard Interface

CRL TDC has been contributing to the establishment of the VLBI standard interface (VSI) with Dr. Alan R. Whitney, Technology Coordinator of IVS. We had international telephone conferences several times to discuss VSI and reached the agreed specification of VSI hardware (VSI-H). VSI-H Ver1.0 was opened to public in August, 2000. It can be accessed through the VSI homepage (**http://dopey.haystack.edu/vsi/**) or Japanese VSI homepage (**http://www2.crl.go.jp/ka/radioastro/tdc/ivs/vsi/**).

We are adapting VSI-H to S2-K4 copying system and VSI-based K4 data acquisition system. One of the motivations was the request for a S2-K4 data copying system. Antarctica VLBI data observed in 1997-1999 and Pulsar VLBI observation data are recorded on an S2 system. These data are desired to be correlated with K4-type (K4, KSP) correlators because of easiness to handle it in Japan. Also S2-K4 copier will expand the ability of organizing VLBI network observation [6].

Late 2000 supplementary budget to make upgrade of the giga-bit VLBI system was approved. The importance of the parallel data transmission is recognized again in the VSI-H, while IT technology promoted high-speed serial transmission by IP. All the VLBI instruments in the Gbps system developed by CRL will adopt VSI-H. We also intend to encourage the application of the VSI interface to a wide scientific use through the demonstration that will be made using the upgraded giga-bit VLBI system. Preliminary plan of the enhanced Gbit VLBI system is shown in Fig.4. Upgraded Gbit data recorders are introduced and new Gbit samplers, ADS-1000 are disposed to each station. The number of the Gbit recorders is doubled and this will increase Gbps observation sites. As well as K4 and/or KSP system, a robot tape exchanger is being designed for automatic observation. While the experimental correlator UWBC-GICO will continue its operation, a new multi-baseline Gbit correlator equipped with VSI-H ports will start operation. The correlator system of the CRL-TDC is promised to open in the other VLBI groups and new countries. Technical supports and VSI related supplies are also planned [7].

3. Future Perspectives

CRL TDC will continue to make efforts to develop new technologies introduced in this report and to apply them to actual observations. In particular, we will demonstrate VSI-H instruments as soon as possible. We also continue the development of the "Internet VLBI" system which is the succession of the current real-time VLBI technique but aims at realizing more economical (lower running cost) and flexible connections between VLBI stations by using the Next Generation Internet (NGI).

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Combination of VLBI, GPS and SLR Software Development at FFI

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center will focus primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS and SLR. This report briefly summarises the latest improvements of the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. The GEOSAT software

The advantages of the combination of independent and complementary space geodetic data at the observation level is discussed in Andersen ([1]). The models of GEOSAT are listed in Andersen ([2]). Recent changes are described in the following.

The GEOSAT software has recently extended the analysis capability from 30 to 60 GPS stations per day. In addition, a new procedure for the generation of a priori GPS orbits for the filter has been implemented. A three day IGS precise orbit for each GPS satellite is used as observations for the determination of a GEOSAT-generated GPS orbit. In this fit six orbital elements in addition to nine solar radiation pressure (SRP) parameters are solved for. The rms of residual fit for the three-day orbital dataset is typically between 2 and 4 cm for all satellites except for 2-4 satellites where the rms is significantly larger. The estimated orbit is used to generate a priori observation residuals and observation partial derivatives to be used in the filter where all data types are combined. In the 24 hour filter solution the nine-parameter SRP model are kept fixed and only the six orbital elements and one SRP-scaling parameter and a Y-bias parameter are solved for. In this way the one-day orbits will be based on a very realistic SRP model. However, for satellites with large rms of orbital fit two additional stochastic velocity change parameters are solved for. Experiments with the IGS precise orbits show that this parameterization is sufficient in order to fit a 24 hour GEOSAT-generated GPS orbit for all satellites including the outlier satellites with an rms of 2-3 cm in each coordinate. A significant part of the 2-3 cm difference is due to the use of inconsistent values for the EOPs. EOP values are taken from IERS and not the IGS EOP estimates to be used with the precise IGS orbits. In conclusion, a highly sophisticated GPS orbit strategy has been established. The use of a large number of GPS stations in combination with a moderate number of dynamical solve-for parameters and a realistic dynamical model is expected to result in GPS orbits with a precision level of a few cm in each coordinate.

It is a fact that the position of the effective phase center of the transmitter antenna of the GPS satellites is not very well known. This leads to a scale inconsistency with VLBI and SLR of approximately 2 ppb. It is therefore a standard procedure in analysis with GEOSAT to estimate the z-coordinate of the mean position of the transmitter phase center. With GPS-data alone it is only possible to determine the phase center position relative to the position of the phase center of a reference satellite. Since the GPS data in our case are combined with VLBI and SLR data absolute positions of the phase center of all satellites can be determined.

Another possible candidate for scale inconsistency between the different techniques is the tropospheric mapping function. In order to be consistent with VLBI and GPS the SLR data are analyzed with the use of the dry NMF mapping function which is used for VLBI and GPS. The signal delay in the zenith direction is however calculated using the Marini-Murray model. This procedure is in accordance with recent recommendations given by Richard Eanes. A model for tidal geocenter motion is implemented (Watkins and Eanes, [3]).

In GEOSAT data from the different techniques are combined in batches of one day which is called an arc. The state vectors and complete variance-covariance matrices from the analyses of a number of independent arcs of space geodetic data can be combined using the CSRIFS (Combined Square Root Information Filter and Smoother) program. Four parameter levels are available and any parameter can, at each level, either be represented as a constant or a stochastic parameter (white noise, colored noise, or random walk). The batch length (i.e. the time interval between the addition of noise to the SRIF array) can be made time- and parameter dependent. More details can be found in Andersen ([1]).

2. Prospects

Two new programs in the GEOSAT system are under development. The IERS program will transform the output from internal reference frames in GEOSAT to the external reference frames of the IERS. Also the final combined covariance matrix of CSRIFS will be rotated. The SINEX program will write the global solution in the SINEX format.

Statens kartverk has recently received a copy of the GEOSAT software.

The GEOSAT software will be converted to PC/LINUX in the near future.

3. Technical Staff

Table 1 lists the FFI staff involved in IVS activities.

Table 1. Staff working at the FFI AC and TDC

Name	Background	Dedication	Agency
Per Helge Andersen	geodesy	40%	FFI

References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

[2] Andersen, P. H. High-precision station positioning and satellite orbit determination. PhD Thesis, NDRE/Publication 95/01094.

[3] Watkins M., Eanes R. Observations of tidally coherent diurnal and semidiurnal variations in the geocenter. Geophysical Research Letters, Vol. 24, No. 17, 2231-2234, Sep 1, 1997.

GSFC IVS Technology Development Center Report

Ed Himwich, Nancy Vandenberg, Tom Clark

Abstract

This report summarizes the activities of the GSFC IVS Technology Development Center from the establishment of IVS to the end of 2000. The report forecasts activities planned for the year 2001. The GSFC IVS Technology Development Center (TDC) develops station software including the Field System (FS), scheduling software (SKED), hardware including tools for station timing and meteorology, scheduling algorithms, operational procedures, and provides a pool of individuals to assist with station implementation, check-out, upgrades, and training.

1. Technology Development Center Operation

The GSFC IVS Technology Development Center (TDC) develops hardware, software, algorithms, and operational procedures. It provides manpower for station visits for training and upgrades. There are other techology development areas at GSFC covered by other IVS components such as the GSFC Analysis Center.

The current staff of the GSFC TDC consists of Tom Clark, Nancy Vandenberg, Ed Himwich, Chuck Kodak, Raymond Gonzalez, and William Wildes.

The remainder of this report covers the status of the main areas of development that are currently being pursued.

2. Field System

During this period two major new features were released: Y2K support and mode independent parity checks. Y2K support was of course necessary for continued operation of the FS in the year 2000 and beyond. Mode independent parity checks removed the need for stations to change parity check procedures for every experiment that used a different mode than the previous experiment.

In addition several new features under development during this period will be released in the next major release, 9.5. Some of the features included are: (1) Support for K4 systems, (2) support for sequential use of two longitudinal tape recorders, (3) better handling of default values for Mark III/IV IF attenuators, (4) a utility "msg" for sending Ready, Start, and End messages for geodetic sessions, (5) support for report logging maser offset data from a TAC, (6) support for NTP, (7) a command, "ifadjust" to automate determining the IF attenuator settings for a given mode, (8) an experimental tool for monitoring FS operation remotely, ARTS, (9) a command, "tnx" to disable reporting of an error message that can't be fixed, and (10) an experimental program, "erchk" to display only error messages to make it easier for the operator to keep track of them. This release is expected in the first quarter of 2001.

In the following FS release, 9.6, several other improvements are expected; among these are: (1) dual head recording for Mark IV and VLBA4, (2) support for the new Mark IV firmware, (3) onsource flagging formatted in AIPS flagging file format, (4) improved Tsys measurements with automatically generated procedure files, frequency dependent noise diode temperatures, and ANTTAB file format output, (5) faster set-up when the formatter set-up doesn't change between scans. The release is expected the third quarter of 2001.

3. SKED and DRUDG

The GSFC Technology Development Center is responsible for development, maintenance, and documentation of the SKED and DRUDG programs. These two programs operate as a pair for preparation of the detailed observing schedule for a VLBI session and its proper execution in the field. During 2000 SKED was enhanced to add new user interface features, the ability to write VEX files, and K4 and S2 scheduling support. Some bugs remain to be worked out before official release of the new SKED version. Meanwhile users are testing and using the available version.

- A Java-based user interface was added to SKED by Kristian Refinetti, a Chalmers University engineering student on a trainee program sponsored by NVI/GSFC. The SKED catalog files can now be accessed with a set of screens that make selection of sources, stations, observing modes, and scheduling parameters more powerful and flexible.
- New SKED commands to generate a VEX file from the schedule file were added. The VEX file is required as input to the Mark IV correlators. The native SKED format is still the standard schedule file format and the VEX file is only an output format.
- Scheduling support for K4 and S2 systems was added to SKED so that geodetic schedules could be easily generated for these recording systems. Displays of tape usage and tape speed are handled in the native units for each system.

4. VLBI Timing

At Goddard, we have continued to stress the development of high accuracy (~20 nsec for each day) GPS-based timing measurements at VLBI stations; this data is needed for several reasons:

- Correlator efficiency is improved significantly if the relative station clocks are known at the ~50 nsec level and clock drift rates are known at levels ~1:10^{13}.
- To produce accurate UT1 measurements, station clocks need to be tied to UTC(USNO) to a few hundred nsec.
- Discontinuities seen in timing data are an excellent diagnostic of performance problems in hydrogen masers.

  After much discussion we decided that the ideal timing system for VLBI stations would

- Run continuously, logging data between experiments,
- Be easily reproducible at all stations and be low cost,
- Produce daily timing accuracy of 20-30 nsec anywhere in the world.

Our R&D testing beginning in 1993 showed that we could meet the accuracy goal with a particular low-cost GPS receiver (the Motorola PVT-6) and by 1995, we distributed ~50 timing clocks for the community - for humorous reasons, these receivers were named the TAC - Totally Accurate Clock. The historical archives of the early TAC development are available at ftp://aleph.gsfc.nasa.gov/GPS/totally.accurate.clock. The current software package, called TAC32Plus is a VLBI "plug in". Some of the VLBI features are depicted in the final figure of this report ("Recommended Clock and Timing Setup for a Mark4 VLBI Station") and include:

- Full-time logging of Time Interval Counter (TIC) data to disk in a "friendly" format,
- Automatic application of corrections for quantization dither (amounting to 104 nsec peak-to-peak with the ONCORE) inherent in the GPS receivers,
- Providing smoothed TIC data to the VLBI system via a TELNET socket,
- Providing station-wide network computer synchronization using NTP,
- Access to timing data via FTP for remote maintenance and diagnostics.
- Full support for TIC+TAC+TAC32Plus system is included in the LINUX PC Field System.

Before May 2000, timing performance was limited by the U.S. Dept. of Defense through a process called Selective Availability (SA). With SA, the atomic clock onboard each GPS satellite was "diddled" with a pseudo-random code that spoiled the spectral purity of GPS timing signal in the range from a few seconds to ~1/2 hour. With the TAC, we provided some mitigation against SA by averaging the timing over all satellites in view, and by averaging timing over many minutes in the time domain. With this process, the ONCORE-based TACs routinely yield timing smooth at the 15-20 nsec level at all times from minutes to a day. After May 2nd when SA was turned off, the short-term stability, as judged by taking the RMS noise of all samples in a 5 minute window, improved from ~15 nsec to ~5 nsec. The dominant error source suddenly became the diurnal signature of the ionosphere, amounting to ~15 nsec peak-to-peak.

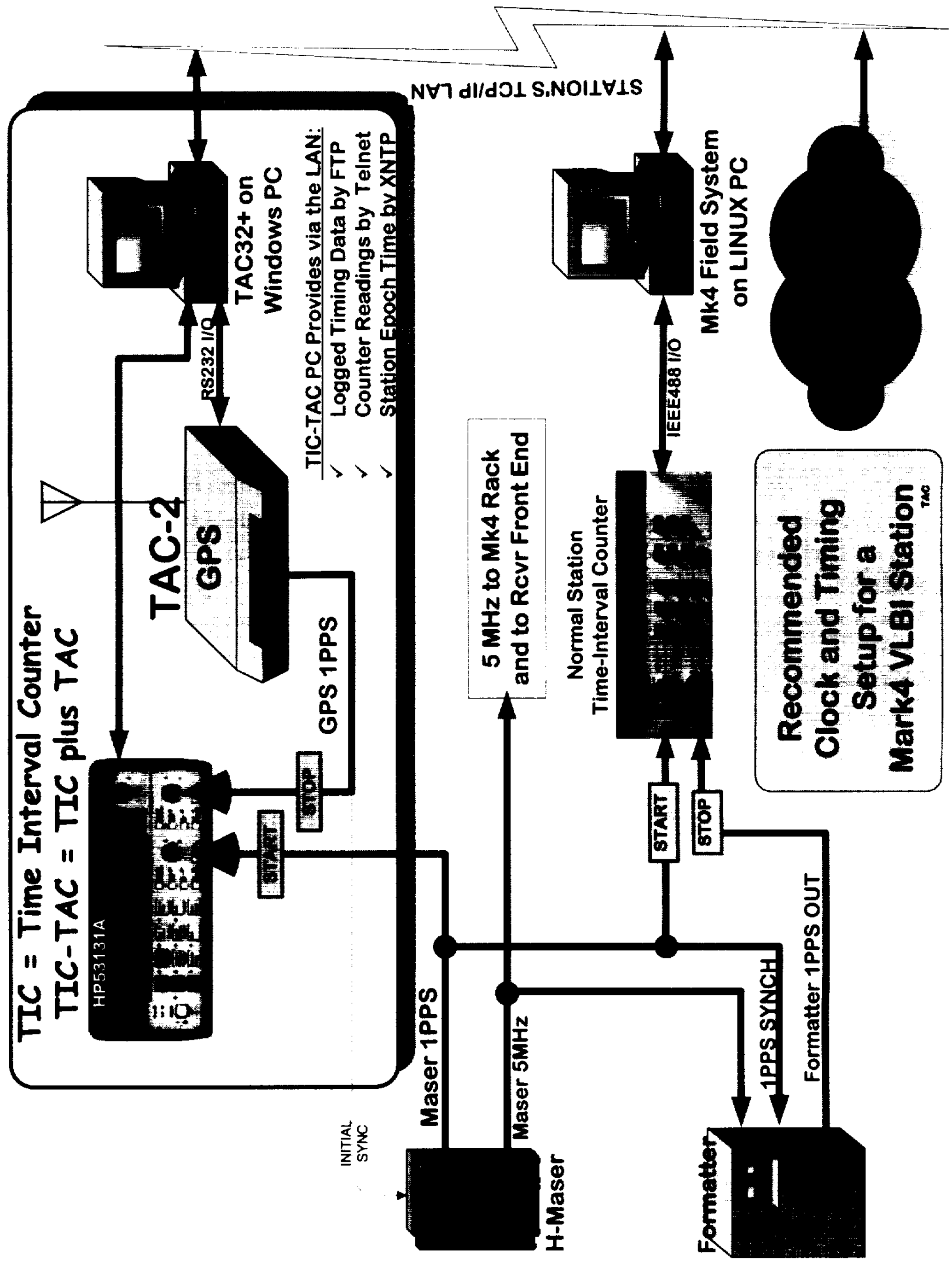
Data was logged during a 9 week period at the end of 2000 with an ONCORE receiver and the data system described above logging the H-Maser at GGAO in Greenbelt. The Maser had a rate offset of ~20 nsec/day (a frequency error of ~2.4 x 10-13). On Nov.22, the drift rate was observed to increase, which was subsequently traced to a temperature change at the H-Maser chamber. A figure demonstrating this is available at ftp://aleph.gsfc.nasa.gov/ivscc/annual_report/2000/oncore-ggao.ps.

In late 1999, Motorola announced that they were discontinuing the ONCORE VP receiver that had been used in the TAC-2 and CNS GPS clocks. We began to work with a software developer who had made an excellent timing receiver based on the SiRF-1 chipset. Where the ONCORE VP shows ~4 nsec noise in the 5 minute samples, the SiRF prototype shows ~650 psec of noise, a factor ~5 better. A figure demonstrating this is available at ftp://aleph.gsfc.nasa.gov/ivscc/annual_report/2000/sirf-ggao.ps.

A paper on these receiver developments was presented at the Sept.2000 ION meeting (T.Clark, R.Hambly and R.Abtahi "Low Cost, High Accuracy GPS Timing", Proceedings of Institute of Navigation GPS 2000, Salt Lake City, pp.905-913 (2000)) and copies are available on http://www.gpstime.com.

5. New Meteorological Sensors

GSFC has investigated new meteorological sensors to replace the aging standard CDP-era sensors in use at many sites. We are planning to provide FS support for the following devices: MET-3A Meteorological Sensor Part #1539-001 and Handar 425 Ultrasonic Wind Sensor (Model 425A/AH) both available from Paroscientific at http://www.paroscientific.com. We expect to install these at NASA supported sites within the next year.


TIC = Time Interval Counter
TIC-TAC = TIC plus TAC
HP53131A
TAC-2
GPS
GPS 1PPS
STOP
START
RS232 I/O
TAC32+ on Windows PC
TIC-TAC PC Provides via the LAN:
Logged Timing Data by FTP
Counter Readings by Telnet
Station Epoch Time by XNTP
STATION'S TCP/IP LAN
5 MHz to Mk4 Rack and to Rcvr Front End
Normal Station Time-Interval Counter
IEEE488 I/O
Mk4 Field System on LINUX PC
START
STOP
Recommended Clock and Timing Setup for a Mark4 VLBI Station
Maser 1PPS
Maser 5MHz
INITIAL SYNC
H-Maser
1PPS SYNCH
Formatter 1PPS OUT
Formatter

Haystack Observatory Technology Development Center

Alan Whitney

Abstract

Current work in VLBI technology at Haystack Observatory includes further development of the Mark IV correlator system, plus a new initiative to develop a low-cost high-performance Mark V VLBI record/playback system, that will utilize mostly commercial-off-the-shelf (COTS) technology and most likely incorporate magnetic discs as the storage media.

1. Mark IV Correlator

Mark IV correlators have been operational at USNO, MPI, JIVE and Haystack for about a year and have now completely replaced the Mark IIIA correlators. Haystack Observatory maintains the software for the USNO, MPI and Haystack installations.

Before the changeover from the Mark IIIA correlators to the Mark IV correlators, extensive cross comparison tests were done to ensure that the Mark IV results were of the highest integrity. In fact, the first published results from the Mark IV correlators occurred less than 2 months after the changeover from the Mark IIIA correlator.

The Mark IV correlator software has been continuously improved over the past year to include new operational capabilities and efficiency improvements, and all Mark IV correlators are now operating at an efficiency exceeding that of the Mark IIIA, with still more improvements to be made. Some of the features that are now supported are:

- Processing of Mark IIIA, Mark IV and VLBA tape formats
- GUI control interface
- Simultaneous auto and cross-correlation
- Support for 1 and 2-bit samples
- Full phase-cal extraction
- Bar-code-driven tape library
- Transparent file-version control
- Full configuration specified by a set of VEX-format files
- HOPS post-correlation package

Soon to be implemented will be:

- Multiple-stream processing (multiple simultaneous independent scans)
- Faster tape synchronization
- 'Double-speed' tape playback, followed by 'quadruple-speed' tape playback

2. Mark V VLBI Data System Development

With support from NASA, JIVE and NRAO, Haystack Observatory is now developing the Mark V VLBI record/playback system based on the requirements for the next generation of VLBI systems:

- Minimum of 1 Gb/sec data rate
- Economically upgradeable/expandable to $\sim$ 8 Gb/sec over the coming decade
- Design based primarily on unmodified off-the-shelf subsystems and components
- Modular, easily upgradeable as better/cheaper technology becomes available
- Robust operation, low maintenance cost
- Easy transportability
- Conformance to VLBI Standard Interface (VSI) specification
- Flexibility to support electronic transfer ('e-VLBI') and computer processing of recorded data
- Minimum of 24-hour unattended operation at 1 Gb/sec

Though this list of goals may appear idealistic, we believe they can be achieved in a system which can be designed today, and which will evolve in the following years to even higher data rates and additional storage capacity with minimal additional engineering effort.

2.1. Magnetic discs on the way to surpassing tape

Though both magnetic disc technology and magnetic tape technology have made great strides over the past few years, the pace of magnetic disc development has been so great that it is very likely that disc storage will become cheaper than magnetic tape storage by $\sim$ 2004. This trend can be clearly seen in Figure 1, where the $/GB for both disc drives and magnetic tape media (including projections for LTO tape media, which we focused on in the original COTS concept proposal) are plotted as a function of time. In addition are shown two 1998 projections for disc- storage costs, one from IBM and the other from the National Storage Industry Consortium (NSIC); the latter suggests a tape-to-disc crossover in the latter part of this decade. However, it is clear that the cost decreases of magnetic disc storage have dramatically accelerated over the past two years, far exceeding industry projections of only 3 years ago, and show no signs of ceasing. Current disc industry predictions suggest that in 2004 the cost per GB will be $\sim$ $.30 for low-cost 'dimestore' IDE (aka ATA) drives, but even these predictions may well prove conservative. As you can see from Figure 1, by $\sim$ 2004-5 the cost of disc drive storage is expected to fall below that of magnetic tape. Magnetic tape industry predictions have historically been pretty much on target and are expected to continue to be so, provided magnetic tape can even survive in the face of magnetic disc progress! Furthermore, note that the costs shown in Figure 1 are for complete disc drive units, while the tape costs are for the magnetic tape *media*, ignoring the substantial cost of tape drives.

The reason for this happening is quite clear - the flow of money into magnetic disc development is perhaps two orders of magnitude greater than that for magnetic tape! The disc industry sees no apparent obstacles to the current breakneck pace of development for at least several more years. Magnetic disc area-bit-densities on modern discs now (in early 2001) are $\sim$ 15 Gb/in^2, and are expected to rise to at least $\sim$ 100 Gb/in^2 by 2004. This is even far outstripping optical recording technology, which appeared to have such a bright future just a few years ago but has not become a serious competitor to magnetic discs for high-data-rate, high-density storage. We believe the VLBI community should begin to prepare now for a changeover to magnetic discs, which is the front-runner technology for the new Haystack Mark V system.

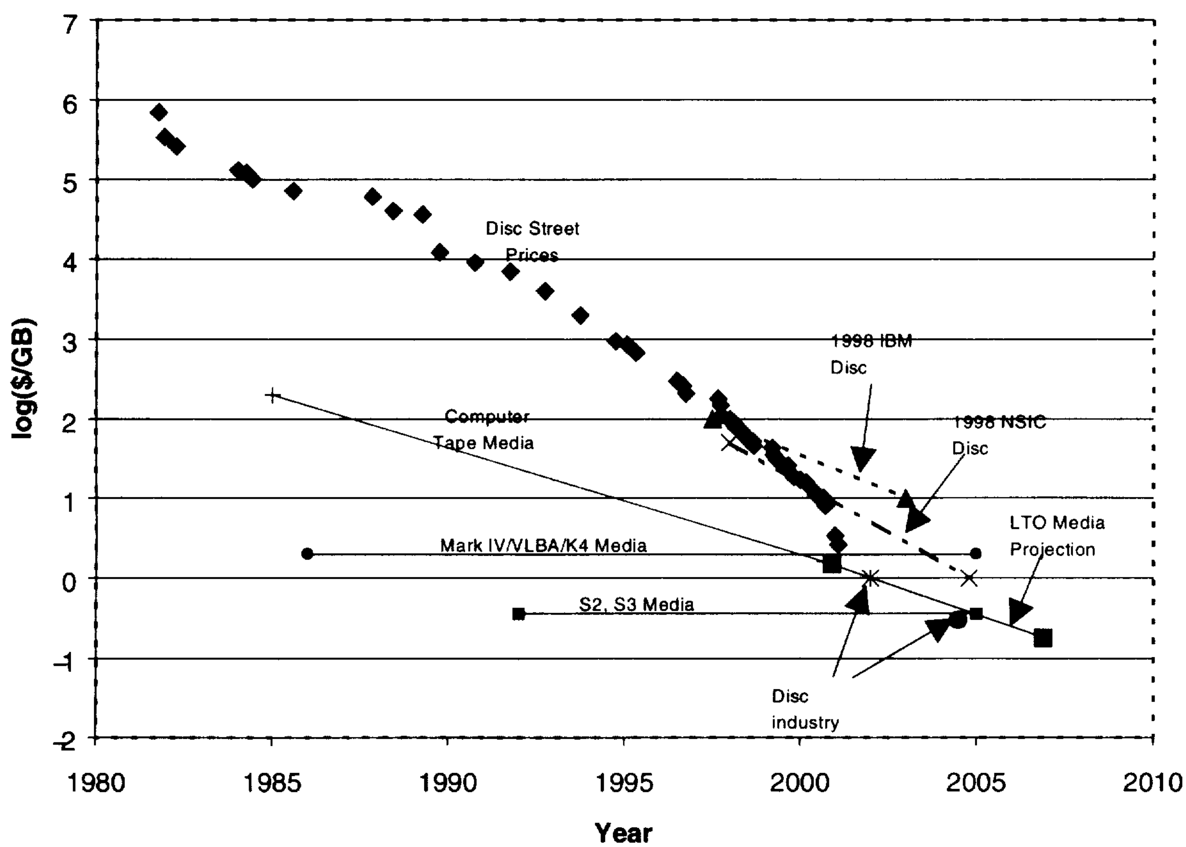


Figure 1. Disc/Tape Price Comparisons

2.2. The Mark V VLBI Data System

A 'Mark V' VLBI data system based on magnetic disc technology is now being designed at Haystack Observatory. Based on a standard PC platform with standard commercial busses and interfaces, it will support a continuous data flow of at least 1 Gb/sec to an array of up to ~16 magnetic discs. The only custom hardware will be VSI-H formatter and deformatter interfaces. Because the Mark V system is based on a standard PC platform, the data stored to discs will also be available for local analysis by the PC or for transmission over a network for e-VLBI. The cost of either the 1 Gb/sec Mark V recording or playback system (without discs) is expected to be <$25K. Multi-Gb/sec systems will be constructed simply by using Mark V systems in parallel, though future versions of the Mark V may have standalone multi-Gb/sec capability. The Mark V system will be explicitly based on disc drives with IDE interfaces, which are the most cost-effective consumer discs that can be procured. Furthermore, the IDE interface is so pervasive and so successful that any successful follow-on to magnetic discs, such as (possibly) optical discs, will almost certainly also be available with IDE interfaces, in which case they can be adapted to the Mark V system almost seamlessly. It is important to note that the Mark V data system is only a data recording and playback system and will require the use of a separate set of back-end electronics (IF converters, BBC's, samplers, etc).

2.3. The 24-hour Challenge

Disc industry expectations are that in 2004 a terabyte disc will be available for $\sim$ \$300. The recording of a continuous data rate of 1 Gb/sec for 24 hours will consume $\sim$ 11 TB of storage, so that an array of only $\sim$ 12 such discs for a total cost of \$3600 will comfortably operate unattended at 1 Gb/sec for 24 hours. This compares to today's cost of >\$20K for VLBA/Mark IV media of the same storage capacity.

Disc drives will be mounted in carriers, holding either single or multiple discs, made for multiple insertion/removal cycles. When modern disc drives are powered down, they are quite robust to external handling forces and can be shipped easily in padded containers. Including the carriers, the shipping weight per disc should be $<\sim$1.5 kg, so that the shipping weight of 12 discs containing an aggregrate of 11 TB will be $<\sim$18 kg.

2.4. Other Benefits of Disc-Based Mark V VLBI Data System

There are a number of other obvious benefits of magnetic discs over magnetic tape:

- Rapid random access to any data
- Essentially instant synchronization on playback into a correlator
- Self contained; expensive tape drives are not needed
- Can always buy and use the latest and cheapest 'dimestore' IDE disc drives, while still using older ones
- The entire host platform, including the computer and interface cards, can be easily and inexpensively upgraded as newer models become available

2.5. Mark V Development Schedule

Haystack is now beginning the development of the Mark V system based on magnetic disc technology. Early demonstrations of feasibility may occur as early as the end of 2001, with a deployable system ready as soon as $\sim$ 2003.

Institute of Applied Astronomy Technology Development Center

Alexander Ipatov

Abstract

IAA TDC works on the base of Radioastronomy apparatus building Section of IAA. The field of IAA TDC includes the devices of receiving, recording and processing of radio signals on QUASAR dishes. Now it consists of two radio telescopes (Zelenchukskaya and Svetloe), Badary under construction.

1. 1999-2000 Activities

Zelenchukskaya Station. Two years ago we planned the hard work on the new dish. Really, we spend all time for this work. At this time the 18–21 cm, 13 cm, 6 cm, 3.5 cm and 1.35 cm receivers are mounted on the dish. Six cryogenic machines are installed too.

Svetloe Station. On this station continues the routine work for supporting receiving equipment in working status. Measurements of the radio-telescope parameters were carried out. Performance parameters of the Svetloe Station are given in Table 1.

Table 1. Performance parameters of the Svetloe Station.

Wave band cm	Frequency GHz	Polarization	*r*	*dish*	*sys*	SEFD Ja	*cal*
13	2.15–2.5	L	18.5	39.5	58	430	13.5
		R	42.5	37.5	80	600	35
3.5	8.18–8.68	L	17	26	43	300	1.2
		R	32	26	58	470	5.7

The investigations of pointing corrections were carried out using Field System software for automatic pointing measurements. Pointing corrections models for wave bands 3.5 cm and 6 cm were determined.

A new system of radiometrical recording was constructed by Prof. Koltsov's group. It is installed on the Svetloe dish and now is being tested.

We created an experimental prototype of an automatic control system for one channel of the receiver's complex. This system consists of:

- a personal computer;
- an interface between the computer and the receiver on a parallel channel LPT-port; this interface was developed in the laboratory;
- programs for checking and remote control.

To this moment this system passed the laboratory tests. In future we will plan to increase the system possibilities for the control of all 10 channels of receiving system of complex "Quasar".

Technical Staff of IAA TDC is stable and did not change.

2. Prospects

For the 2001-year we are planning:

1. To begin in Zelenchukskaya dish:
    - putting into operation antenna tracking control system;
    - the adjustment of reflector and feed system;
    - radio telescope performance parameters measurement.
2. Test VLBI observations on baseline Zelenchukskaya-Svetloe.

Technology Development at IEEC

Dirk Behrend, Antonio Rius

Abstract

A summary is presented of the work carried out at the Institut d'Estudis Espacials de Catalunya (IEEC) regarding geodetic VLBI. The main activities encompass the geodetic surveillance of the DSS65 VLBI antenna at Robledo de Chavela (Madrid) and comparisons of tropospheric parameters derived from VLBI with those from GPS, WVR and numerical weather prediction (NWP) models.

1. Past and Current Activities

In 1997 a track and wheel repair work had to be performed at the Madrid telescope (DSS65) due to the formation of cracks in and a deformation of the concrete foundation. As for this task the telescope had to be lifted up and put back again, it is possible that the position of the geodetic reference point was changed. In order to monitor such a change conventional geodetic surveys have been done with respect to the local geodetic footprint of the telescope before and after the repair work (see e.g. [6]). Two additional local surveys have been performed after the repair work at roughly annual intervals (Table 1). Prior to the repair only one additional survey is available which was done some 9 years before the repair. Thus, five local geodetic control surveys are available to date. Table 1 gives a summary of the campaigns' results using the June 1997 campaign as reference.

Table 1. Position of the DSS65 reference point derived from conventional geodetic surveys using the June 1997 campaign as origin. Error estimates are 1σ standard deviations resulting from the least squares adjustment procedure. The table is divided into two parts: the upper part refers to the time before and the lower part to the time after the repair work. The repair was completed on April 30th, 1997.

Campaign	North [mm]	East [mm]	Height [mm]
December 1988	0.4 ± 3.0	0.3 ± 3.1	-23.2 ± 1.3
March 1997	7.0 ± 3.8	-1.5 ± 3.9	-6.0 ± 1.6
June 1997	0.0	0.0	0.0
April 1998	0.1 ± 3.1	-0.5 ± 3.2	-0.7 ± 1.6
March 1999	2.0 ± 3.2	1.6 ± 3.3	-0.3 ± 1.4

It appears that the east component was stable over the entire time span. The north component, on the other hand, was stable after the repair, but the repair itself caused a decrease of -7.0 mm (March 1997 to June 1997). Still, it seems that the repair re-created the initial state of December 1988. In height, an increase of 17.2 ± 1.3 mm (December 1988 to March 1997) and an uplift of 6.0 ± 1.6 mm (March 1997 to June 1997) are discernible where the latter can be attributed to the repair work. After the repair work the height can be considered stable.

Provided that sufficient geodetic VLBI observations before and after the repair work are available, the above found displacements should also show up in the time series of these experiments in the form of offsets. A respective study has been done (see [7]) for three stations of the European geodetic VLBI network including the antenna in Madrid. For this a drift rate as well as possible offsets caused by the repair work have been modelled. The drift rates were forced to be the same before and after the offset [7]. Offsets that did not pass a signifance test were rejected, i.e. only jumps that are statistically significant are retained (cf. Figure 1).

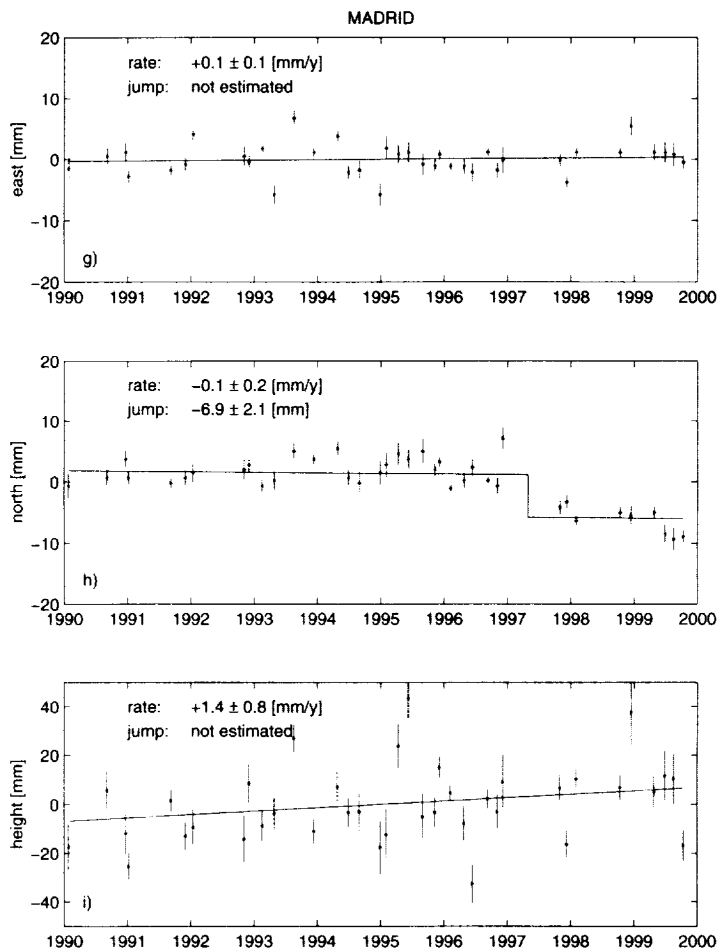


Figure 1. Time series of topocentric site movements for the station Robledo de Chavela (Madrid) as derived from an analysis of European geodetic VLBI data. Only jumps that proved statistically significant are shown.

The horizontal displacements (east and north) show a good agreement with the conventional surveys, i.e. at the level of some millimetres the east component remained stable whereas the north component performed a significant jump of −7 mm. With the height component, however, an abrupt uplift caused by the repair work is not discernible. This is probably due to the short time series available after the repair work and will hopefully be cured when more geodetic VLBI data become available. Nonetheless, the decadal trend of +1.4 mm/y conforms with the station height increase. Apart from investigating the site stability other activities have been done at the Madrid site and are summarized in [8] and [2].

At the NASA Madrid Deep Space Communications Complex (MDSCC), Spain, different microwave techniques are collocated: VLBI, GPS and WVR. These have been used in an intercomparison study for the derivation of tropospheric parameters (zenith wet delays, horizontal delay gradients). The comparison was performed on the basis of 10 disconnected days with simultaneous observations for the years 1994 and 1995 [1]. The estimates of the zenith wet delay are consistent between all three techniques. The results agree at the 1.6 cm WRMS level. The horizontal gradients, on the other hand, agree at the WRMS level of 0.15 cm.

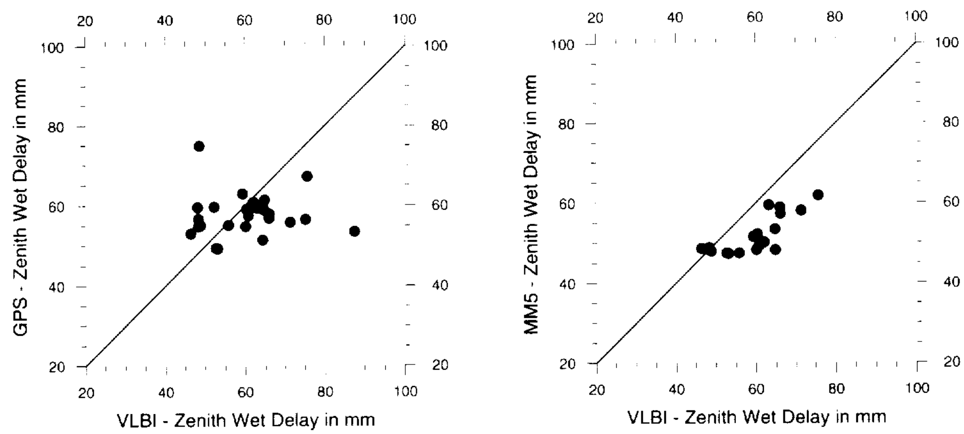


Figure 2. Scatter plots of ZWD values. *Left panel:* VLBI vs. GPS. Time span: Dec. 6, 1996 (9.5 h). Sampling rate: 30 min. *Right panel:* VLBI vs. MM5. Time span: Dec. 6, 1996 (9.5 h). Sampling rate: 30 min.

Furthermore, a preliminary comparison between zenith wet delays derived from VLBI, GPS, and numerical weather prediction (NWP) models has been done. The results agree to the subcentimetre level. The correlation values obtained from a time series of two weeks amount to 0.87 (GPS vs. MM5), 0.81 (GPS vs. HIRLAM), and 0.84 (MM5 vs. HIRLAM); the bias and RMS difference values fall within the error frames provided by the internal accuracies of the respective methods. The VLBI data employed in the comparison cover a time span of 9.5 hours, so that the comparison results should be considered indicative only. With correlation values of 0.78 (VLBI vs. MM5) and 0.66 (VLBI vs. GPS) they, nevertheless, look promising. For more details see [3] and [4].

2. Personnel

The Technology Development Center is formed by two people (Table 2): the head of the Earth observation group and a young researcher within the frame of the Training and Mobility of Researchers (TMR) programme of the European Community (grant FMRX-CT960071 "Measurement of Vertical Crustal Motion in Europe by VLBI"). The latter position is temporary and will terminate at the end of September 2001.

Table 2. Staff members of IEEC contributing to geodetic VLBI.

Name	Description	Allocation
Antonio Rius	head of Earth observation group	50%
Dirk Behrend	temporary TMR position	50%

3. Future Plans

It is intended to continue the surveillance of the site stability of the DSS65 VLBI antenna. Moreover, comparisons of VLBI derived atmospheric parameters with those from GPS, WVR, radiosondes, and NWP models shall be extended.

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The IVS Technology Development Center at the Onsala Space Observatory

Rüdiger Haas, Gunnar Elgered, Borys Stoew, and Lars Pettersson

Abstract

We give a short overview of the activities at the Onsala Space Observatory in its function as an IVS Technology Development Center. We describe the new microwave radiometer and the ongoing development of a new S/X-band feed system for the 20-m telescope.

1. The New Microwave Radiometer at Onsala

The new microwave radiometer developed during the last couple of years at the Onsala Space Observatory (OSO) [1], [2], [3] has been completed and first test measurements were carried out in summer 2000. The new instrument is equipped with narrow beam horns and fast pointing drives. One of its main applications is to study small scale atmospheric structures. We are looking forward to use the two microwave radiometers at OSO collocated with GPS and VLBI for atmospheric studies. Table 1 gives an overview on the specifications of the new instrument. Figure 1 shows a photo of the new instrument and Figure 2 gives a schematic representation of its control and data acquisition systems. Each of the two microwave channels is equipped with a horn antenna, mechanical switch, ferrite switch, mixer IF amplifier, baseband amplifier and A/D converter.

Table 1. Specifications of the new microwave radiometer developed at the Onsala Space Observatory.

Mechanical part		Azimuth	Elevation
	Maximum pointing resolution	0.0072°	0.0144°
	Achieved pointing resolution	0.1°	0.05°
	Pointing range	0–360°	0–360°
	Slew rates of motor drives	> 20°/s	> 30°/s
Microwave part		**Channel 1**	**Channel 2**
	Centre frequency	20.6 GHz	31.63 GHz
	Channel bandwidth RF	380 MHz	380 MHz
	Horn beam width (E/H) plane	2.9°/3.4°	2.0°/2.3°
	Side lobes (5° from boresight)	−18 dB	−23 dB
	Calibrated load stability	100° ± 0.01° C	100° ± 0.01° C
	A/D converter resolution	16 bit	16 bit

First successful measurements with the new instrument have been performed during the summer and fall 2000 [4]. The measurements were carried out at the Esrange Space Centre near Kiruna in northern Sweden where the instrument was collocated with one of the receiving sites in the continuously operating Swedish GPS network.

Figure 3 shows the time series of derived wet propagation delay for the month of August 2000 and a comparison between estimates of the wet propagation delay using the GPS data and the results inferred from the observed WVR sky brightness temperatures.

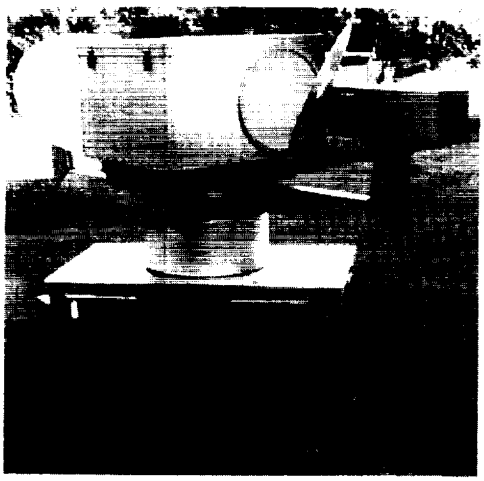

Figure 1. The new WVR.

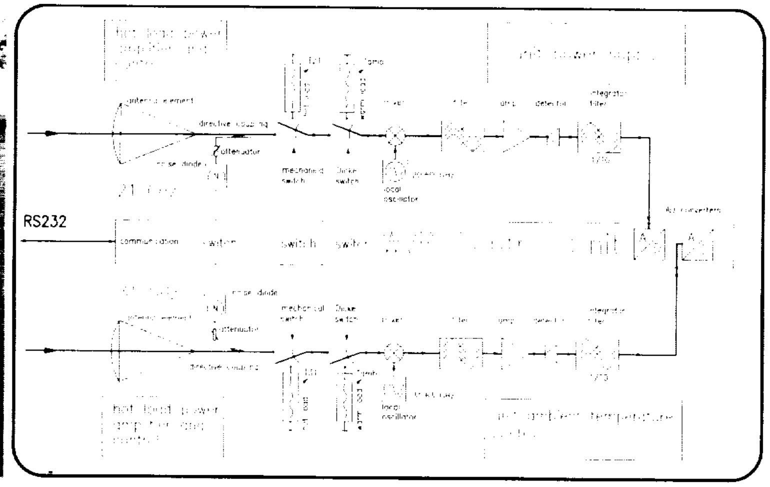

Figure 2. Schematic representation of the control and the data acquisition systems of the new WVR.

As expected the WVR time series contain more short term variations compared to the smooth Kalman filter estimates using GPS data (see Fig. 3). However, we find the white noise in the observed brightness temperatures to be higher than expected and modifications will be made to the software integration algorithms.

There is a clear bias between the GPS and the WVR results (see Fig. 3). The origin of this is unknown but we are investigating the following possible explanations: errors in the observed brightness temperatures; error in the WVR algorithm used to calculate wet delay from brightness temperatures (the algorithm used at Kiruna was derived for the Swedish west coast); error in the GPS estimates; error in the model used to interpolate the ground pressure at the GPS antenna.

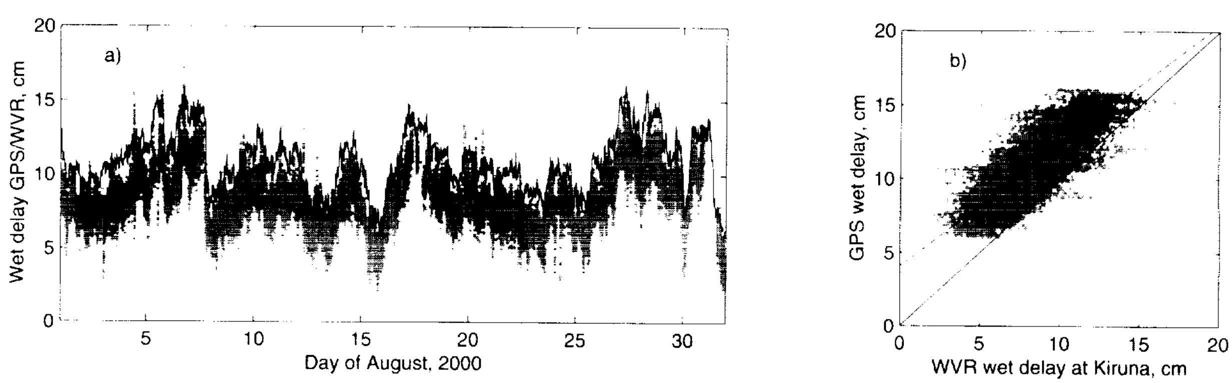

Figure 3. Equivalent zenith wet delay derived from observations with the new WVR and from GPS measurements during August 2000 at the Esrange Space Centre (Kiruna): a) Time series of wet delay results from the new WVR (green/gray dots) and from GPS (thin black/blue line); b) Wet delay results from the two methods GPS and microwave radiometry.

2. Development of a New S/X Feed System

The development of a new S- and X-band feed [5], [6] is ongoing. After the successful re-design of the corrugated horn that resulted in good antenna diagrams the coaxial waveguide transformer (COWAT) was also re-designed since its centre frequency was slightly off the desired value [7].

The re-designed COWAT was manufactured during 2000 with good cross-polarization isolation (24 dB at 8.12 GHz, 38 dB at 8.62 GHz) and good return loss at X-band (-22 dB). However, with only −8 dB for the S-band return loss it did not reach the specifications for S-band. No S-band polarizers have been manufactured yet, so no cross-polarization data are available for S-band.

Currently a re-design of the horn throat is under consideration in order to overcome the return loss difficulties (see Fig. 4). The intention is to make a wider waveguide opening at S-band, improving the return loss, but without affecting the behavior at X-band. The frequency selective surface is supposed to let S-band through, and act as a horn wall for X-band.

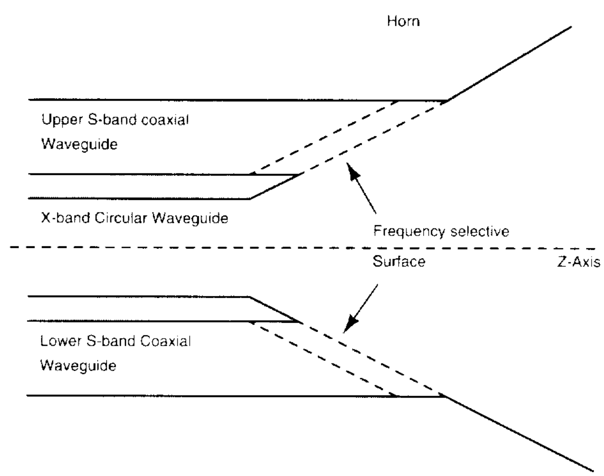

Figure 4. Considered re-design of the horn throat for the new S/X-feed system.

3. Outlook

The IVS Technology Development Center at the Onsala Space Observatory will continue with the development of the new radiometer and the new S/X feed system.

We will concentrate our efforts on the software integration algorithms for the new WVR in order to improve its performance. We will especially investigate the reason for the obvious bias between the radiometer results and GPS results for wet delay obtained from the measurements at Kiruna. Extensive test measurements will be carried out at the Onsala Space Observatory and the results for atmospheric parameters will be compared to results from the other collocated techniques.

The development of the new S/X feed system will focus on the return loss difficulties. A re-design of the horn throat will hopefully solve the problems.

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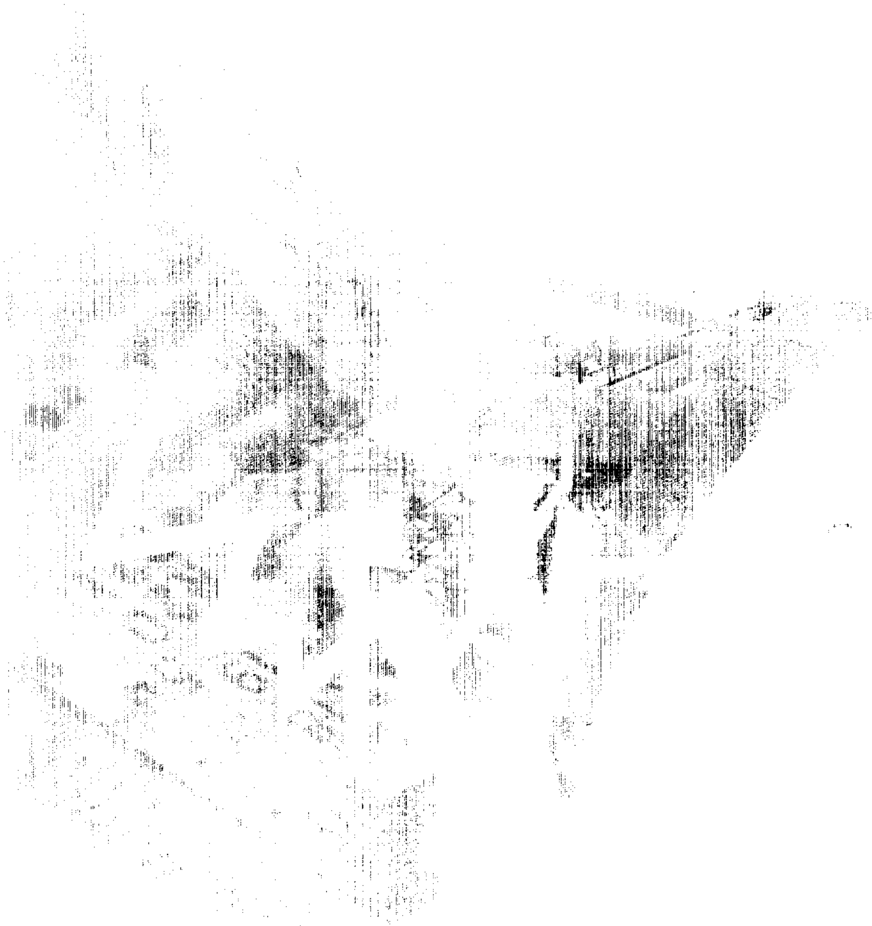

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IVS INFORMATION

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IVS Terms of Reference

1. Summary

1.1. Charter

The International VLBI Service for Geodesy and Astrometry (IVS) is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. IVS provides a service which supports geodetic and astrometric work on reference systems, Earth science research, and operational activities.

IVS is an official Service of the International Association of Geodesy (IAG) and of the International Astronomical Union (IAU).

1.2. Objectives

IVS fulfills its charter through the following objectives. The primary objective of IVS is to foster VLBI programs as a joint service. This is accomplished through close coordination to provide high-quality VLBI data and products.

The second objective of IVS is to promote research and development activities in all aspects of the geodetic and astrometric VLBI technique. This objective also supports the integration of new components into IVS. The further education and training of VLBI participants is supported through workshops, reports, electronic network connections, and other means.

The third objective of IVS is to interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system. IVS interacts closely with the International Earth Rotation Service (IERS) which is tasked by the IAU and IUGG with maintaining the international celestial and terrestrial reference frames and with monitoring Earth rotation.

To meet these objectives, IVS coordinates VLBI observing programs, sets performance standards for VLBI stations, establishes conventions for VLBI data formats and data products, issues recommendations for VLBI data analysis software, sets standards for VLBI analysis documentation, and institutes appropriate VLBI product delivery methods to ensure suitable product quality and timeliness. IVS closely coordinates its activities with the astronomical community because of the dual use of many VLBI facilities and technologies for both astronomy and astrometry/geodesy.

IVS accepts observing proposals for research and operational programs that conform to the IVS objectives.

1.3. Data Products

VLBI data products contribute uniquely to these important determinations:

- definition and maintenance of the celestial reference frame
- monitoring universal time (UT1) and length of day (LOD)
- monitoring the coordinates of the celestial pole (nutation and precession)

These results are the foundation of many scientific and practical applications requiring the use of an accurate inertial reference frame, such as high-precision navigation and positioning. IVS provides, through the collaborative efforts of its components, a variety of significant VLBI data products with differing applications, timeliness, detail, and temporal resolution, such as:

- all components of Earth orientation parameters at regular intervals
- terrestrial reference frame
- VLBI data in appropriate formats
- VLBI results in appropriate formats
- local site ties to reference points
- high-accuracy station timing data
- surface meteorology, tropospheric and ionospheric measurements

All VLBI data products are archived in IVS Data Centers and are publicly available.

1.4. Research

The VLBI data products are used for research in many related areas of geodesy, geophysics, and astrometry, such as:

- UT1 and polar motion excitation (over periods of hours to decades)
- solid Earth interior research (mantle rheology, anelasticity, libration, core modes, nutation/precession)
- characterization of celestial reference frame sources and improvements to the frame
- tidal variations (solid Earth, oceanic, and atmospheric)
- improvements in the terrestrial reference frame, especially in the vertical (scale) component
- climate studies

To support these activities, there are ongoing research efforts whose purpose is to improve and extend the VLBI technique in such areas as:

- improvements in data acquisition and correlation
- refined data analysis techniques
- spacecraft tracking (Earth-orbiting and interplanetary)
- combination of VLBI data and results with other techniques

2. Permanent Components

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic, astrometric, and other results, and archives and publicizes data products. IVS accomplishes its goals through the types of permanent components described in this section. IVS will accept proposals at any time for a permanent component. Such proposals will be reviewed by the Directing Board. The seven types of IVS permanent components are:

- Network Stations

- Operation Centers
- Correlators
- Analysis Centers
- Data Centers
- Technology Development Centers
- Coordinating Center

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic and astrometric results, and archives and publicizes data products. IVS accomplishes its goals through the operational components described below.

2.1. Network Stations

The IVS observing network consists of high performance VLBI stations.

- Stations can be dedicated to geodesy or have multiple uses (including astronomical observations or satellite tracking applications).
- Stations comply with performance standards for data quality and operational reliability set up by the Directing Board.
- VLBI data acquisition sessions are conducted by groups of Network Stations that are distributed either globally or over a geographical region.

2.2. Operation Centers

The IVS Operation Centers coordinate the routine operations of one or more networks. Operation Center activities include:

- planning network observing programs,
- establishing operating plans and procedures for the stations in the network,
- supporting the network stations in improving their performance,
- making correlator time available at an IVS Correlator,
- generating the detailed observing schedules for use in data acquisition sessions by IVS Network Stations,
- posting the observing schedule to an IVS Data Center for distribution and to the Coordinating Center for archiving.

IVS Operation Centers follow guidelines from the Coordinating Center for timeliness and schedule file formats. Operation Centers cooperate with the Coordinating Center in order to define:

- the annual master observing schedule,
- the use of antenna time,
- tape availability and shipping,
- the use of other community resources.

2.3. Correlators

The IVS Correlators process raw VLBI data and station log files following a data acquisition session. Their other tasks are to:

- provide immediate feedback to the Network Stations about problems that are apparent in the data,
- jointly maintain the geodetic/astrometric community's tape pool,
- make processed data available to the Analysis Centers,
- regularly compare processing techniques, models, and outputs to ensure that data from different Correlators are identical.

2.4. Analysis Centers

The IVS coordinates VLBI data analysis to provide high-quality products for its users. The analyses are performed by Analysis Centers and by Associate Analysis Centers.

Analysis Centers are committed to produce series of Earth Orientation Parameters (EOP) or series of individual EOP components, without interruption and at a specified time lag to meet IVS requirements. In addition, Analysis Centers produce station coordinates and source positions in regular intervals.

The Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Analysis Center makes from IVS recommendations are properly documented. Analysis Centers provide timely feedback about station performance. In addition to these regular services, Analysis Centers may also perform any task of an Associate Analysis Center.

Associate Analysis Centers are committed to regularly submit specialized products using complete series or subsets of VLBI observing sessions. The analysis is performed for specific purposes as recognized by the Directing Board such as exploitation of VLBI data for new types of results, investigations of regional phenomena, reference frame maintenance, or special determinations of Earth orientation parameters. The Associate Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Associate Analysis Center makes from IVS recommendations are properly documented.

2.5. Data Centers

The IVS Data Centers are repositories for VLBI observing schedules, station log files, and data products. Data Centers may mirror other Data Centers to make the distribution and maintenance of data more efficient and reliable.

- Data Centers are the primary means of distributing VLBI products to users.
- Data Centers work closely with the Coordinating Center and with the Analysis Centers to ensure that all the information and data required by IVS components are quickly and reliably available.

Data Centers provide the following functions:

- receive and archive schedule files from Operation Centers,
- receive and archive log files and ancillary data files from the Network Stations,
- receive and archive data products from the Analysis Centers,
- provide access and public availability to IVS data products for all users.

2.6. Technology Development Centers

The IVS Technology Development Centers contribute to the development of new VLBI technology. They may be engaged in hardware and/or software technology development, or evolve new approaches that will improve the VLBI technique and enhance compatibility with different data acquisition terminals. They will:

- design new hardware,
- investigate new equipment,
- develop new software for operations, processing or analysis,
- generate new information systems,
- develop, test, and document prototypes of new equipment or software,
- assist with deployment, installation, and training for any new approved technology.
- After dissemination of the new hardware or software, the centers may continue to provide maintenance and updating functions.

2.7. Coordinating Center

The IVS Coordinating Center is responsible for coordination of both the day-to-day and the long-term activities of IVS, consistent with the directives and policies established by the Directing Board. Specifically, the Coordinating Center monitors, coordinates, and supports the activities of the Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers. The Coordinating Center works closely with the Technology Coordinator, the Network Coordinator, and the Analysis Coordinator to coordinate all IVS activities.

The primary functions of the Coordinating Center are to:

- coordinate observing programs approved by the Directing Board,
- maintain the master schedule of observing sessions, coordinating the schedule with astronomical observing programs and with IVS networks,
- foster communications among all components of the IVS,
- define the best use of community resources,
- develop standards for IVS components,
- provide training in VLBI techniques,
- organize workshops and meetings, including an annual IVS technical meeting,
- produce and publish reports of activities of IVS components,

- maintain the IVS information system and archive all documents, standards, specifications, manuals, reports, and publications,
- provide liaison with the IERS, IAG, IAU, and other organizations,
- provide the Secretariat of the Directing Board.

3. Coordinators

Specific IVS activities for technology, network data quality, and data products are accomplished through the functions performed by three coordinators: a Network Coordinator, an Analysis Coordinator, and a Technology Coordinator.

3.1. Network Coordinator

The IVS Network Coordinator is selected by the Directing Board from responses to an open solicitation to all IVS components. The Network Coordinator represents the IVS Networks on the Directing Board and works closely with the Coordinating Center. The Network Coordinator is responsible for stimulating the maintenance of a high quality level in the station operation and data delivery. The Network Coordinator performs the following functions:

- monitors adherence to standards in the network operation,
- participates in the quality control of the data acquisition performance of the network stations,
- tracks data quality and data flow problems and suggests actions to improve the level of performance,

The Network Coordinator works closely with the geodetic and astronomical communities who are using the same network stations for observations. The Coordinator takes a leading role in ensuring the visibility and representation of the Networks.

3.2. Analysis Coordinator

The IVS Analysis Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Analysis Centers. The Analysis Coordinator is responsible for coordinating the analysis activities of IVS and for stimulating VLBI product development and delivery. The Analysis Coordinator performs the following functions:

- fosters comparisons of results from different VLBI analysis software packages and different analysis strategies,
- encourages analysis software documentation,
- participates in comparisons of results from different space geodetic techniques,
- monitors Analysis Centers' products for high quality results and for adherence to IVS standards and IERS Conventions,
- ensures that analysis products from all Analysis Centers are archived and available for the scientific community, and
- forms the official products of IVS, as decided by the IVS Directing Board, using a suitable combination of the analysis results submitted by the Analysis Centers.

The Analysis Coordinator works closely with the geodetic and astronomical communities who are using some of the same analysis methods and software. The Analysis Coordinator plays a leadership role in the development of methods for distribution of VLBI products so that the products reach the widest possible base of users in a timely manner. The coordinator promotes the use of VLBI products to the broader scientific community and interacts with the IVS Coordinating Center and with the IERS.

3.3. Technology Coordinator

The IVS Technology Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Technology Development Centers. The Technology Coordinator is responsible for coordinating the new technology activities of IVS and for stimulating advancement of the VLBI technique. The Technology Coordinator performs the following functions:

- maintains cognizance of all current VLBI technologies and ongoing development
- coordinates development of new technology among various IVS components
- helps promulgate new technologies to the geodetic/astrometric community
- strives to ensure the highest degree of global compatibility of VLBI data acquisition systems

The Technology Coordinator works closely with the astronomical community because of the many parallels between the technology development required for both groups.

4. Directing Board

4.1. Roles and Responsibilities

The Directing Board determines policies, adopts standards, and approves the scientific and operational goals for IVS. The Directing Board exercises general oversight of the activities of IVS including modifications to the organization that are deemed appropriate and necessary to maintain efficiency and reliability.

A specific function of the Board is to set scientific goals for the IVS observing program. The Board will establish procedures for external research programs and will review any proposals thus received.

The Board may determine appropriate actions to ensure the quality of the IVS products and that the IVS components maintain the adopted standards.

4.2. Membership

The Directing Board consists of appointed members who serve ex officio, members elected by the Directing Board, and members elected by the IVS components. The members are:

Appointed members ex officio:

- IAG representative
- IAU representative
- IERS representative
- Coordinating Center Director

Through a reciprocity agreement between IVS and IERS the IVS serves as the VLBI Technique Center for IERS, and as such its designated representative(s) serve on the IERS Directing Board. In turn, the IERS Directing Board designates a representative to the IVS Directing Board. This arrangement is to assure full cooperation between the two services.

Selected by Directing Board upon review of proposals from IVS Member Organizations:

- Technology, Network, and Analysis Coordinators (3 total)

Elected by Directing Board upon recommendation from the Coordinating Center (see below):

- Members at large (2)

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: 14

The four appointed members are considered ex officio and are not subject to institutional restrictions. The five members of the Directing Board who are elected by IVS Permanent Components must each be a member of a different IVS Member Organization. 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 as possible. All elected members serve staggered four-year terms once renewable.

A Board member who departs before the end of his/her term is replaced by a person selected by the Directing Board. The new member will serve for the remainder of the original term.

The three Coordinators are selected by the Directing Board on the basis of proposals from IVS Member Organizations. On a two-thirds vote the Directing Board may call for new proposals for any Coordinator when it determines that a new Coordinator is required. Coordinators are encouraged to give at least three months notice before resigning.

4.3. Elections

Election of Board members by the IVS components shall be conducted by a committee of three Directing Board members, the chair of which is appointed by the chair of the Directing Board. The committee solicits nominations for each representative from the relevant IVS components. For each position, the candidate who receives the largest number of votes from the Associate Members will be elected. In case of a tie the Directing Board will make the decision.

4.4. Chair

The chair is one of the Directing Board members and is elected by the Board for a term of four years with the possibility of reelection for one additional term. The chair is the official representative of IVS to external organizations.

4.5. Decisions

Most decisions by the Board are made by consensus or by simple majority vote of the members present. In case of a tie, the chair shall vote but otherwise does not vote. If a two-thirds quorum is not present, the vote shall be held later by electronic mail. A two-thirds vote of all Board members is required to modify the Terms of Reference, to change the chair, or to change any of the members elected by the Directing Board before the normal term expires.

4.6. Meetings

The Board meets at least annually, or more frequently if meetings are called by the chair or at the request of at least three Board members. The Board will conduct periodic reviews of the IVS organization and its mandate, functions, and components. The reviews should be done every four years.

5. Definitions

5.1. Member Organizations

Organizations that support one or more IVS components are IVS Member Organizations. Individuals associated with IVS Member Organizations may become IVS Associate Members.

5.2. Affiliated Organizations

Organizations that cooperate with IVS on issues of common interest, but do not support an IVS component, are IVS Affiliated Organizations. Affiliated Organizations express an interest in establishing and maintaining a strong working association with IVS to mutual benefit. Individuals affiliated with IVS Affiliated Organizations may become IVS Correspondents.

5.3. Associate Members

Individuals associated with organizations that support an IVS component may become IVS Associate Members. Associate Members are generally invited to attend non-executive sessions of the Directing Board meetings with voice but without vote. Associate Members take part in the election of the incoming members of the Directing Board representing the IVS components.

5.4. Corresponding Members

IVS Corresponding Members are individuals on a mailing list maintained by the Coordinating Center. They do not actively participate in IVS but express interest in receiving IVS publications, wish to participate in workshops or scientific meetings organized by IVS, or generally are interested in IVS activities. Ex officio corresponding members are the following:

- IAG General Secretary
- President of IAG Section II – Advanced Space Technology
- President of IAG Section V – Geodynamics
- President of IAU Division I – Fundamental Astronomy

- President of IAU Commission 19 – Rotation of the Earth
- President of IAU Commission 8 – Positional Astronomy
- President of IAU Commission 31 – Time
- President of IAU Commission 40 – Radio Astronomy
- President of URSI Commission J – Radio Astronomy

Individuals are accepted as IVS Corresponding Members upon request to the Coordinating Center.

IVS Member Organizations

(alphabetized by country)

Organization	Country
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
Chinese Academy of Sciences	China
Observatoire de Paris	France
Observatoire de Bordeaux	France
Deutsches Geodätisches Forschungsinstitut	Germany
Bundesamt für Kartographie und Geodäsie	Germany
Geodetic Institute of the University of Bonn	Germany
Istituto di Radioastronomia CNR	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
Communications Research Laboratory	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Institute of Applied Astronomy	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Institut d'Estudis Espacials de Catalunya	Spain
Instituto Geográfico Nacional	Spain
Chalmers University of Technology	Sweden
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
Joint Institute for VLBI in Europe (JIVE)	Netherlands
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National Radio Astronomy Observatory, Green Bank	U. S. Naval Observatory	USA
Hartebeesthoek Radio Astronomy Observatory	Hartebeesthoek Radio Astronomy Observatory	South Africa
Kashima 34m antenna	Communications Research Laboratory	Japan
Key Stone Project Koganei 11m antenna	Communications Research Laboratory	Japan
Key Stone Project Kashima 11m antenna	Communications Research Laboratory	Japan
Key Stone Project Miura 11m antenna	Communications Research Laboratory	Japan
Key Stone Project Tateyama 11m antenna	Communications Research Laboratory	Japan
Kokee Park Geophysical Observatory	National Earth Orientation Service	USA
Matera	Agenzia Spaziale Italiana	Italy
Medicina (Italy)	Istituto di Radioastronomia CNR	Italy
Mizusawa	National Astronomical Observatory of Japan	Japan
Noto (Sicily)	Istituto di Radioastronomia CNR	Italy
Ny Ålesund Geodetic Observatory	Norwegian Mapping Authority	Norway
ERS/VLBI Station O'Higgins	Bundesamt für Kartographie und Geodäsie	Germany
Onsala Space Observatory	Chalmers University of Technology	Sweden
Seshan	Shanghai Observatory, Chinese Academy of Sciences	China
Simeiz	Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
Svetloe Radio Astronomy Observatory	Institute of Applied Astronomy	Russia
JARE Syowa 11m antenna	National Institute of Polar Research	Japan
Transportable Integrated Geodetic Observatory (TIGO)	Bundesamt für Kartographie und Geodäsie	Germany

Tsukuba VLBI Station	Geographical Survey Institute	Japan
Nanshan VLBI Station of Urumqi Astronomical Observatory (UAO)	Shanghai Observatory, Chinese Academy of Sciences	China
Westford Antenna, Haystack Observatory	NASA Goddard Space Flight Center	USA
Fundamentalstation Wettzell	Bundesamt für Kartographie und Geodäsie and Forschungseinrichtung Satellitengeodäsie de Technischen Universität München	Germany
Observatorio Astronómico Nacional - Yebes	Instituto Geografico Nacional	Spain
Yellowknife Geophysical Observatory	Geodetic Survey Division, Natural Resources Canada	Canada

Operation Centers

Component Name	**Sponsoring Organization**	**Country**
Geodetic Institute Bonn	Geodätisches Institut der Universität Bonn	Germany
CORE Operation Center	NASA Goddard Space Flight Center	USA
NEOS Operation Center	National Earth Orientation Service	USA

Correlators

Component Name	**Sponsoring Organization**	**Country**
Astro/Geo Correlator at the Max-Planck-Institute for Radio Astronomy	Bundesamt für Kartographie und Geodäsie and Geodätisches Institut der Universität Bonn	Germany
Communications Research Laboratory	Communications Research Laboratory	Japan
MIT Haystack Observatory Correlator	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Correlator	Institute of Applied Astronomy	Russia
Tsukuba VLBI Center	Geographical Survey Institute	Japan
Washington Correlator	National Earth Orientation Service	USA

Data Centers

Component Name	Sponsoring Organization	Country
BKG, Leipzig	Bundesamt für Kartographie und Geodäsie	Germany
Communications Research Laboratory	Communications Research Laboratory	Japan
Crustal Dynamics Data Information System (CDDIS)	NASA Goddard Space Flight Center	USA
GeoDAF	Agenzia Spaziale Italiana	Italy
Italy CNR	Istituto di Radioastronomia CNR	Italy
Observatoire de Paris	Observatoire de Paris	France

Analysis Centers

Component Name	Sponsoring Organization	Country
Astronomical Institute of St.-Petersburg University	Astronomical Institute of St.-Petersburg University	Russia
Bordeaux Observatory	Observatoire de Bordeaux	France
Centro di Geodesia Spaziale (CGS)	Agenzia Spaziale Italiana	Italy
Communications Research Laboratory	Communications Research Laboratory	Japan
DGFI	Deutsches Geodätisches Forschungsinstitut	Germany
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
GIUB-BKG Analysis Center	Geodätisches Institut der Universität Bonn and Bundesamt für Kartographie und Geodäsie	Germany
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Analysis Center	Institute of Applied Astronomy	Russia
Institute of Geodesy and Geophysics Analysis Center	Institute of Geodesy and Geophysics/University of Technology, Vienna	Austria
Italy CNR	Istituto di Radioastronomia CNR	Italy
Jet Propulsion Laboratory	Jet Propulsion Laboratory	USA
Main Astronomical Observatory	National Academy of Sciences, Kiev	Ukraine
NAOJ	National Astronomical Observatory of Japan	Japan
Observatoire de Paris	Observatoire de Paris	France
Onsala Space Observatory	Chalmers University of Technology	Sweden

Shanghai Observatory	Shanghai Observatory, Chinese Academy of Sciences	China
U. S. Naval Observatory	U. S. Naval Observatory	USA
USNO Analysis Center for Source Structure	U. S. Naval Observatory	USA

Technology Development Centers

Component Name	Sponsoring Organization	Country
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Communications Research Laboratory	Communications Research Laboratory	Japan
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
MIT Haystack Observatory	National Earth Orientation Service	USA
Institute of Applied Astronomy Technology Development Center	Institute of Applied Astronomy	Russia
Institut d'Estudis Espacials de Catalunya	Institut d'Estudis Espacials de Catalunya	Spain
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List of Acronyms

AGU	American Geophysical Union
AIPS	Astronomical Image Processing System
APSG	Asia-Pacific Space Geodynamics Project
APT	Asia Pacific Telescope
ARIES	Astronomical Radio Interferometric Earth Surveying program
ARO	Algonquin Radio Observatory (Canada)
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ATNF	Australia Telescope National Facility (Australia)
BIPM	Bureau International des Poids et Measures (France)
BKG	Bundesamt für Kartographie und Geodäsie (Germany)
CAS	Chinese Academy of Sciences (China)
CDDIS	Crustal Dynamics Data Information System (USA)
CDP	Crustal Dynamics Project (USA)
CGLBI	Canadian Geodetic Long Baseline Interferometry (Canada)
CGS	Centro di Geodesia Spaziale (Italy)
CNR	Consiglio Nazionale delle Ricerche (Italy)
CORE	Continuous Observations of the Rotation of the Earth
COTS	Commercial-Off-The-Shelf
CRAAE	Center for Radio Astronomy and Space Applications (Brazil)
CRF	Celestial Reference Frame
CRL	Communications Research Laboratory (Japan)
CTVA	Canadian Transportable VLBI Antenna (Canada)
DAR	Data Acquisition Rack
DAS	Data Acquisition System
DAT	Data Acquisition Terminal OR Digital Audio Tape
DGFI	Deutsches Geodätisches ForschungsInstitut (Germany)
DLR	Deutsche Forschungsanstalt für Luft – und Raumfahrt (Germany)
DOMES	Directory Of MERIT Sites
DORIS	Doppler Orbitography by Radiopositioning Integrated on Satellite
DRAO	Dominion Radio Astrophysical Observatory (Canada)
DSN	Deep Space Network
EOP	Earth Orientation Parameters
ESA	European Space Agency
ESO	European Southern Observatory
EU	European Union
EVN	European VLBI Network
FFI	Forsvarets ForskningsInstitutt (Norwegian Defence Research Establishment) (Norway)
FGS	Forschungsgruppe Satellitengeodäsie (Germany)
FITS	Flexible Image Transport System
FS	Field System
FTP	File Transfer Protocol

GALAXY	Giga-bit Astronomical Large Array with cross connect (Japan)
GAPE	Great Alaska and Pacific Experiment
GARNET	GSI Advanced Radiotelescope NETwork (Japan)
GARS	German Antarctic Receiving Station (Antarctica)
GCGO	Gilmore Creek Geophysical Observatory (USA)
GEMSTONE	GEodetic Measurements by the colocation of Space Technique ON Earth (Japan)
GEX	Giga-bit VLBI system performance check EXperiments
GGAO	Goddard Geophysical and Astronomical Observatory (USA)
GIPSY	GPS Inferred Positioning SYstem
GIUB	Geodetic Institute of the University of Bonn (Germany)
GLONASS	GLObal NAvigation Satellite System
GLORIA	GLObal Radio Interferometry Analysis
GPS	Global Positioning System
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)
GUI	Graphical User Interface
GeoDAF	Geodetical Data Archive Facility (Italy)
HartRAO	Hartebeesthoek Radio Astronomy Observatory (South Africa)
HTSI	Honeywell Technology Solutions Incorporated (USA)
IAA	Institute of Applied Astronomy (Russia)
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IEEC	Institut d'Estudis Espacials de Catalunya (Spain)
IERS	International Earth Rotation Service
IGG	Institute of Geodesy and Geophysics (Austria)
IGGOS	Integrated Global Geodetic Observing System
IGM	Instituto Geográfico Militar (Chile)
IGN	Instituto Geográfico Nacional (Spain)
IGS	International GPS Service
ILRS	International Laser Ranging Service
IMF	Isobaric Mapping Function
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
IRA	Istituto di RadioAstronomia (Italy)
IRIS	International Radio Interferometric Surveying
ISAS	Institute of Space and Astronautical Sciences (Japan)
ITIS	Istituto di Tecnologia Informatica Spaziale (Italy)
ITRF	International Terrestrial Reference Frame
ITSS	(Raytheon) Information Technology and Science Services (USA)
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI (Japan)

JARE	Japanese Antarctic Research Expedition (Japan)
JIVE	Joint Institute for VLBI in Europe (Netherlands)
JMA	Japan Meteorological Agency (Japan)
JPL	Jet Propulsion Laboratory (USA)
KPGO	Kokee Park Geophysical Observatory (USA)
KSP	Key Stone Project (Japan)
LNA	Low Noise Amplifier
MERIT	Monitoring of Earth Rotation and Intercomparison of Techniques
MIT	Massachusetts Institute of Technology (USA)
MLRO	Matera Laser Ranging Observatory (Italy)
MPI	Max-Planck-Institute (Germany)
MPIfR	Max-Planck-Institute for Radioastronomy (Germany)
MRI	Meteorological Research Institute of JMA (Japan)
MTLRS	Modular Transportable Laser Ranging System
NAO	National Astronomical Observatory (China, also Japan)
NASA	National Aeronautics and Space Administration (USA)
NEOS	National Earth Orientation Service (USA)
NGS	National Geodetic Survey (USA)
NIPR	National Institute of Polar Research (Japan)
NMA	Norwegian Mapping Authority (Norway)
NMF	Niell Mapping Function
NOAA	National Oceanic and Atmospheric Administration (USA)
NRAO	National Radio Astronomy Observatory (USA)
NRCan	Natural Resources Canada (Canada)
NVI	NVI, Inc. (USA)
OAN	Observatorio Astronómico Nacional (Spain)
OPAR	PARis Observatory (France)
OSO	Onsala Space Observatory (Sweden)
PRARE	Precision RAnge and Range-rate Experiment
RAS	Russian Academy of Sciences (Russia)
ROEN	Rádio-Observatório Espacial do Nordeste (Brazil)
SEFD	System Equivalent Flux Density
SGL	Space Geodynamics Laboratory (Canada)
SHAO	SHanghai Astronomical Observatory (China)
SINEX	Solution INdependent EXchange format
SLR	Satellite Laser Ranging
SPBU	Saint-PetersBurg University (Russia)
STDN	Satellite Tracking Data Network
SWT	SW Technology (USA)
TAC	Totally Accurate Clock
TIGO	Transportable Integrated Geodetic Observatory (Germany)
TMR	Training and Mobility of Researchers program of the European Community
ToR	IVS Terms of Reference
TRF	Terrestrial Reference Frame
UAO	Urumqi Astronomical Observatory (China)

URSI	International Radio Science Union
USNO	U. S. Naval Observatory (USA)
UT1	Universal Time
UTC	Coordinated Universal Time
VERA	VLBI Exploration of Radio Astrometry
VEX	VLBI EXperiment Language
VLBA	Very Long Baseline Array (USA)
VLBI	Very Long Baseline Interferometry
VSI	VLBI Standard Interface
VSOP	VLBI Space Observatory Program
WACO	WAshington COrrelator (USA)
WGRF	Working Group on Reference Frames
WRMS	Weighted RMS
WVR	Water Vapor Radiometer
WWW	World Wide Web

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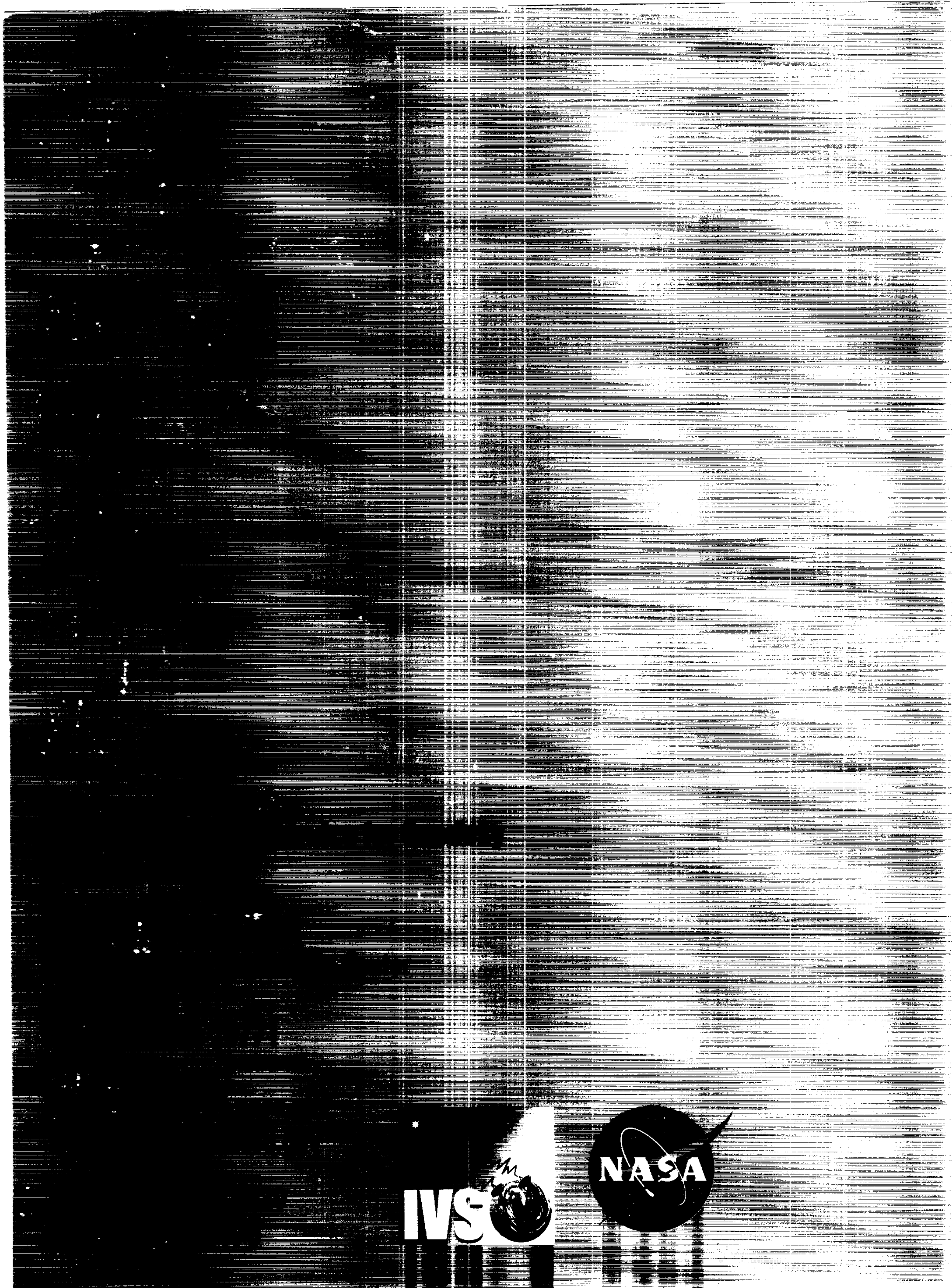
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