# 2004 IVS 3rd GENERAL MEETING

*Today's Results and Tomorrow's Vision*

**Ottawa, Canada**
February 9-11

IVS 3rd GENERAL MEETING 2004 Ottawa, Canada • February 9-11

hosted by
**Geodetic Survey Division, Natural Resources Canada**

http://ivscc.gsfc.nasa.gov/meetings/gm2004

**International VLBI Service for Geodesy and Astrometry**

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# SCHEDULE

## Monday, February 9, 2004

| | |
|---|---|
| 09:00-10:45 | Session 1. VLBI: Today's Results and Tomorrow's Vision |
| 10:45-11:15 | Break |
| 11:15-12:15 | Session 1. (continued) |
| 12:15-13:45 | Lunch |
| 13:45-15:30 | Session 2. VLBI2010 |
| 15:30-16:00 | Break |
| 16:00-17:45 | Session 2. (continued) |
| 17:45-19:30 | Poster Sessions and Refreshments |

## Tuesday, February 10, 2004

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|---|---|
| 08:30-10:00 | Session 3. Network Stations, Operation Centers, Correlators |
| 10:00-10:30 | Break |
| 10:30-11:30 | Session 3. (continued) |
| 11:30-13:00 | Lunch |
| 13:00-14:30 | Session 4. New Technology Developments in VLBI |
| 14:30-15:00 | Break |
| 15:00-17:15 | Session 4. (continued) |
| 18:00 | Banquet |

## Wednesday, February 11, 2004

| | |
|---|---|
| 08:30-10:30 | Session 5. Analysis Strategies and Software |
| 10:30-11:00 | Break |
| 11:00-12:00 | Session 6. Results and Geodetic/Geophysical/Astrometric Interpretation |
| 12:00-13:30 | Lunch |
| 13:30-15:30 | Session 6. (continued) |
| 15:30-16:00 | Break |
| 16:00-18:00 | Session 6. (continued) |

# PROGRAM

### Monday, February 9, 2004

## Session 1. VLBI: Today's Results and Tomorrow's Vision
## Chair: Wayne Cannon

**9:00 Welcome by host Natural Resources Canada**

**9:15 1-01 Welcome by IVS Chair and Chair's Report**
Wolfgang Schlüter, Bundesamt für Kartographie und Geodäsie (BKG)

**9:30 1-02 Coordinating Center Report**
Nancy Vandenberg, NVI, Inc./GSFC

**9:45 1-03 The ICRF: 2010 and Beyond** *(invited)*
Patrick Charlot, Observatoire de Bordeaux

**10:15 1-04 VLBI and the Earth's Rotation: Geophysical and Geodetic Challenges** *(invited)*
Martine Feissel-Vernier (1), Jim Ray (2), Veronique Dehant (3), Olivier de Viron (3), (1) Paris Observatory and IGN, (2) Bureau International des Poids et Mesures, (3) Observatoire Royal de Belgique

**10:45 Break**

## Session 1. VLBI: Today's Results and Tomorrow's Vision (cont.)
## Chair: Wolfgang Schlüter

**11:15 1-05 IGGOS – Its Mission, Scientific Rationale, and First Steps and Ideas for Its Design and Development** *(invited)*
Christoph Reigber, GeoForschungsZentrum Potsdam (GFZ), Hermann Drewes, DGFI

**11:45 1-06 Earth Rotation Dynamics: Review and Prospects** *(invited)*
Benjamin Chao, NASA/GSFC

**12:15 Lunch**

## Session 2. VLBI2010
## Chair: Alan Whitney

**13:45 2-01 The International Global Network of Geodetic Fiducial Stations** *(invited)*
John LaBrecque, NASA

**14:15 2-02 VLBI2010: Networks and Observing Strategies**
Bill Petrachenko (1), Brian Corey (2), Ed Himwich (3), Chopo Ma (4), Zinovy Malkin (5), Arthur Niell (2), David Shaffer (6), Nancy Vandenberg (3), (1) Natural Resources Canada, (2) MIT Haystack Observatory, (3) NVI, Inc./GSFC, (4) NASA/GSFC, (5) Institute of Applied Astronomy, (6) Radiometrics, Inc.

**14:30 2-03 Preliminary Results of VLBI2010 Subgroup "RF/IF, Frequency and Time"**
Hayo Hase (1), Brian Corey (2), Yasuhiro Koyama (3), Dave Shaffer (4), Bill Petrachenko (5), Wolfgang Schlüter (1), (1) BKG, (2) MIT Haystack Observatory, (3) Communications Research Laboratory, (4) Radiometrics Inc., (5) Natural Resources Canada

**14:45 2-04 Standard Observing Bands: Is Now the Time To Replace S/X with X/Ka?**
Chris Jacobs, Gabor Lanyi, and Charles Naudet, Jet Propulsion Laboratory

**15:00 2-05 VLBI at Some Higher Frequencies, an Overview**
Chopo Ma (1), David Gordon (2), Chris Jacobs (3), Gabor Lanyi (3), Charles Naudet, (3), Alan Fey (4), David Boboltz (4), Ed Fomalont (5), Patrick Charlot (6), Ojars Sovers (7), (1) NASA/GSFC, (2) Raytheon/GSFC, (3) Jet Propulsion Laboratory, (4) U.S. Naval Observatory, (5) National Radio Astronomy Observatory, (6) Bordeaux Observatory, (7) Remote Sensing Analysis Systems

**15:15 2-06 Backend Systems -- Perspectives in 2010**
Gino Tuccari (1), Alan Whitney (2), Hans Hinteregger (2), Yasuhiro Koyama (3), Tetsuro Kondo (3), (1) IRA CNR, (2) MIT Haystack Observatory, (3) Communications Research Laboratory

**15:30 Break**

## Session 2. VLBI2010 (cont.)
## Chair: Arthur Niell

**16:00 2-07 Data-Acquisition and Transport – Look Forward to 2010 and Beyond**
Alan Whitney (1), Hans Hinteregger (1), Tetsuro Kondo (2), Yasuhiro Koyama (2), (1) MIT Haystack Observatory, (2) Communications Research Laboratory

**16:15 2-08 Correlators in 2010 and Beyond**
Yasuhiro Koyama (1), Tetsuro Kondo (1), Bill Petrachenko (2), Hans Hinteregger (3), and Alan Whitney (3), (1) Kashima Space Research Center, CRL (2) Natural Resources Canada, (3) MIT Haystack Observatory

**16:30 2-09 Subgroup "Data Analysis" of Working Group 3 VLBI2010**
Harald Schuh, Vienna University of Technology

**16:45 2-10 VLBI Data Longevity Beyond 2010**
Chopo Ma, NASA/GSFC

**17:00 2-11 Future Directions on the VLBA**
R. Craig Walker, National Radio Astronomy Observatory

**17:15 2-12 Impact of Interstellar Scintillation on Astrometric VLBI**
David Jauncey (1), Jim Lovell (1), Roopesh Ojha (1), Alan Fey (2), Yasuhiro Koyama (3), Hayley Bignall (4), Lucyna Kedziora-Chudczer (5), Jean-Pierre Macquart, (6), Barney Rickett (7), Tasso Tzioumis, (1) Australia Telescope National facility, CSIRO, Australia, (2) USNO, (3) CRL Kashima

**17:30 Sessions 1 and 2 Poster Overview**
Arthur Niell, MIT Haystack Observatory

**17:45 Poster Sessions and Refreshments**

## Tuesday, February 10, 2004

## Session 3. Network Stations, Operation Centers, Correlators
## Chair: Hayo Hase

**8:30 3-01 Correlator Experiences with Mark 5 in Operation** *(invited)*
Arno Mueskens (1), Walter Alef (2), David Graham (2), Geodetic Institute of the University of Bonn, (2) Max-Planck Institut for Radioastronomie

**9:00 3-02 Recent Results from the EVN Mk4 Data Processor at JIVE**
Bob Campbell, Joint Institute for VLBI in Europe

**9:15 3-03 Washington Correlator Update**
Kerry Kingham, U.S. Naval Observatory

**9:30 3-04 Overview of Geodetic Experiments at the Bonn Correlator**
Alessandra Bertarini, Arno Mueskens, Alexandra Hoefer, Geodetic Institute of the University of Bonn

**9:45 3-05 Network Coordinator's Report**
Ed Himwich, NVI, Inc./GSFC

**10:00 Break**

## Session 3. Network Stations, Operation Centers, Correlators (cont.)
## Chair: Kerry Kingham

**10:30 3-06 Present Status and Future Plan on the Chinese VLBI Network**
Zhihan Qian, Shuhua Ye, Xiaoyu Hong, Xiuzhong Zhang, Jin Zhang and Xizhen Zhang, Shanghai Astronomical Observatory, CAS

**10:45 3-07 VLBI-GPS Collocation Results in Japan**
Shigeru Matsuzaka, Y. Masaki, Hiromichi Tsuji, Kazuhiro Takashima, T. Tsutsumi, M. Ishimoto, M. Machida, H. Wada, Shinobu Kurihara, Geographical Survey Institute, Japan

**11:00 3-08 Status and Plan of Geodetic and Astrometric Observations with VERA**
Seiji Manabe, Yoshiaki Tamura, Takaaki Jike, Koji Horiai and VERA team, National Astronomical Observatory of Japan

**11:15 Session 3 Poster Overview**
Kerry Kingham, U. S. Naval Observatory

**11:30 Lunch**

## Session 4. New Technology Developments in VLBI
## Chair: Shigeru Matsuzaka

**13:00 4-01 The Mark 5B VLBI Data System**
Alan Whitney, Will Aldrich, John Ball, Brian Fanous, Dan Smythe, MIT Haystack Observatory

**13:15 4-02 Gbit/s VLBI and eVLBI with Off-the-Shelf Components**
Jouko Ritakari, Ari Mujunen, Metsähovi Radio Observatory

**13:30 4-03 Current Status of Software Correlators Developed at Kashima Space Research Center**
Tetsuro Kondo, Moritaka Kimura, Yasuhiro Koyama, Hiro Osaki, Kashima Space Research Center/CRL

**13:45 4-04 SOFTC: An Operational Software Correlator**
Stephen Lowe, Jet Propulsion Laboratory

**14:00 4-05 eVLBI Developments in Europe**
Stephen Parsley, Zsolt Paragi, Sergei Pogrebenco, Cormac Reynolds, Arpad Szomoru, Joint Institute for VLBI in Europe (JIVE)

**14:15 4-06 E-VLBI Progress of the Chinese VLBI Network**
Zheng Weimin, Zhang Xiuzhong, Shu Fengchun, Shanghai Astronomical Observatory, Chinese Academy of Sciences

**14:30 Break**

## Session 4. New Technology Developments in VLBI (cont.)
## Chair: Alan Whitney

**15:00 4-07 Transporting VLBI Data Across Long Fat Networks: A Practical Approach**
David Lapsley, MIT Haystack Observatory

**15:15 4-08 Geodetic VLBI Experiments with the K5 System**
Yasuhiro Koyama (1), Tetsuro Kondo (1), Hiro Osaki (1), Masaki Hirabaru (1), Kazuhiro Takashima (2), Kazuo Sorai (3), Hiroshi Takaba (4), Kenta Fujisawa (5), David Lapsley (6), Kevin Dudevoir (6), Alan Whitney (6), (1) Communications Research Laboratory, (2) Geographical Survey Institute of Japan (GSI), (3) Hokkaido U., (4) Gifu U., (5) Yamaguchi U., (6) MIT Haystack Observatory

**15:30 4-09 Millimeter Wave Multi-Channel Receivers System for VLBI**
Seog-Tae Han, Korea Astronomy Observatory

**15:45 4-10 DBBC - A Wide Band Digital Base Band Converter**
Gino Tuccari, IRA CNR

**16:00 4-11 Toward Standard Wideband Digital Backends for Next-Generation Radio Astronomy: ATNF, LOFAR, (e)-VLBI, ATA, SKA**
Hans Hinteregger, MIT Haystack Observatory

**16:15 4-12 VLBI Observation for Spacecraft Navigation (NOZOMI) – Data Processing and Analysis Status Report**
Mamoru Sekido (1), Ryuichi Ichikawa (1), Hiro Osaki (1), Tetsuro Kondo (1), Yasuhiro Koyama (1), Makoto Yoshikawa (2), Takafumi Ohnishi (3),Wayne Cannon (4), Alexander Novikov (4), Mario Berube (5), (1) Kashima Space Research Center, CRL, (2) ISAS/JAXA, (3) Fujitsu Co. Ltd, (4) SGL/CRESTech, (5) Natural Resources Canada

**16:30 Session 4 Poster Overview**
Alan Whitney, MIT Haystack Observatory

**16:45 Session 5 Poster Overview**
Volker Tesmer, DGFI

**17:00 Session 6 Poster Overview**
Rüdiger Haas, Onsala Space Observatory

**18:00 Banquet**

### Wednesday, February 11, 2004

## Session 5. Analysis Strategies and Software
## Chair: Calvin Klatt

**8:30 5-01 MODEST: A Tool for Geodesy and Astrometry**
Ojars Sovers (1), Chris Jacobs (2), Gabor Lanyi (2), (1) Remote Sensing Analysis Systems, (2) Jet Propulsion Laboratory/NASA

**8:45 5-02 OCCAM v.6.0 Software for VLBI Data Analysis**
Oleg Titov (1), Volker Tesmer (2), Johannes Boehm (3), (1) Geoscience Australia, (2) DGFI, (3) Vienna University of Technology

**9:00 5-03 Past, Present and Future of Sked**
John Gipson, NVI, Inc/GSFC

**9:15 5-04 Residual Plotting and Ambiguity Resolution in Calc/Solve**
Volkmar Thorandt, Gerald Engelhardt, Bundesamt für Kartographie und Geodäsie (BKG)

## Session 5. Analysis Strategies and Software (cont.)
## Chair: Harald Schuh

**9:30 5-05 An Advanced Stochastic Model for VLBI Observations and its Application to VLBI Data Analysis**
Volker Tesmer, Hansjoerg Kutterer, DGFI

**9:45 5-06 Vienna Mapping Functions in VLBI Analyses**
Johannes Boehm, Harald Schuh, Vienna University of Technology

**10:00 5-07 Reliability Measures for Geodetic VLBI Products**
Hansjoerg Kutterer, DGFI

**10:15 5-08 Activities of the IVS Analysis Center at BKG in 2003**
Gerald Engelhardt, Volkmar Thorandt, Dieter Ullrich, Bundesamt für Kartographie und Geodäsie (BKG)

**10:30 Break**

# Session 6. Results and Geodetic/Geophysical/Astrometric Interpretation
## Chair: Rüdiger Haas

**11:00 6-01 Refinement of the ICRF**
Chopo Ma, NASA Goddard Space Flight Center

**11:15 6-02 Status of the International Celestial Reference Frame**
Alan Fey, U.S. Naval Observatory

**11:30 6-03 VLBA Impact on Geodesy and Astrometry**
David Gordon, Raytheon/Goddard Space Flight Center

**11:45 6-04 The VLBI Contribution to Precession (Present and Future)**
Nicole Capitaine (1), Patrick Wallace (2), (1) Observatoire de Paris/SYRTE, France, (2) HM Nautical Almanac Office, Rutherford Appleton Laboratory, UK,

**12:00 Lunch**

**13:30 6-05 Ring Downs of Free Core Nutations in the GSFC and USNO VLBI Nutation Series** *(Invited)*
Douglas Smylie, Andrew Palmer, York University

**14:00 6-06 Viscosity of the Earth's Fluid Core from VLBI Data**
George Krasinsky, Institute of Applied Astronomy, RAS

**14:15 6-07 Contribution of VLBI to Earth Orientation Monitoring: State-of-the-Art and Future Prospects**
Daniel Gambis, Christian Bizouard, Observatoire de Paris

**14:30 6-08 UT1 Intensive Series Using K4 Technology**
Dorothee Fischer (1), Richard Kilger (2), Shinobu Kurihara (3), Axel Nothnagel (1), Wolfgang Schlüter (2), Kazuhiro Takashima (3), (1) Geodetic Insitute of the University of Bonn, (2) Bundesamt für Kartographie und Geodäsie, (3) Geographical Survey Institute of Japan

**14:45 6-09 Considering a priori Correlations in the IVS Combined EOP Series**
Christoph Steinforth, Axel Nothnagel, Geodetic Institute of the University Bonn

**15:00 6-10 CONT02 campaign - Combination of VLBI with GPS**
Volker Tesmer (1), Manuela Kruegel (1), Detlef Angermann (1), Daniela Thaller (2), Markus Rothacher (2), Ralf Schmid (2), (1) DGFI, (2) Technische Universitaet Muenchen

**15:15 6-11 First Results of SINEX Combinations**
Markus Vennebusch, Geodetic Institute of the University Bonn

**15:30 Break**

## Session 6. Results and Geodetic/Geophysical/Astrometric Interpretation (cont.)
## Chair: Zinovy Malkin

**16:00 6-12 Evaluation of Global Ionosphere TEC Map by Comparison with VLBI Data** *(invited)*
Mamoru Sekido, Tetsuro Kondo, Eiji Kawai, and Michito Imae, Communications Research Laboratory

**16:30 6-13 How VLBI Contributes to Ionospheric Research**
Thomas Hobiger, Harald Schuh, Vienna University of Technology

**16:45 6-14 Limitations to Dual Frequency Ionospheric Corrections for Frequency Switched K-Q Observations with the VLBA**
Gabor Lanyi (1), David Gordon (2), Ojars Sovers (3), (1) Jet Propulsion Laboratory, (2) Raytheon/GSFC, (3) Remote Sensing Analysis Systems

**17:00 6-15 Tropospheric Parameters Estimated by Geodetic VLBI Data**
Monia Negusini, Paolo Tomasi, Istituto di Radioastronomia, Bologna, Italy

**17:15 6-16 Mass Loading Effects on Crustal Displacements Measured by VLBI**
Daniel MacMillan, NVI, Inc./GSFC

**17:30 6-17 First Results of the IVS Pilot Project "Time Series of Baseline Lengths"**
Axel Nothnagel, Geodetic Institute of the University of Bonn

**17:45 6-18 Preliminary Results of the IVS Gravity Experiment grav01**
Leonid Petrov, NVI, Inc./GSFC

# Posters

## Session 1P. VLBI: Today's Results and Tomorrow's Vision

**1-01P 5,000,000 Delays – Some Statistics**
Zinovy Malkin, Institute of Applied Astronomy RAS

## Session 2P. VLBI2010

**2-01P Worlds of 1996, 2003, and 2010**
Ari Mujunen, Jouko Ritakari, Metsähovi Radio Observatory

**2-02P Vienna Students Project (VSP) – A VLBI Experiment by Students**
Wolfgang Winkler, et al., University of Technology, Vienna

## Session 3P. Network Stations, Operation Centers, Correlators

**3-01P Present Status of the Korean VLBI Network Construction**
Young Chol Minh, Korea Astronomy Observatory

**3-02P Projects at TIGO**
H. Hase (1), S. Sobarzo (2), C. Jara (2), R. Aedo (3), G. Remedi (3), M. Moreno (2), M. Sanchez (2), G. Hermosilla (2), (1) BKG, (2) UdeC, (3) UBioBio

**3-03P New Technologies for the Real 3D Reference Point Determination**
Maria Hennes, Cornelia Eschelbach, Geodetic Institute, University of Karlsruhe

**3-04P VLBI Status of the Bear Lakes Radio Astronomy Station**
Igor Molotov (1), Yurii Gorshenkov (2), Alexander Stepanov (1), Boris Lipatov (3), Gino Tuccari (4), Valery Saurin (2), Alexis Zinoviev (1), (1) Central Pulkovo Astronomical Observatory, (2) Power Engineering Institute, (3) Radio Physical Research institute, (4) Istituto di Radioastronomia CNR

**3-05P Some Results of the First Year of Participation of the Svetloe Observatory in IVS Observing Programs**
Andrey Finkelstein, Valery Gratchev, Alexander Ipatov, Zinovy Malkin, Ismail Rahimov, Elena Skurikhina, Sergey Smolentsev, Institute of Applied Astronomy RAS

**3-06P Radio Astronomy Observatories in Svetloe, Zelenchukskaya and Badary of VLBI Network QUASAR**

Andrey Finkelstein, Alexander Ipatov, Sergey Smolentsev, Institute of Applied Astronomy, Russian Academy of Sciences

**3-07P The New 40-m Radiotelescope of the Spanish National Geographical Institute (IGN) at Yebes**

Maria Rioja, Observatorio Astronomico Nacional (OAN), Spain

## Session 4P. New Technology Developments in VLBI

**4-01P FS Developments**

Ed Himwich (1), Ray Gonzalez (1), Jonathan Quick (2), John Gipson (1), (1) NVI, Inc./GSFC, (2) Hartebeesthoek Radio Astronomy Observatory

**4-02P The Data Acquisition System Developed for Quasar Network**

Alexander Ipatov, Nikolay Koltsov, Leonid Fedotov, Institute of Applied Astronomy, Russian Academy of Sciences

**4-03P Data Acquisition System of Korean VLBI Network**

Duk-Gyoo Roh, Korea Astronomy Observatory

**4-04P New Correlator PARSEC**

Valery Gratchev, Institute of Applied Astronomy, RAS

**4-05P VLBI@home – VLBI Correlator by GRID Computing System**

Takeuchi Hiroshi, Kondo Tetsuro, Koyama Yasuhiro, and Nakajima Junichi, Kashima Space Research Center/CRL

**4-06P A Near Real Time e-Radar/VLBI Network**

Gino Tuccari (1), Igor Molotov (2), S. Buttaccio (1), G. Nicotra (1), B. Lipatov (3), Alexis Zinoviev (2), Y. Gorshenkov (4), L. Xiang (5), Xiaoyu Hong (6), Alexnder Volvach (7), (1) Istituto di Radioastronomia CNR, (2) Central Pulkova Astronomical Observatory, (3) Radio Physical Research Institute, (4) Power Engineering Institute, (5) Urumqi Astronomical Observatory, (6) Shanghai Astronomical Observatory, (7) Crimean Astrophysical Observatory

**4-07P An Evaluation of VLBI Observations for Deep Space Tracking of Interplanetary Spacecraft**

Ryuichi Ichikawa (1), Mamoru Sekido (1), Hiro Osaki (1), Yasuhiro Koyama (1), Tetsuro Kondo (1), T. Ohnishi (1), M. Yoshikawa (1), Wayne Cannon (2), Alexander Novikov (2), Mario Berube (3), (1) Kashima Space Research Center/CRL, (2) SGL/CRESTech, (3) Natural Resources Canada

## Session 5P. Analysis Strategies and Software

**5-01P VLBI Analysis at Bordeaux Observatory**
P. Charlot, A. Bellanger, A.Baudry, Observatoire de Bordeaux

**5-02P Calc: The Next Upgrade**
David Gordon, Raytheon/GSFC

**5-03P Project: Global Analysis of 1979-2004 VLBI Data**
Vadim Gubanov, Institute of Applied Astronomy, RAS

**5-04P VLBI Analysis at the United States Naval Observatory**
David Hall, David Boboltz, Alan Fey, Kerry Kingham, U.S. Naval Observatory

**5-05P Modeling Vertical Total Electron Content from VLBI Observations**
Thomas Hobiger, Harald Schuh, Vienna University of Technology

**5-06P Towards an IVS Analysis Conventions**
Zinovy Malkin, Institute of Applied Astronomy RAS, St. Petersburg, Russia

**5-07P Solve: Past, Present and Future**
Leonid Petrov (1), Chopo Ma (2), James Ryan (3), John Gipson (1), Karen Baver (4), Volkmar Thorandt (5), Gerald Engelhardt (5), (1) NVI, Inc./GSFC, (2) NASA/GSFC, (3) NASA/GSFC Retired, (4) Raytheon/GSFC, (5) BKG

**5-08P An Embedded Expert System for the Automation of the VLBI Data Analysis: Concept, Implementation and Results**
Wolfgang Schwegmann, Bundesamt für Kartographie und Geodäsie

**5-09P Towards an Operational Automatic VLBI Data Analysis Tool for INTENSIVE Sessions**
Wolfgang Schwegmann, Volkmar Thorandt, Gerald Engelhardt, Bundesamt für Kartographie und Geodäsie

**5-10P Simultaneous Estimation of a TRF, the EOP and a CRF from VLBI Observations - First DGFI Results using OCCAM**
Volker Tesmer, Hansjoerg Kutterer, Hermann Drewes, DGFI

## Session 6P. Results and Geodetic/Geophysical/Astrometric Interpretation

**6-01P Stability of the VLBI-Derived Celestial Reference Frame**
Martine Feissel-Vernier, Observatoire de Paris and IGN

**6-02P Southern Hemisphere Astrometry**
Alan Fey (1), Roopesh Ojha (2), et al., (1) U.S. Naval Observatory, (2) Australia Telescope National Facility

**6-03P Extending the ICRF to Higher Radio Frequencies – Imaging and Source Structure**
David Boboltz (1), Alan Fey (1), Patrick Charlot (2), Ed Fomalont (3), Gabor Lanyi (4), L.D. Zhang (4) and the K-Q VLBI Survey Collaboration, (1) U.S. Naval Observatory, (2) Bordeaux Observatory, (3) National Radio Astronomy Observatory, (4) Jet Propulsion Laboratory

**6-04P Investigation of Nutation Beyond the IAU2000 Model**
Véronique Dehant (1), Olivier De Viron (1), Martine Feissel-Vernier (2), (1) Royal Observatory of Belgium, (2) Paris Observatory and IGN

**6-05P A New FCN Model with Variable Period and Amplitude**
Zinovy Malkin (1), Toshimichi Shirai (2), (1) Institute of Applied Astronomy RAS, (2) Goldman Sachs (Japan) Ltd.

**6-06P Analysis of the VLBI Intensive Sessions**
Karen Baver (1), Dan MacMillan (2), Leonid Petrov (2), David Gordon (1), (1) Raytheon/GSFC, (2), NVI, Inc./GSFC

**6-07P Investigations of High-Frequency Earth Rotation Variations from VLBI CONT Observations**
Raymundo Del Cojo Lopez, Juan Mata Lozano, Rüdiger Haas, Onsala Space Observatory

**6-08P High Resolution Earth Rotation Parameters Determined During the CONT02 Campaign**
Jolanta Nastula (1), Barbara Kolaczek (1), Robert Weber (2), Johannes Boehm (2), Harald Schuh (2), (1) Space Research Center PAS, Warsaw Poland, (2) Vienna University of Technology

**6-09P Ionospheric Parameters Obtained by Different Space Geodetic Techniques During CONT02**
Thomas Hobiger, Sonya Todorova, Harald Schuh, Vienna University of Technology

**6-10P Comparison of Ionospheric Activity Derived from GPS and Different VLBI Networks**
Sten Bergstrand, Rüdiger Haas, Onsala Space Observatory

**6-11P IVS Tropospheric Parameters**
Harald Schuh, et al., Vienna University of Technology

**6-12P Long Time ZTD Series for Some Stations**
Elena Skurikhina, Institute of Applied Astronomy

**6-13P Calculating Mapping Functions from the HIRLAM Numerical Weather Prediction Model**

Bisser Stoyanov, Rüdiger Haas, Lubomir Gradinarsky, Onsala Space Observatory, Chalmers University of Technology

**6-14P Relative Deformations Between Collocated VLBI Stations and Comparisons with VTRF2003**

Zhigen Yang, (1), Mario Berube (2), Anthony Searle (2), (1) Shanghai Astronomical Observatory, Chinese Academy, (2) Geodetic Survey Division, Natural Resources Canada

**6-15P Postseismic Transient After the 2002 Denali Fault Earthquake from VLBI Measurements at Fairbanks**

Daniel MacMillan, NVI, Inc./GSFC

**6-16P Post-Seismic Motion of Gilcreek Geodetic Sites Following the November, 2002 Denali Earthquake**

Oleg Titov (1), Paul Tregoning (2), (1) Geoscience Australia, (2) Research School of Earth Sciences, ANU

# ABSTRACTS

## Session 1. VLBI: Today's Results and Tomorrow's Vision

**1-01 Welcome by IVS Chair and Chair's Report**

Wolfgang Schlüter, Bundesamt für Kartographie und Geodäsie (BKG)

**1-02 Coordinating Center Report**

Nancy Vandenberg, NVI, Inc./GSFC

**1-03 The ICRF: 2010 and Beyond** *(invited)*

Patrick Charlot, Observatoire de Bordeaux

This presentation considers future directions for improving the International Celestial Reference Frame (ICRF) over the next decade, building on the work accomplished so far and ongoing research in astrometric VLBI. The current ICRF includes a total of 700 extragalactic objects, most of which have position accuracies of 250-1000 microarcseconds. Beyond 2010, the radio realization of the ICRF may be challenged by space-based optical interferometers like GAIA which will observe $10^5$-$10^6$ extragalactic objects with astrometric precision of 10-50 microarcseconds. The IVS should prepare to meet this challenge by improving as far as possible the present ICRF accuracy and source density. Position accuracies better than 100 microarcseconds may already be achievable (or will be soon achievable) considering possible modeling refinements (troposphere, source structure) and improved instrumentation. Recent initiatives to densify the ICRF as well as future possibilities to massively increase the number of sources will be discussed. Over 10+ years, the realization of an ultra-accurate extragalactic reference frame at both optical and radio wavelengths is an exciting perspective not only for astrometry but also for studying physics of active galactic nuclei.

**1-04 VLBI and the Earth's Rotation: Geophysical and Geodetic Challenges** *(invited)*

Martine Feissel-Vernier (1), Jim Ray (2), Veronique Dehant (3), Olivier de Viron (3), (1) Paris Observatory and IGN, (2) Bureau International des Poids et Mesures, (3) Observatoire Royal de Belgique

The impact of VLBI Earth rotation measurements will remain unique in a number of geophysical and geodetic research fields for many years to come, as no replacement method is currently proposed to monitor the orientation of planet Earth in inertial space. The challenges for VLBI will come from ongoing progress in the theory of the non-rigid Earth, as well as in better understanding of the dynamics of the fluid layers that excite rotational variations. While VLBI will remain the only provider of sidereal time, an indispensable external information in space geodetic applications, it will also need to confront the question of how best to merge complementary information from satellite techniques to provide the maximum benefit for users, the proper balance will probably evolve continuously. The opportunities and consequences of these challenges for VLBI in the next decade will be examined

**1-05 IGGOS – Its Mission, Scientific Rationale, and First Steps and Ideas for Its Design and Development** *(invited)*

Christoph Reigber, GeoForschungsZentrum Potsdam (GFZ), Hermann Drewes, DGFI

The Integrated Global Geodetic Observing System IGGOS was accepted as the project of the International Association of Geodesy (IAG) at the IAG General Assembly in Sapporo, Japan in July 2003. IGGOS should bring together the contributions of geodesy to global change studies and provide the focus for the various elements of the new IAG structure. IGGOS shall integrate the three pillars of geodesy: geometry and kinematics, Earth orientation and rotation, gravity field and its variability. IGGOS should stimulate close collaboration between the existing and new IAG services. By integrating different models, techniques and approaches it should achieve better consistency and long term stability in the products generated by the services. The mission's scientific rationale will be pointed out and first steps and ideas for its design and development will be presented.

**1-06 Earth Rotation Dynamics: Review and Prospects** *(invited)*

Benjamin Chao, NASA/GSFC

Modern space geodetic measurement of Earth rotation variations, particularly by means of the VLBI technique, has over the years allowed studies of Earth rotation dynamics to advance in ever-increasing precision, accuracy, and temporal resolution. A review will be presented on our understanding of the geophysical and climatic causes, or "excitations", for length-of-day change, polar motion, and nutations. These excitations sources come from mass transports that constantly take place in the Earth system comprised of the atmosphere, hydrosphere, cryosphere, lithosphere, mantle, and the cores. In this sense, together with other space geodetic measurements of time-variable gravity and geocenter motion, Earth rotation variations become a remote-sensing tool for the integral of all mass transports, providing valuable information about the latter on a wide range of spatial and temporal scales. Future prospects with respect to geophysical studies with even higher accuracy and resolution will be discussed.

**1-01P 5,000,000 Delays – Some Statistics**

Zinovy Malkin, Institute of Applied Astronomy RAS

5,000,000 VLBI delays are stored now in the IVS data base and available for scientific analysis. This is a remarkable result of more than 20 years geodetic VLBI history. The paper presents some statistics related to the VLBI observations.

## Session 2. VLBI2010

**2-01 The International Global Network of Geodetic Fiducial Stations** *(invited)*

John LaBrecque, NASA

Scientific need and technological opportunity require that we move toward implementing a global network of geodetic fiducial stations which feature collocated SLR, VLBI, GNSS, and DORIS instrumentation. Earth science of the next decade will require more accurate global change measurements of sea level topography, sea level change, polar ice mass balance, hydrological and atmospheric mass flux, and topographic deformation, real time mm scale navigation and precision time transfer on a global scale. These scientific requirements have been translated into a goal of mm scale annual stability for the terrestrial reference frame, earth orientation parameters, as well as the orbit and clock determinations for the GNSS systems. To meet these challenges, the four geodetic observing systems must be more tightly integrated in technology, location, and analysis. NASA strongly supports the objectives of the IGGOS initiative vis NASA's National Geodetic Observatory and INDIGO programs. The global networks of GNSS, SLR, and VLBI observatories are for the most part poorly suited for these new demands. These important geodetic networks have evolved with little planning yet these systems are providing essential measurements to a wide swath of society. New signal structures in the GPS and the developing Galileo GNSS will soon require replacement of the GNSS receivers. The SLR network is poorly distributed globally, requires labor intensive observations and analysis, and for the most part relies upon antiquated technology. The VLBI observatories utilize large radio telescopes in remote regions that are poorly distributed globally. Collocation of these networks is sparse and collocation errors contribute significantly to the observing error spectrum. Increasing use of the S and X band by commercial and other government services will also contribute to increased observational errors. The time is upon us for an international effort to develop an optimized global geodetic fiducial network of twelve or more integrated automated geodetic observatories that will provide in near real time, high density measurements of Earth orientation, geodetic positioning, and GNSS system monitoring. The strategic goal for the optimized global fiducial network should be efficient autonomous operation, real time data streaming to analysis centers with an integrated near real time analysis capability for all four observing systems. These goals are achievable in the next decade given the dramatic technological improvements in all geodetic systems. For VLBI, the BKG TIGO might be viewed as a preliminary prototype of technology for fundamental stations. Mark 5, PC-VSI, e-VLBI broadband development efforts are laying the ground work to reduce the aperture of the VLBI antennas and to allow for precision mm level collocation of observing systems. Operating costs and enhanced accuracy would accrue from the elimination of hydrogen maser clocks using double differencing, GNSS time transfer technology, GHz broadband recording, real time analysis, and mm wavelength VLBI observations. A global geodetic fiducial network will not be realizable without international efforts and the support of the four services.

**2-02 VLBI2010: Networks and Observing Strategies**

Bill Petrachenko (1), Brian Corey (2), Ed Himwich (3), Chopo Ma (4), Zinovy Malkin (5), Arthur Niell (2), David Shaffer (6), Nancy Vandenberg (3), (1) Natural Resources Canada, (2) MIT Haystack Observatory, (3) NVI, Inc./GSFC, (4) NASA/GSFC, (5) Institute of Applied Astronomy, (6) Radiometrics, Inc.

The Observing Strategies Sub-group of IVS's Working Group 3 has been tasked with producing a vision for the following aspects of geodetic VLBI: frequency bands, RFI; field system and scheduling; source strength/structure/distribution; and antenna-network structure and observing strategies. These are high level considerations that have far reaching impact since they significantly influence performance potential and also constrain requirements for a number of other WG3 sub-groups. The paper will present the status of the sub-group's work on these topics.

**2-03 Preliminary Results of VLBI2010 Subgroup "RF/IF, Frequency and Time"**

Hayo Hase (1), Brian Corey (2), Yasuhiro Koyama (3), Dave Shaffer (4), Bill Petrachenko (5), Wolfgang Schlüter (1), (1) BKG, (2) MIT Haystack Observatory, (3) Communications Research Laboratory, (4) Radiometrics Inc., (5) Natural Resources Canada

This subgroup discusses how a future VLBI system should be designed with respect to the problems of existing RFI, the existence of new antenna concepts, the developments of high speed samplers, the demands for high stability of frequency normal. The current status of the discussion will be presented.

**2-04 Standard Observing Bands: Is Now the Time To Replace S/X with X/Ka?**

Chris Jacobs, Gabor Lanyi, and Charles Naudet, Jet Propulsion Laboratory

We believe that the time has come for the VLBI community to consider a new set of standard observing frequencies. Since the late 1970s, astrometric and geodetic observations have been done with simultaneous S (2.3 GHz) and X-band (8.4 GHz) observations. After 25 years of S/X observations has the time now come to move to new standard observing bands? In this paper we will argue that the VLBI community should be developing a road map to transition from S/X to simultaneous X and Ka-band (32 GHz) observations. There are both negative and positive reasons for planning such a transition. On the negative side, we will outline concerns that S-band observations may be headed toward obsolescence. On the positive side, we will refer to evidence that X/Ka has potential for providing a more stable reference frame than S/X. We will propose timetables for a transition to X/Ka observing starting from the current status of X/Ka and plans that are now taking shape. First X/Ka fringes were obtained in 2001 with the Deep Space Network (DSN). Future plans will be discussed including a proposed X/Ka-band upgrade to the VLBA. Lastly, we will consider the need for a period of overlap between S/X and X/Ka so that the long and rich history of astrometric and geodetic VLBI is not compromised.

**2-05 VLBI at Some Higher Frequencies, an Overview**

Chopo Ma (1), David Gordon (2), Chris Jacobs (3), Gabor Lanyi (3), Charles Naudet, (3), Alan Fey (4), David Boboltz (4), Ed Fomalont (5), Patrick Charlot (6), Ojars Sovers (7), (1) NASA/GSFC, (2) Raytheon/GSFC, (3) Jet Propulsion Laboratory, (4) U.S. Naval Observatory, (5) National Radio Astronomy Observatory, (6) Bordeaux Observatory, (7) Remote Sensing Analysis Systems

The present fundamental celestial reference frame (CRF) is determined by two decades of S/X-band observations. Work has begun to establish a CRF at a higher frequency, initially at K/Q-band. This frequency pair is motivated by the NASA decision to move future spacecraft telemetry from X-band to Ka-band (~32 GHz, between K-band (24 GHz) and Q-band (43 GHz)) and the availability of K/Q-band on the VLBA. Four K/Q-band sessions and one K-band survey have been observed and analyzed by the K-Q VLBI Survey Collaboration. These observations show that the higher frequencies will support the long term CRF goal of more compact reference sources. The current K/Q-band observations are stepping stones to a Ka-band CRF to support spacecraft navigation using differential VLBI, which awaits creation of sufficient Ka-band observing capability. The

observing program, technical challenges, and possible evolution of the CRF and spacecraft tracking will be described.

**2-06 Backend Systems -- Perspectives in 2010**

Gino Tuccari (1), Alan Whitney (2), Hans Hinteregger (2), Yasuhiro Koyama (3), Tetsuro Kondo (3), (1) IRA CNR, (2) MIT Haystack Observatory, (3) Communications Research Laboratory

A new technological vision on the future of the VLBI backend area let us envision a fully digital implementation of what was until now performed in the analog domain. Several advantages can indeed be expected moving the domain's transition point to an earlier stage, at IF frequency instead of at the final base-band. Such a quantum leap can be afforded because of the rapid changes in digital technology that radio observatories continue to look for maintaining their competitive edge. New processing technologies here discussed will make it possible to reconfigure the whole data handling process using digital conversion to base-band and then to fully benefit from the high data rates in new acquisition and data transport systems, while simultaneously improving the reliability and flexibility of the signal path. In addition, the digital nature of the IF and base-band signals will provide the opportunity to correct for various RFI and calibration effects using embedded DSP algorithms. In order to implement these new techniques a number of major modifications are needed at all telescopes for both single-dish and for VLBI operations. Such modifications could greatly enhance the overall sensitivity of the observatories and improve the reliability of operations. The new hardware should comply with the internationally adopted standards for VLBI in order to allow global applications. A further final step we could anticipate is a brief look at a "next" future, after this near future: a trend to move yet the transition point closer to the sky frequency, overlapping with the receiver area.

**2-07 Data-Acquisition and Transport – Look Forward to 2010 and Beyond**

Alan Whitney (1), Hans Hinteregger (1), Tetsuro Kondo (2), Yasuhiro Koyama (2), (1) MIT Haystack Observatory, (2) Communications Research Laboratory

In contrast to the first nearly 30 years of VLBI development, where highly specialized equipment for VLBI data-acquisition was designed and built at great cost, the last few years are being driven more and more by adapting to rapidly developing technology in the computer and networking industry. This trend is only likely to accelerate, and VLBI must position itself to take maximum advantage of these technologies. Already, the transition from magnetic tapes to magnetic disks has been very rapid, and disks will almost certainly be the mainstay of VLBI data-acquisition for the next few years. However, development of e-VLBI continues to be rapid and will accelerate. Already, international e-VLBI links of more than 500 Mbps have been demonstrated, with speeds in excess of 1-10 Gbps surely achievable in the near future. The advantages of real-time and near-real-time VLBI made possible by e-VLBI are significant, but major potential stumbling blocks are "last-mile" connectivity for many telescopes and potentially high networking costs. The future of VLBI data-acquisition and transport in the light of current and projected developments will be examined.

**2-08 Correlators in 2010 and Beyond**

Yasuhiro Koyama (1), Tetsuro Kondo (1), Bill Petrachenko (2), Hans Hinteregger (3), and Alan Whitney (3), (1) Kashima Space Research Center, CRL (2) Natural Resources Canada, (3) MIT Haystack Observatory

The current generation VLBI correlators have given us tremendous amounts of data products from regular IVS sessions. However, at the same time, it is also true that the capacity of the correlation processing is one of the limiting factors today which are restricting the number of stations and frequency of sessions to be performed. At present, at least three large scale correlators are under discussions for developments. These projects are, ALMA, SKA, and Extended VLA. All of these projects are seeking possibilities to enlarge current limitations in numbers of baselines and maximum speed of data rates and we have to learn a lot from these projects. On the other hand, the processing speed of the software correlators with distributed processing are getting faster and it seems it will become feasible to use the software correlators for large scale VLBI processing by the year 2010. We would like to discuss various possibilities of correlators to be used for IVS sessions in 2010 and beyond.

**2-09 Subgroup "Data Analysis" of Working Group 3 VLBI2010**

Harald Schuh, Vienna University of Technology

An overview about the topics covered by subgroup "Data Analysis" of the IVS Working Group 3 will be given. The work is split up into two lines. The first line deals with improved models and new strategies applied to VLBI data analysis. In the second line the atmosphere is treated with respect to new models and ancillary data. This includes the use of numerical weather models for the mapping functions and the measurement of tropospheric parameters by other instruments. New goals to be aimed at by VLBI and new VLBI configuration and observing systems will be presented, too.

**2-10 VLBI Data Longevity Beyond 2010**

Chopo Ma, NASA/GSFC

The current cache of S/X-band geodetic/astrometric VLBI data accumulated since 1979 is over 4 million observations and is increasing by ~300,000 observations per year. The long time interval and access to all such VLBI data for re-analysis have contributed to their usefulness for the terrestrial and celestial reference frames, Earth orientation parameters, tidal and nontidal loading, and troposphere. While data access and integrity have been maintained through the Mark III data base system as storage devices and media have evolved, past transitions have been major projects. A new format and retention concept to ensure eternal archiving and access should make use of self-documentation, generalized media, network connectivity and multiple redundancy. Similarly permanent organizations or sequences of organizations are also necessary.

**2-11 Future Directions on the VLBA**

R. Craig Walker, National Radio Astronomy Observatory

A major upgrade is under way for the VLA. This upgrade will eventually impact the VLBA in a number of ways. The correlator will have extra capacity and is capable of VLBI correlation, so the intent is to use that extra capacity to replace the current VLBA correlator. This will allow a significant increase in the bandwidth of VLBI observations.

A second phase of the VLA upgrade, about to be proposed, includes extending the resolution of the VLA by a factor of 10. This involves building 8 new antennas and incorporating the Pie Town and Los Alamos VLBA antennas, the latter of which may need to be moved for reasons unrelated to the project. This “New Mexico Array” (NMA) will blur the lines between the VLA and the VLBA and, because of the shared antennas and correlator, tightly integrate their operation. The long range hope is that the VLBA+NMA+VLA will all be one instrument that can be apportioned to observations as the science requires. On the shorter term, we hope to switch to the Mark5 recording system. We are most interested in Mark5B because, without it, the formatters and playback interface limit the VLBA to 512 Mbps. We have also begun a NASA-funded pilot project to use the VLBA in a phase-referencing mode to help with navigation of interplanetary spacecraft. The data processing for this project will probably have much in common with the geodetic data processing path.

**2-12 Impact of Interstellar Scintillation on Astrometric VLBI**

David Jauncey (1), Jim Lovell (1), Roopesh Ojha (1), Alan Fey (2), Yasuhiro Koyama (3), Hayley Bignall (4), Lucyna Kedziora-Chudczer (5), Jean-Pierre Macquart, (6), Barney Rickett (7), Tasso Tzioumis, (1) Australia Telescope National facility, CSIRO, Australia, (2) USNO, (3) CRL Kashima

The last several years have seen a conclusive demonstration that interstellar scintillation (ISS) is the principal cause of the rapid intra-day variability (IDV) seen at cm wavelengths in many flat-spectrum extragalactic sources. The presence of ISS implies that the source possesses an ultra-compact component with microarcsecond angular size. We have recently undertaken the Micro-Arcsecond Scintillation-Induced Variability (MASIV) survey of the northern sky at 5 GHz with the VLA (Lovell et al., 2003, AJ., 126, 1699), and find that about 20% of all compact, flat-spectrum sources exhibit IDV. Our VLBA images of a sample of the MASIV IDV sources show them, as a class, to be amongst the most compact, core-dominated sources known. Such sources are ideal as VLBI astrometric reference sources, and this is confirmed by the positional quality of the MASIV scintillators in the list of stable astrometric sources (Feissel-Vernier 2003, A&A., 403, 105). We therefore suggest that with the advent of the new Mark 5 broad-band VLBI recording system and associated increase in sensitivity, the next generation of the VLBI astrometric and geodetic celestial reference frame, be made up of a selection of the most compact IDV sources from the MASIV Survey.

**2-01P Worlds of 1996, 2003, and 2010**

Ari Mujunen, Jouko Ritakari, Metsähovi Radio Observatory

In the VLBI2010 session we are trying to predict the world a mere seven years in the future. In these seven years the infrastructure in computing and data communications will change more than anybody realizes now. We can get some insight about the rate of change by looking back seven years into year 1996. At that time microcomputers had 133 MHz processors, 16 MB of main memory and the largest hard disk was 2 GB. Mainstream networking technology was 10 Mbit/s Ethernet, the first 100 Mbit/s equipment was starting to arrive. Global Internet connections were typically 155 Mbit/s at their best. Now we have 3 GHz processors (22 times improvement), 1 GB main memory (62 times more), 200 GB hard disks (100 times larger) and 1 Gbit/s Ethernet networking (100 times faster). Internet backbone networks routinely use 10 Gbit/s connections (66 times faster). If the trend continues, in 2010 we will have 66 GHz processors with 60 GB main memory and 20 TB hard disks. Networks will work at 100 Gbit/s speeds. Global connectivity will be available at 660 Gbit/s. Of course these numbers are wrong in details, but it is better to use them than to think in terms of today's technology. It is imperative that we do our development work as fast as the computer industry and we must accept that at least one generation (possibly two) of VLBI equipment will become totally obsolete before we reach 2010.

**2-02P Vienna Students Project (VSP) – A VLBI Experiment by Students**

Wolfgang Winkler, et al., University of Technology, Vienna

While studying geodesy at the Vienna University of Technology, students often get in touch with VLBI. During the winter-term 2003/04 the experiment VSP (Vienna Students Project) was planned and realized at the Institute of Geodesy and Geophysics involving the students in all relevant steps of a VLBI experiment. This project included scheduling with program SKED of a 3h session which was done in cooperation with the University of Bonn. Then, the observations at stations Wettzell, Concepcion (TIGO) and O'Higgins took place on November 27. A video-conference was set up between Concepcion and Vienna and some students went to Wettzell to help with the observations. The three tapes will be correlated at the end of 2003 in Bonn, and finally the experiment will be analyzed in Vienna.

## Session 3. Network Stations, Operation Centers, Correlators

**3-01 Correlator Experiences with Mark 5 in Operation** *(invited)*

Arno Mueskens (1), Walter Alef (2), David Graham (2), Geodetic Institute of the University of Bonn, (2) Max-Planck Institut for Radioastronomie

We give a short overview of the present situation at the astronomy/geodesy correlator in Bonn. Most IVS and astronomy telescopes are now equipped with Mk5A units. We present our experience with the new recording system both in standard geodetic correlation as well as the correlation of astronomical projects at 512 and 1024 Mbps with up to four Mk5A units.

**3-02 Recent Results from the EVN Mk4 Data Processor at JIVE**

Bob Campbell, Joint Institute for VLBI in Europe

The majority of astronomical EVN experiments, and about half of the global experiments, are correlated at JIVE. Recent achievements include decreasing read-out times for the whole correlator (32 Mk4 boards) to 0.25s, improving the end quality of user data (e.g., excising TRM byte-slips, applying an improved 2-bit van Vleck correction), developing new astronomical capabilities (e.g., oversampling), and strengthening liaison procedures with PIs (e.g., through the new EVN archive facility). The move to Mk5 and fiber-linked VLBI (e-VLBI) is well underway. We currently have 6 Mk5A units connected to station units for operational correlation, with another 3 in house. 90% of the user experiments from the Oct/Nov'03 EVN session had at least one station recording onto disk, and we have correlated our first of these mixed disk/tape experiments. Ftp fringe-tests have been included as a regular feature of EVN sessions, allowing faster feedback to stations. 64Mb/s data have been recorded over the internet directly from the formatters at Jodrell Bank and Westerbork to Mk5 disks at JIVE, without any local buffering at the stations. In the longer term, we have entered into a proof-of-concept project with a pan-European gigabit research network (GEANT) and various national research and educational networks, with a goal of achieving real-time correlation of up to 5 EVN stations by the middle of 2005.

**3-03 Washington Correlator Update**

Kerry Kingham, U.S. Naval Observatory

Since the last General Meeting, the Washington Correlator has continued to be one of the heavier loaded geodetic/astrometric correlator facilities. In addition, the Washington Correlator has integrated 8 Mark 5A playback systems while attempting to maintain enough tape drives to meet correlation assignments. The Washington Correlator staff has over a year of experience with Mark 5 experiments, including the IVS-Intensives which were converted to Mark 5-only in November, 2002. Experiences with the Mark 5 conversion, an update on staff and resources and the outlook for the future will be discussed.

**3-04 Overview of Geodetic Experiments at the Bonn Correlator**

Alessandra Bertarini, Arno Mueskens, Alexandra Hoefer, Geodetic Institute of the University of Bonn

We present an overview of the time delays occurring in the processing of geodetic experiments correlated in Bonn during the years 2001 to 2003 showing the efficiency improvements achieved over that period

**3-05 Network Coordinator's Report**

Ed Himwich, NVI, Inc./GSFC

**3-06 Present Status and Future Plan on the Chinese VLBI Network**

Zhihan Qian, Shuhua Ye, Xiaoyu Hong, Xiuzhong Zhang, Jin Zhang and Xizhen Zhang, Shanghai Astronomical Observatory, CAS

At present, there are two fixed VLBI stations and one mobile VLBI station in China. A SHAO Disk-array recording system has been successfully completed. A two-station correlator which can accept either Mk4 tapes or SHAO Disk-array was also finished. A 10m antenna which is located in the south-west of China and was used for solar radio observations will be modified for VLBI observations. A 50m antenna which will be located in the Miyun county, near Beijing, and also is with the capability of S/X dual-band VLBI observation is under construction. The four-station VLBI network will be used for the orbit determination of the future Chinese lunar orbiter. A ten-station VLBI correlator which will be compatible with Mk5 is under consideration.

**3-07 VLBI-GPS Collocation Results in Japan**

Shigeru Matsuzaka, Y. Masaki, Hiromichi Tsuji, Kazuhiro Takashima, T. Tsutsumi, M. Ishimoto, M. Machida, H. Wada, Shinobu Kurihara, Geographical Survey Institute, Japan

This is a status report of VLBI-GPS collocation surveys in Japan. GSI has conducted precise collocation surveys at three VLBI stations in Japan, i.e. Tsukuba, Shintotsukawa, and Aira, using total stations with a Cateye reflector and first class tilting levels. These surveys yielded mm-level local connections of those VLBI stations and nearby GPS permanent stations. Using this local tie, we compared regional VLBI and GPS time series of the 800 km baseline between Tsukuba and Shintotsukawa. They agree within 1cm in horizontal and length components, which suggests there is no systematic difference exceeding 10-8. Reasons of a few cm discrepancies in vertical component need investigation.

**3-08 Status and Plan of Geodetic and Astrometric Observations with VERA**

Seiji Manabe, Yoshiaki Tamura, Takaaki Jike, Koji Horiai and VERA team, National Astronomical Observatory of Japan

VERA (VLBI Exploration of Radio Astrometry) aims at exploring Galactic structure by precise determination of 3-dimensional positions and velocities of Galactic maser sources. The four-station network of VERA was completed in 2002 and the system performance is examined. The enormous capability for compensating atmospheric fluctuation of visibility phases with the dual-beam receiving system has been proved (Honma et al., 2003) and some phase-compensated maps of radio sources have been obtained recently. As for geodetic observations, Mizusawa station joined some domestic experiments by the Geographic Survey Institute of Japan and its coordinates have been determined. These experiments were done with the use of the K4 data acquisition terminal. However, a full one-day experiment with 1 Gbps recording by using DIR2000 recorders has not been tried yet (12/1/03). Current status and plans for regular geodetic observations in S/X and K bands will be presented at the meeting.

**3-01P Present Status of the Korean VLBI Network Construction**

Young Chol Minh, Korea Astronomy Observatory

It is the 4th year to construct the Korea's new VLBI facility, KVN. This project is going on as scheduled and will be completed in 2007. Here we introduce the present status of this project to construct 3 new radio telescopes and VLBI facilities, focused on the mm-VLBI, in 3 places in Korea. We are eagerly waiting for not only carrying out the domestic VLBI research works, but also the active involvements in the international VLBI activities.

**3-02P Projects at TIGO**

H. Hase (1), S. Sobarzo (2), C. Jara (2), R. Aedo (3), G. Remedi (3), M. Moreno (2), M. Sanchez (2), G. Hermosilla (2), (1) BKG, (2) UdeC, (3) UBioBio

The VLBI group at TIGO is currently involved in some projects: upgrade of the antenna control unit during 2004, bandwidth monitoring in data networks for eVLBI, incorporating Mk5. Further activities at TIGO related to VLBI are the installation of a tidegauge and a permanent regional GPS monitor network at four sites in 20-50km distance.

### 3-03P New Technologies for the Real 3D Reference Point Determination

Maria Hennes, Cornelia Eschelbach, Geodetic Institute, University of Karlsruhe

Because VLBI-technology improves continually, a geometric control of a telescopes (i.e. the determination of its reference point and the deformation of the antenna due to thermal and gravitational effects) in (sub-) mm range is essential. Furthermore, the combination of different space techniques (VBLI and GPS) at one station requires a local tie of the telescope's reference point to the local reference frame. In this contribution, a successful reference point determination by angle measurements is presented. Moreover, new measurement technologies (robot-tacheometer, laser tracker, laser radar) are presented. Most of these technologies aim at reducing the telescope downtime during the surveying process.

### 3-04P VLBI Status of the Bear Lakes Radio Astronomy Station

Igor Molotov (1), Yurii Gorshenkov (2), Alexander Stepanov (1), Boris Lipatov (3), Gino Tuccari (4), Valery Saurin (2), Alexis Zinoviev (1), (1) Central Pulkovo Astronomical Observatory, (2) Power Engineering Institute, (3) Radio Physical Research institute, (4) Istituto di Radioastronomia CNR

The Bear Lakes Radio Astronomy Station (BLRAS) based on 64-m dish antenna near Moscow was organized by Pulkovo Astronomy Observatory and Special Research Bureau in the end of 2002. The joint efforts of few institutions under INTAS IA-01-02 project allowed refurbishing the RT-64 construction and scientific infrastructure: modernizing the pointing system, adjusting two H-masers, upgrading GPS time service, repairing the building and rooms, painting the antenna. The apparatus rooms were connected to Internet by optical cable with possibility to transfer up to 500 Mb/s. Currently RT-64 has the receivers of three frequency bands: 0.327 GHz, 1.665 GHz and 5 GHz. Three new receivers (0.61 GHz, 2.3 GHz and 8.4 GHz) are in production. VLBI complex includes a BBC of 8 MHz bandwidth, sampler, S2 system and Mk-2 terminal. The elaboration of the 128 MHz 8-channel BBC was interrupted due to the stop of INTAS IA-01-02 financing. This circumstance also cancelled our plans about purchasing the FS computer and Mk5 terminal. The INTAS-01-0669 support allowed installing new VLBR terminal designed in Noto. This terminal records the VLBI data on PC-discs and then translates them in Internet for e-VLBI processing. BLRAS participated in two sessions of the Low Frequency VLBI Network (LFVN): at 1.665 GHz with S2 terminal for the investigations of the AGN, stars, OH-masers and solar wind; and at 5 GHz with both Mk2 and VLBR terminals for the accurate radiolocation of Mars, 2000 PH 5 asteroid and high-orbit space debris. In the next year, we would like to obtain the large bandwidth BBC to participate in S2 geodetic VLBI and to support the LFVN activities. The works were partially supported also by RFBR 02-02-17568 and RFBR-02-02-39023 grants.

**3-05P Some Results of the First Year of Participation of the Svetloe Observatory in IVS Observing Programs**

Andrey Finkelstein, Valery Gratchev, Alexander Ipatov, Zinovy Malkin, Ismail Rahimov, Elena Skurikhina, Sergey Smolentsev, Institute of Applied Astronomy RAS

In this paper results of the first geodetic VLBI observations obtained at the Svetloe Radio Astronomical Observatory (SvRAO) since March 2003 in the framework of the IVS observing programs. SvRAO is conducting in the VLBI observations since 1998 with S2 registration. After installation of Mark 3A terminal in cooperation with NASA in Nov-Dec 2002 and several test sessions, SvRAO started to observe in regular IVS programs. The first IVS experiment R4061 (March 6, 2003) was followed by other ones in the framework of the IVS R4, EURO, TRF programs. In total, more than 20 sessions were observed in 2003. All these observations were analyzed at the IAA, along with other IVS sessions. One of the main results of this analysis is improvement of station coordinates. Also, we estimated how the including Svetloe observatory in the IVS network improve network performance. We found that including Svetloe station in the IVS network allow us to decrease errors in EOP, postfit rms, and correlation between EOP. Obtained results show high quality of both observations and analysis made at the IAA. Results of correlation of Svetloe sessions at the Washington and Bonn correlators were also analyzed to investigate existing station problems.

**3-06P Radio Astronomy Observatories in Svetloe, Zelenchukskaya and Badary of VLBI Network QUASAR**

Andrey Finkelstein, Alexander Ipatov, Sergey Smolentsev, Institute of Applied Astronomy, Russian Academy of Sciences

The QUASAR project, which is carried out under the guidance of the Russian Academy of Sciences, involves creation of the full time operating VLBI network, consisting of the 3 radio astronomical observatories. These observatories are located on the Svetloe site, the Leningrad region; the Zelenchukskaya site, the Republic of Karachaevo-Cherkessia, and the Badary site, the Republic of Buryatia and linked by connecting channels with the processing center, located in the IAA, St-Petersburg, Russia. At present time 2 observatories on the Svetloe (1998) and on the Zelenchukskaya (2000) sites are operating; the observations are made on the one telescope schedule and according to the VLBI programs. Observatory on Badary site is under installing and testing the hardware. The parameters of the radio astronomical observatories and the future plans to take part into IVS observing programs will be discussed.

**3-07P The New 40-m Radiotelescope of the Spanish National Geographical Institute (IGN) at Yebes**

Maria Rioja, Observatorio Astronomico Nacional (OAN), Spain

The National Geographical Institute of Spain is constructing a new 40-meter radiotelescope at Centro Astronomico de Yebes (Guadalajara,Spain). The new instrument, which is expected to start operating in 2004, will replace the current 14-meter telescope as an IVS network station by mid-2005. More information at the URL http://www.oan.es/.

# Session 4. New Technology Developments in VLBI

## 4-01 The Mark 5B VLBI Data System

Alan Whitney, Will Aldrich, John Ball, Brian Fanous, Dan Smythe, MIT Haystack Observatory

The Mark 5B VLBI data system is now being developed at MIT Haystack Observatory. It is based on the same physical platform, uses the same disk-modules as the Mark 5A, and supports the same maximum data rate of 1024 Mbps. However, the Mark 5B will incorporate a VSI standard interface and command set. This will allow VLBA systems to bypass any existing formatter and connect directly to the output of VLBA samplers (through a simple interface) at a maximum data rate of 1024 Mbps. For existing Mark 4 systems, the Mark 5B will allow connection of all 14 BBC's to two Mark 5B's for a total aggregate data rate of 1792 Mbps. In addition, the Mark 5B is being designed to support all critical functionality of the Mark 4 Station Unit, so that the Mark 5B may played back directly to the Mark 4 correlator through a simple interface. Prototype Mark 5B systems are expected to be available mid-to-late 2004.

## 4-02 Gbit/s VLBI and eVLBI with Off-the-Shelf Components

Jouko Ritakari, Ari Mujunen, Metsähovi Radio Observatory

Metsähovi Radio Observatory has pioneered in the use of off-the-shelf microcomputers in VLBI. During the years 2001 and 2002 MRO developed a hard-disk based data acquisition and playback terminal for VLBI. The recording system is VSI-H compatible and uses off-the-shelf microcomputers with unmodified Linux operating system. Only minimal hardware and software development were needed. One data acquisition terminal can record at 512 Mbit/s speed, but the system is designed to be easily scalable to multi-gigabit per second speeds. The system is compatible with most of the standards used in VLBI, it can record data from the ADS-1000 Gbit/s sampler developed in CRL, VLBA samplers, VLBA formatter, Mk4 formatter and S2. K4 compatibility has been designed but not yet tested. It must be emphasized that the MRO data acquisition terminal is not a prototype but a mass-produced product. Boards for sixty data acquisition terminals have been produced in August 2002 and seventeen terminals have been deployed to nine radio telescopes so far. During the years 2002 and 2003 Metsähovi made several 1 Gbit/s and 2 Gbit/s VLBI observations with Kashima station at 22 GHz frequency. These observations used the ADS-1000 sampler and were correlated with a high-speed software correlator at Kashima. In May 2003 Metsähovi and Jodrell Bank Observatory succeeded in the first European 1 Gbit/s Mk5-style VLBI experiment. Data was recorded in MRO-designed hard disk recorders, transferred to JIVE via Internet and played back to the correlator with Mk5 terminals. During the second half of 2003 the MRO team has concentrated in evaluating the new reliable UDP-based protocols for eVLBI. Several candidates have been found. Initial tests using these protocols are very promising and demonstrate the advantages of having the data in normal Linux files.

**4-03 Current Status of Software Correlators Developed at Kashima Space Research Center**

Tetsuro Kondo, Moritaka Kimura, Yasuhiro Koyama, Hiro Osaki, Kashima Space Research Center/CRL

At the beginning era of VLBI development, correlation processing was performed by a computer program. However it took a long time, so that it was unrealistic to process huge data such as 24-hour session data. A hardware correlator was hence developed and has been used for a long time. Kashima VLBI group used to develop the "Software Correlator" named CCC (Cross Correlation in a Computer) for a fringe test of domestic VLBI observations about 20 years ago. The CCC performed correlation processing using the data prepared by the K-3 (or Mark III) decoder. The substance of CCC was a FORTRAN program running on an HP-1000 series mini-computer (e.g., 45F, A900, etc.). It took about 8 hours to obtain 64 lag correlation function by processing 16 Mbit data in the HP-1000 45F. The CCC was used in the actual fringe test of a domestic VLBI measurement in 1985, and we could get fringes. However, it was not practical from the reason that not only data processing but also data transmission took time too much. We had to wait for progresses of both computing speed and data transmission speed to put a software correlator in practical use. Recently the performance of a computer is remarkably developed. For an example, the computing speed of a recent PC is much faster than that of the workstations of ten years ago. Then the use of a software correlator for VLBI data processing has become realistic. We have been developing a PC-based VLBI data-acquisition terminal named K5 dedicated to transmitting the data through the Internet. A software correlator based on the CCC aiming at obtaining the correlation data compatible with those processed by the hardware correlator has also been developed by using the C language for K5 data processing for geodetic use. A bandwidth-synthesizing program can handle correlated data directly to get a precise observed delay. At present time this software correlator dedicated to a geodetic use can process 4 Mbps data in real time when it runs on a PC equipped with the Pentium III 1 GHz processor. We processed 24-hour session data by using the software correlator and it was confirmed that geodetic results obtained by the software correlator gave reasonable results compared with those obtained by the hardware correlator. On the other hand, the development of an ultra high-speed software correlator for processing gigabit VLBI data has also been carried out. In this development, in order to maximize the performance of CPU, various kinds of optimizations, multi-baseline correlation with multi-PCs and effective use of multi-processors and utilization of SIMD technology for parallel processing, etc., were performed. An assembler language program was also used partially to improve the performance. At present time, this software correlator can process 100 Mbps data in real time on a PC equipped with dual AMD Athlon 1.8 GHz processors. By use of the latest and fastest four PCs, it is possible to process 1 Gbps data in real time. A software correlator will take over a hardware correlator in near future and will be one of key technologies for e-VLBI. We are now developing the distributed processing technique for further speedup to realize real-time correlation in the e-VLBI system.

**4-04 SOFTC: An Operational Software Correlator**

Stephen Lowe, Jet Propulsion Laboratory

SOFTC is a general purpose VLBI correlator, with emphasis on high precision astrometry. It is capable of correlating data with observation frequencies between 100 MHz and 100 GHz, sampling rates above 100 kHz, data in 1, 2, 4, or 8-bit formats, with upper, lower or double-sideband bandpasses, and maintain better than 0.1 picosecond processing accuracy, for up to 32 lag operations. A much greater number of lags, higher observation frequencies, and lower sampling rates can also be processed with correspondingly lower processing accuracy for less demanding applications. A large part of SOFTC's development effort went into a Monte Carlo VLBI simulator to verify all aspects of its operation. SOFTC was tested with geodetic/astrometric experiments and Mars Global Surveyor navigation data, and has been in use operationally for 2 years at JPL. Its most stringent test was its use in Mars Odessey's orbit insertion around Mars in Oct 2001: the craft reached Mars within 700 m of its target. SOFTC is currently in use tracking the two Mars Exploration Rover missions, and Europe's Mars Express; by sending the VLBI data over the internet, we correlate and fully process our navigation data within 6-8 hours of the experiment's end. In the future, SOFTC will process all JPLs's VLBI data when our planned upgrade to the Mark 5 system is complete in about a year.

**4-05 eVLBI Developments in Europe**

Stephen Parsley, Zsolt Paragi, Sergei Pogrebenco, Cormac Reynolds, Arpad Szomoru, Joint Institute for VLBI in Europe (JIVE)

Multi-gigabit connections are now available in most European countries via National Research and Education Networks (NRENs) and across Europe via GÉANT. The EVN Data Processor at JIVE, and a growing number of telescopes now have high bandwidth connections to these networks. With the support of GÉANT and a consortium of NRENs, the European VLBI Network (EVN) is currently involved in a Proof-of-Concept project to connect up to six European telescopes directly to the JIVE data processor. The project will explore the feasibility of achieving real-time eVLBI using shared IP across the production R&E networks. As a direct result of this activity the use of FTP for fringe checks has already become a routine facility. In the longer term network experts predict the use of dedicated wavelengths for high demand users. The DWDM connection to JIVE forms an integral part of Netherlight, with links to the global optical-switching test bed. European VLBI is primed to play an important role as a test application in this development. Results and current status of these projects will be discussed.

**4-06 E-VLBI Progress of the Chinese VLBI Network**

Zheng Weimin, Zhang Xiuzhong, Shu Fengchun, Shanghai Astronomical Observatory, Chinese Academy of Sciences

The Chinese VLBI Network (CVN) contains 2 fixed stations, a mobile station and a 2-station correlator nowadays. A PC-based VLBI data acquisition terminal and playback unit named CVN harddisk system was developed at Shanghai Astronomical Observatory recently. The current prototype unit achieved data recording at 512 Mbps (32 track * 16 Mbps/track) by one PC (4 * 120 GB removable harddisks), and the playback rate was up to 256 Mbps (32 tracks * 8 Mbps/track). Two CVN harddisk systems were installed at

Sheshan station and Urumqi station in 2003, and several e-VLBI testing observations were completed successfully. Now the Shanghai correlator is able to correlate the data from tape or harddisk. The correlation software was also developed. Through observing the high SNR signals of a GEO satellite, we can do the fringe test by this software using only 8 Mbyte VLBI data from each station through ftp. The CVN harddisk system can also do some data quality and time code checks by itself. Several VLBI observations of satellite positioning test were finished based on the CVN harddisk system, both hardware correlator and software correlator produced the group delay & delay rate. The digital BBC technique is also being studied. Another two VLBI stations and a new 4 or 5 station real-time correlator will join in the Chinese VLBI network. This real-time VLBI network will be applied to the Chinese Lunar explorer navigation as well as the geodetic and astronomical observations in the future.

**4-07 Transporting VLBI Data Across Long Fat Networks: A Practical Approach**

David Lapsley, MIT Haystack Observatory

e-VLBI promises a number of scientific and practical advantages over traditional VLBI: higher sensitivity of measurement through rapidly increasing data transmission speeds, the ability to perform real-time correlation of data, the reduction/elimination of an expensive media pool, and the streamlining of VLBI operations to name a few advantages. However, in order to realize this potential, a number of challenges must be overcome. In this presentation, we outline some of the challenges facing e-VLBI and some of the approaches that can be used to overcome these challenges. In particular, we discuss some of the tools that can be used by e-VLBI applications: the various network models, traditional and state-of-the-art congestion control models as well as application layer high speed transport protocols. The aim of this paper is to provide a broad understanding of the data transport framework in which the e-VLBI application operates. One possible framework that will provide high speed data transport, interchangeability of transport protocols and interoperability will be discussed. Much of the work discussed in this paper will be based on the practical experiences of the author in transporting e-VLBI data across national and international networks.

**4-08 Geodetic VLBI Experiments with the K5 System**

Yasuhiro Koyama (1), Tetsuro Kondo (1), Hiro Osaki (1), Masaki Hirabaru (1), Kazuhiro Takashima (2), Kazuo Sorai (3), Hiroshi Takaba (4), Kenta Fujisawa (5), David Lapsley (6), Kevin Dudevoir (6), Alan Whitney (6), (1) Communications Research Laboratory, (2) Geographical Survey Institute of Japan (GSI), (3) Hokkaido U., (4) Gifu U., (5) Yamaguchi U., (6) MIT Haystack Observatory

At Kashima Space Research Center of Communications Research Laboratory, developments of the K5 VLBI system have been continuing based on conventional PC systems to realize e-VLBI observations and data processing over the high speed shared networks using Internet Protocol. By using the prototype models of the K5 system, various geodetic VLBI experiments have been performed and the results were evaluated to investigate the performance and the function of the K5 system. In the two domestic geodetic VLBI experiments, the results from the K5 system were compared with the results from the K4 VLBI system and it was confirmed that the K5 system is performing as expected. A series of short e-VLBI sessions was performed by using the Mark-5 system at Westford station and the K5 system at Kashima station to demonstrate rapid turn around UT1-UTC estimation from international e-VLBI. Since October 2003, all IVS sessions in which Kashima 34-m station participated were recorded by the VLBA recorder as well as by the K5 system in parallel, and the K5 data files are being transferred to MIT Haystack Observatory after converting the format of K5 data files to the Mark-5 data format. The data will then be recorded to Mark-5 disk units for correlation processing. These procedures will become first and important steps towards the routine e-VLBI operations in the IVS sessions in the future.

**4-09 Millimeter Wave Multi-Channel Receivers System for VLBI**

Seog-Tae Han, Korea Astronomy Observatory

The most important thing in millimeter and sub-millimeter wave VLBI is how to calibrate the variations in the phase of an electromagnetic wave propagating through the troposphere. A lot of techniques for calibrating the phase fluctuations due to troposphere have been well proposed and demonstrated (W. Alef et al and T. Sasao 2002). The millimeter wave multi-channel receiver system which can be used for phase calibration in millimeter wave VLBI observation are proposed. In this talk, a conceptual multi-channel receiver system which can be simultaneously observed 23 GHz, 43 GHz, 86 GHz and 129 GHz frequency channels, and a quasi-optical filters which could be used in this receiver system will be presented.

**4-10 DBBC - A Wide Band Digital Base Band Converter**

Gino Tuccari, IRA CNR

It is presented a description of a project to develop a fully digital backend system to replace the presently used terminals. The need for such replacement is well known and motivated by the necessity to both renew an obsolete system whose component replacement is every day more difficult, and for achieving better performance making use of the more predictable digital techniques. Field Programmable Gate Array (FPGA) components show continuous increasing performance in terms of gate density and working frequency, giving a real opportunity to take advantages within a concept of fully upgrading methodology. Then, what could now be developed to accomplish the transition between recording systems and the application of the VSI interfacing standard, is realized in the present, while the same hardware environment can be container of different needs in a near future, with the data transport and correlator evolution. This development is producing some prototypes for testing the performance of different architectures taking into account theoretical achievable performance and the actual features. Two samples with preliminary configurations are placed in Noto and Effelsberg; development and testing are indeed performed on the field.

**4-11 Toward Standard Wideband Digital Backends for Next-Generation Radio Astronomy: ATNF, LOFAR, (e)-VLBI, ATA, SKA**

Hans Hinteregger, MIT Haystack Observatory

Virtually all next-generation radio astronomy applications could be economically served by a new wideband digital backend with a common block diagram. Basically, this consists of 1) a high-speed A/D sampling a wide baseband or higher Nyquist zone filtered signal, followed by 2) one or more stages of filterbank (polyphase/FFT), followed by 3) a high-speed (now up to 10 Gb/s) serial transceiver for transport to storage and/or correlation processor. Design of such a wideband digital backend is outlined, with examples of modern low-cost components: high-speed A/Ds, FPGAs, and 1-10 Gb/s serial transceivers that are now available. For LOFAR, for example, a dual 600 Msample/sec backend with 1024-channel filter-banks may be built for as little as about $500.

**4-12 VLBI Observation for Spacecraft Navigation (NOZOMI) – Data Processing and Analysis Status Report**

Mamoru Sekido (1), Ryuichi Ichikawa (1), Hiro Osaki (1), Tetsuro Kondo (1), Yasuhiro Koyama (1), Makoto Yoshikawa (2), Takafumi Ohnishi (3),Wayne Cannon (4), Alexander Novikov (4), Mario Berube (5), (1) Kashima Space Research Center, CRL, (2) ISAS/JAXA, (3) Fujitsu Co. Ltd, (4) SGL/CRESTech, (5) Natural Resources Canada

VLBI has great sensitivity in spherical coordinates measurement in the sky. We started work to apply VLBI technique for spacecraft navigation, and made a series of observations for Japanese Mars explorer NOZOMI with Japanese domestic VLBI antennas and Canadian Algonquin Radio Observatory. The VLBI observation of spacecraft is different from natural radio source target at several points. Since the distance to the radio source is finite, we need to use alternative delay model other than the consensus model. The band width of the signal is order of 1 MHz or so, then we used IP-sampler board for data acquisition, and used software correlator for data reduction. Since accuracy of group delay is not so high due to limited bandwidth, we have to use long baseline to achieve high angular resolution. We are also trying to use phase-delay to get high delay resolution of observation. Efforts to improve processing and analysis is on going. We will report the current status of our data processing and analysis.

**4-01P FS Developments**

Ed Himwich (1), Ray Gonzalez (1), Jonathan Quick (2), John Gipson (1), (1) NVI, Inc./GSFC, (2) Hartebeesthoek Radio Astronomy Observatory

**4-02P The Data Acquisition System Developed for Quasar Network**

Alexander Ipatov, Nikolay Koltsov, Leonid Fedotov, Institute of Applied Astronomy, Russian Academy of Sciences

The new data acquisition system developed at the IAA RAS is described. This system contains 8 base band converters (BBC) for both (lower and upper) side bands. Input IF is from 100 MHz to 1000 MHz. Bandwidths are 0.25 MHz, 2MHz, 8 MHz or 16 MHz. There are two bits samplers and 32 MHz clock and 1 PPS synchronizers. The detectors for IF and the video signals control in BBC channels are installed. The narrow bandwidth channels to select a phase calibration signal are installed. The DAS by computer with Mark 4 FS software is controlled.

**4-03P Data Acquisition System of Korean VLBI Network**

Duk-Gyoo Roh, Korea Astronomy Observatory

We are developing the KVN data acquisition system. For our multi-channel receiver system, and to cover 1 GHz bandwidth, we employ four high speed samplers which can be operated at 2 Gsps and 4 bits per sample. These four data streams of 8 Gbps each will be transported via optical fibers to the operation building, and then distributed among sixteen FIR digital filters. With these filters, we can choose a passband whose center frequency is arbitrarily programmable in the 1 GHz-wide input bandwidth, and then ressample the filtered data at 2 bits per sample. These resampled data streams are then formatted and sent to the recorder. We plan to use the new Mark 5 recorder. KVN is involved in the development consortium for Mark 5, which are led by MIT Haystack Observatory.

**4-04P New Correlator PARSEC**

Valery Gratchev, Institute of Applied Astronomy, RAS

The Institute of Applied Astronomy is developing Altera FPGA-based scalable correlator PARSEC with Mark4 specification. The correlator unit uses PCI-bus correlator boards, standard CompactPCI hardware with single board Intel Pentium control computer and standard Linux operating system. We have estimated that it is possible to provide 4-station and 16-channel 1 or 2-bit data processing by using single correlator unit with Mark5 VSI compatible playback system for VLBI and e-VLBI. We have developed the prototype correlator MicroPARSEC. PCI-bus correlator board MicroPARSEC has the following features: standard office PC board format, single board supports 2 cross-correlation channel with for one baseline, operation at input data rate to 64 Msamples/sec/channel, 1 or 2 bit sampling, integrated input data rate to 512 Mbit/s, the board can be connected directly to Canadian S2-RT or S2-PT. We have produced and tested four prototype correlator boards , which may be used as scalable spectrum analyzer for station phase cal extraction and other different system diagnostic and/or spectral line real time observation data processing in single dish mode on our radio telescopes in Svetloe, Zelenchukskaya and Badary. We are going to start volume production in order of the correlator board MicroPARSEC for standard office PC with standard Windows 98/2000/XP operating system and special control and monitor program developed in IAA.

**4-05P VLBI@home – VLBI Correlator by GRID Computing System**

Takeuchi Hiroshi, Kondo Tetsuro, Koyama Yasuhiro, and Nakajima Junichi, Kashima Space Research Center/CRL

We have started the development of GRID computing system for VLBI correlation processing. Like the SETI@home, client/server model is adopted in the system and screensaver-type correlator program runs only when the client PC is idle. An XML format is used in a socket connection between a control-server and a client PC. In the connection, file names of VLBI raw data and IP addresses of observed stations are communicated from the server to the client. The client downloads the files from FTP servers at each station and correlates the data. The resulting data of correlation process and some information such as download time and correlation time are reported to the server. The beta-version programs are already running and we are now testing a long-term stability of the programs. We will report the details of the system and future possibilities of GRID computing in VLBI.

**4-06P A Near Real Time e-Radar/VLBI Network**

Gino Tuccari (1), Igor Molotov (2), S. Buttaccio (1), G. Nicotra (1), B. Lipatov (3), Alexis Zinoviev (2), Y. Gorshenkov (4), L. Xiang (5), Xiaoyu Hong (6), Alexnder Volvach (7), (1) Istituto di Radioastronomia CNR, (2) Central Pulkova Astronomical Observatory, (3) Radio Physical Research Institute, (4) Power Engineering Institute, (5) Urumqi Astronomical Observatory, (6) Shanghai Astronomical Observatory, (7) Crimean Astrophysical Observatory

A narrow band e-VLBI system is in development as a part of the LFVN (Low Frequency VLBI Network) activity taking advantages of the relatively small portion of band necessary in a certain class of radioastronomy observations. Data are acquired using a simple dedicated terminal and recorded on disk. The maximum recorded signal band is 48 MHz wide, flexibly scalable up to a few kilohertz and then with the concrete possibility to transfer the full amount or portion of it in near real time to a correlation point, using the standard Internet connection, when narrow band acquisitions are appropriate. Radar, spectral lines, low frequency, spacecraft navigation observations could benefit from this inexpensive solution in those stations where large antennas and sensitive receivers are available, and where is still missing the possibility to be aligned with standard VLBI terminals, giving then yet the possibility to perform radio astronomy research. The terminal is at present placed in Noto (Italy), Bear Lakes (Russia), Urumqi (China) and few other stations, Simeiz (Crimea), Seshan (China), Evpatoria (Ukraine), will get a terminal in the first months of 2004. A mixed software/dsp correlator is also in development in Noto, based on a shared computing strategy, allowing us to improve auto- and cross-correlation performance adding a number of PCs equipped with a dedicated DSP board to improve the correlation capability. During the VLBR03.1 radar session in July 2003, the VLBI data from Noto and Bear Lakes were successfully translated to Noto and processed for detecting the spectrum of the echo signals. This work was supported by INTAS 01-0669, INTAS IA-01-02, RFBR 02-02-17568 and RFBR-02-02-39023 grants.

**4-07P An Evaluation of VLBI Observations for Deep Space Tracking of Interplanetary Spacecraft**

Ryuichi Ichikawa (1), Mamoru Sekido (1), Hiro Osaki (1), Yasuhiro Koyama (1), Tetsuro Kondo (1), T. Ohnishi (1), M. Yoshikawa (1), Wayne Cannon (2), Alexander Novikov (2), Mario Berube (3), (1) Kashima Space Research Center/CRL, (2) SGL/CRESTech, (3) Natural Resources Canada

Precise spacecraft positions (5-10 nrad) can be obtained with differential spacecraft-quasar VLBI observations that directly measure the angular position of the spacecraft relative to nearby quasars. We performed more than 30 VLBI experiments for the NOZOMI spacecraft navigation from September 2002 until July 2003. NOZOMI, which means "Hope" in Japanese, is Japan’s first Mars probe developed and launched by the Institute of Space and Astronautical Science (ISAS). NOZOMI’s arrival at Mars is rescheduled in the middle of December 2003 through two additional earth swingbys in December 2002 and June 2003. Our main concern was to determine the NOZOMI orbit just before the second earth swing by on June 19, 2003. We also perform other VLBI experiments in order to establish the differential VLBI positioning technique for the interplanetary spacecrafts in realtime. The one of the candidate targets is HAYABUSA,

which was developed to investigate asteroids. We use nine VLBI antennas in Japan to perform the NOZOMI VLBI experiments at X-band. Algonquin 46-m of Natural Resources Canada (NRCan) also participated in several experiments in collaboration with the Space Geodynamics Laboratory (SGL) of CRESTech. We equipped the state of the art “K5 VLBI system” to these stations. The K5 system is the multiple PC-based VLBI system equipped with a PCI-bus Versatile Scientific Sampling Processor (VSSP) board on the FreeBSD and Linux operating system. The K5 system includes the original software packages which are data sampling and acquisition, real-time IP data transmission, and correlation analysis. For the purpose of analyzing the VLBI observables we are developing the specific VLBI delay model for finite distance radio source. The model is already implemented in the VLBI software package. The package will include the VLBI observation scheduling to take account of the passage of the spacecraft near the quasar line of sight and the propagation delay estimating for the ionosphere and the neutral atmosphere. We can successfully detect fringes of NOZOMI range signal for several baselines using software correlation in spite of weak and narrow-bandwidth signal. The final products obtained from the VLBI experiments were available with approximately 20 hours latency. The several tens of gigabytes data sets were acquired at each station on the K5 system within 3-5 hours VLBI experiment. After the completion of each VLBI experiment, the data sets at Usuda, Gifu, and Koganei were transferred to Kashima using a high-speed optical fiber network on TCP/IP protocol in under 3 hours. Correlation processing was completed at Kashima about 10-15 hours later. The estimation of clock parameter based on the quasar group delays was completed at Kashima ~1 hours later. On the other hand, the removable data hard disks at other stations (Tomakomai, Tsukuba, Yamaguchi, and Algonquin) were mailed to Kashima. Thus, the latency to produce the group delays using these station data were up to several days. The obtained group delays were compared with the NOZOMI orbit using R&RR observables. Preliminary results demonstrate that the VLBI delay residuals are consistent with R&RR observables. However, the rms scatter between them are relatively large up to several tens of nanoseconds. We are now evaluating our VLBI group delays by comparing with the R&RR results more deeply. In addition, the first HAYABUSA VLBI experiment was successfully carried out November 26, 2003. We will also present the comparison between the obtained HAYABUSA group delays and the R&RR results.

## Session 5. Analysis Strategies and Software

### 5-01 MODEST: A Tool for Geodesy and Astrometry

Ojars Sovers (1), Chris Jacobs (2), Gabor Lanyi (2), (1) Remote Sensing Analysis Systems, (2) Jet Propulsion Laboratory/NASA

Features of the JPL VLBI modeling and estimation software “MODEST” are reviewed. Its main advantages include: thoroughly documented model physics, portability, detailed error modeling, and two unique options for modeling error sources – full covariance of tropospheric delays and correction for source structure. History of the code parallels the development of the astrometric and geodetic VLBI technique, and the software retains many of the steps taken along its advancement. The code has been traceably maintained

since the early 1980s, and will continue to be updated with recent IERS standards. Scripts are being developed to facilitate user-friendly data processing in the era of e-VLBI.

**5-02 OCCAM v.6.0 Software for VLBI Data Analysis**

Oleg Titov (1), Volker Tesmer (2), Johannes Boehm (3), (1) Geoscience Australia, (2) DGFI, (3) Vienna University of Technology

The OCCAM package has been developed since the beginning of the 80s and it has been maintained by different scientists from different countries and agencies. The current version 6.0 of OCCAM is a powerful tool with new models and strategies to accomplish several tasks in astrometry and geodesy. For example, new mapping function based on numerical weather models have been implemented in the software. Three options for the adjustment – least squares collocation, least squares method and Kalman Filtering – are available. A short description of the strategies is presented as well as results of their application.

**5-03 Past, Present and Future of Sked**

John Gipson, NVI, Inc/GSFC

Before you can analyze an experiment, you must take the data. Before you take the data you must schedule it. There are currently two scheduling programs in widespread use--sked and sched. Sked was developed by Nancy Vandenberg, and is used for scheduling essentially all geodetic experiments. Currently sked is maintained by John Gipson. This talk will give a brief overview of the history of sked. Following this we will discuss changes made over the last year which include 1) automation of the source selection; 2) increased observations through more efficient scheduling; 3) putting soft constraints on the observing to increase observation of weak sources; 4) improved cable wrap algorithm. We will also discuss changes that we are currently making to automate the monitoring of sources in the celestial reference frame.

**5-04 Residual Plotting and Ambiguity Resolution in Calc/Solve**

Volkmar Thorandt, Gerald Engelhardt, Bundesamt für Kartographie und Geodäsie (BKG)

For migration of the Calc/Solve software package to the LINUX operating system the interactive graphics tool CNPLT had to be replaced by a new one. The new graphics tool REPA (Residual Plotting and Ambiguity Resolution) can be used for visualization of observations and residuals, to remove outliers, and for manual ambiguity resolution on single baselines. A new feature of REPA is the automatic group delay ambiguity resolution for the whole baseline set of a VLBI experiment. REPA can be used either in standalone mode or it can be started from interactive Solve. The program is based on the open PGPLOT software. As of now the program is running on HP workstations on the basis of FORTRAN77 respectively FORTRAN90 and it is planned to run it on LINUX.

**5-05 An Advanced Stochastic Model for VLBI Observations and its Application to VLBI Data Analysis**

Volker Tesmer, Hansjoerg Kutterer, DGFI

A further refinement of the functional representation of the geometric-physical properties of the VLBI observations mostly needs big efforts and is not possible with any precision.

Although the stochastic model is an important part of the VLBI observation equations, the stochastic properties of VLBI observations have not been studied in detail so far. The idea behind is to interpret discrepancies between the functional model and the observations approximately as variances of the observations. In particular, the characterization of station and elevation dependent influences is of limited precision. Remaining influences can be modeled by specific stochastic properties of the respective observations. This paper focuses on the application of a refined stochastic model of the observations to the estimation of VLBI target parameters.

**5-06 Vienna Mapping Functions in VLBI Analyses**

Johannes Boehm, Harald Schuh, Vienna University of Technology

In the past few years, numerical weather models (NWM) have been investigated to improve mapping functions which are used for tropospheric delay modeling in VLBI and GPS data analyses. The Vienna Mapping Functions (VMF) are based on direct raytracing through NWM, and so they are able to exploit the full information provided in the NWM. The VMF are determined for selected stations; these are at present all IVS sites. On the other hand, the Isobaric Mapping Functions (IMF, Niell, 2001) are using intermediate parameters calculated from the NWM. These parameters are determined on a global grid and can be interpolated for all VLBI and GPS stations. In this study, pressure level data from ECMWF (European Centre for Medium-Range Weather Forecasts) are applied to determine the coefficients of the VMF and the IMF. Used for the analyses of IVS-R1 and IVS-R4 VLBI sessions, both mapping functions improve the repeatability of baseline lengths (by ~10% for IVS-R1 and ~5% for IVS-R4) compared to the Niell Mapping Functions (NMF, Niell, 1996). In September 2003, a service for the provision of mapping function parameters using data from ECMWF was introduced and can be used for non-commercial purposes.

**5-07 Reliability Measures for Geodetic VLBI Products**

Hansjoerg Kutterer, DGFI

Several assumptions are needed in the analysis of the VLBI data such as the exclusive randomness of observed delays or the similarity (or congruence, respectively) of the observing network and the underlying reference frames. Moreover, the typical representation of the terrestrial reference frame by five or six telescopes within one session is rather weak. There are some important issues concerning the reliability of VLBI products. In a statistical framework reliability has two meanings. The first one deals with the detectability of incomplete or incorrect parts of the model by means of statistical hypothesis tests (internal reliability). The second one studies the impact of non-detectable model errors on the estimated parameters (external reliability). In this paper the theoretical background is reviewed. The focus lies on its application to the estimation procedure, mainly with respect to errors in the reference frame. Proper reliability measures are derived and discussed for a number of VLBI sessions. The influence of possible but non-detectable errors in the station and source coordinates on all kinds of VLBI products is studied in detail.

**5-08 Activities of the IVS Analysis Center at BKG in 2003**

Gerald Engelhardt, Volkmar Thorandt, Dieter Ullrich, Bundesamt für Kartographie und Geodäsie (BKG)

A UT1 time series derived from about 1-hour measurements of the baseline TSUKUBA-WETTZELL was generated and first results of the data processing were compared with the results of the official BKG UT1 time series derived from data of the baseline KOKEE-WETTZELL. The measurements of the new station TIGOCONC (Conception, Chile) have been used in the processing for about 1.5 years. So, first velocity information about this station could be estimated from the station coordinate series. The use of stable sources identified by Martine Feissel-Vernier ("Selecting stable extragalactic compact radio sources from the permanent astrogeodetic VLBI program") was tested and comparisons were made with the results of the routinely used procedure for the EOP determination of the BKG VLBI group. The main analysis activities at the International VLBI Service (IVS) Analysis Center at BKG can be divided into the processing of the correlator output, the producing of two Earth Orientation Parameter (EOP) time series for submission to the IVS, the regular submissions of tropospheric parameters for the IVS-R1 and IVS-R4 sessions, and the generating of daily SINEX (Solution INdependent EXchange format) files for the IVS. For the IVS products Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF) quarterly updated solutions are computed. The main features of these works are explained and some results are compared to the official IERS (International Earth Rotation and Reference Systems Service) products.

**5-01P VLBI Analysis at Bordeaux Observatory**

P. Charlot, A. Bellanger, A.Baudry, Observatoire de Bordeaux

This paper summarizes ongoing VLBI analysis activities at Bordeaux Observatory. These include regular analysis of the IVS-R4 data for studying source position stability, calculation of "structure indices" for evaluation of the astrometric suitability of the ICRF sources, and development of an observing program on the European VLBI Network for densification of the ICRF in the northern sky. Future plans for developing further these activities will be presented.

**5-02P Calc: The Next Upgrade**

David Gordon, Raytheon/GSFC

Calc is the VLBI analysis program which computes theoretical delays and rates. It is used in conjunction with Solve at many of the analysis centers for analysis of geodetic/astrometric VLBI sessions. It is also used alone at most of the world's VLBI correlators to generate the correlator models needed for proper correlation. An overview of the current capabilities of Calc and plans for its next upgrade are presented. Upgrades will include the use of the IERS2003 CEO-based TRF-to-CRF transformations, a frequency domain approach for computing solid Earth tides and ocean loading, new a priori atmospheric delay models, a thermal deformation model, an axis tilt model, and numerous other new or revised models. Calc, along with the entire Calc/Solve system, will also be modified to run on Linux PCs under Fortran 90.

**5-03P Project: Global Analysis of 1979-2004 VLBI Data**

Vadim Gubanov, Institute of Applied Astronomy, RAS

VLBI observations for the last 25 years will be used for new revision of the ICRF, ITRF (VLBI) and IERS (EOP) reference systems with the help of a new multi-purpose software QUASAR. The package QUASAR allows to compute the residuals (O-C) according to IERS Conventions (2003) and to analyze their by single-/multi-series or global adjustment using parametric, stochastic and dynamical models of data. Seven different methods for analysis of diurnal stochastic signals may be used as follows: a) Multi-Parameter Least-Squares (MPLS), b) Multi-Group Least-Squares (MGLS), c) Moving Least-Squares Filter (MLSF), d) Global Least-Squares Collocation (GLSC), e) Kalman Filter of Markov's Process (KFMP), f) Kalman Filter of Random Walk (KFRW), g) Two-Dimension Kalman Filter (TDKF). The iteration process can be realized with respect to both unknown parameters and stochastic signals. Preliminary results of NEOS-A VLBI data analysis by GLSC-technique are presented.

**5-04P VLBI Analysis at the United States Naval Observatory**

David Hall, David Boboltz, Alan Fey, Kerry Kingham, U.S. Naval Observatory

The United States Naval Observatory (USNO) is currently producing a quarterly global Terrestrial Reference Frame (TRF) solution updated twice a week using the IVS-R4 and IVS-R1 experiments. The USNO analysis center is now responsible for the daily solutions and submission of the IVS-R4 experiment databases to the IVS. Here we present the results of our VLBI analysis with comparisons to other EOP series. Additional information regarding VLBI analysis at the USNO and the quarterly solutions can be found at http://rorf.usno.navy.mil/vlbi/.

**5-05P Modeling Vertical Total Electron Content from VLBI Observations**

Thomas Hobiger, Harald Schuh, Vienna University of Technology

The vertical total electron content can be understood as the sum of electrons in a column ranging in zenith direction from the ground station through the ionosphere with a footprint size of one square meter. Although VLBI is a differential technique it is possible to derive such values for each station from VLBI observations as shown in prior papers and presentations. At the Institute of Geodesy and Geophysics, Vienna investigations of the functional and stochastical model were made. An approach dealing with trigonometric functions that allows direct conclusions on amplitudes and phases of the sub-daily periods will be presented. Other strategies using piece-wise linear functions and an extended piece-wise linear approach that deals with adaptive interval widths will be shown, too. The usage of kernel functions, in this case of Gaussian type, as a very general approach in modeling the ionosphere, will be illustrated. The weights used for the stochastical model should also consider the zenith distance on each station if we want to derive absolute total electron content (TEC) values for them. Therefore a weighting function for baseline dependent observations will be presented that takes the different zenith distances into account.

**5-06P Towards an IVS Analysis Conventions**

Zinovy Malkin, Institute of Applied Astronomy RAS, St. Petersburg, Russia

One of the main goals of the IVS is to provide a supreme quality of the IVS products, such as EOP, TRF, CRF, etc. To achieve this, a comparison and combination of the products contributed by the IVS Analysis Centers is needed to understand and mitigate systematic errors of individual solutions and derive the final IVS combined product of the best quality. However, some inconsistencies in models and processing strategy used in various Analysis Centers still exist, which sometimes makes comparison and combination of their results more difficult then desirable. Moreover, this can lead to errors in the combined products and inconsistency of the IVS products with other IERS techniques. So, an IVS Analysis Conventions are definitely needed. In this paper some steps to establish such a Conventions are proposed. They include standardization of some models used in analysis and other topics.

**5-07P Solve: Past, Present and Future**

Leonid Petrov (1), Chopo Ma (2), James Ryan (3), John Gipson (1), Karen Baver (4), Volkmar Thorandt (5), Gerald Engelhardt (5), (1) NVI, Inc./GSFC, (2) NASA/GSFC, (3) NASA/GSFC Retired, (4) Raytheon/GSFC, (5) BKG

Solve is a part of the Mark-5 VLBI Analysis software system Calc/Solve. It was designed in the 1970s and is being updated by several generations of astronomers. This poster makes an overview of past development, current capabilities and plans for future upgrades. Designed for interactive processing Mark I experiments this software evolved to a versatile and efficient tool for VLBI data analysis. A capability of incorporation in the body of Solve user written routines, which was introduced in early 1990s, made it a very powerful tool for scientific research. The code was upgraded in 2000 for processing Mark 4 and K4 VLBI experiments, and later for processing S2 and Mark 5 experiments. Current efforts of a team of developers are focused on migrating from HP-UX to the Linux platform.

**5-08P An Embedded Expert System for the Automation of the VLBI Data Analysis: Concept, Implementation and Results**

Wolfgang Schwegmann, Bundesamt für Kartographie und Geodäsie

The delay between the time of observation and the availability of results is an important disadvantage of geodetic VLBI compared to other geodetic space techniques. One reason is the complicated and highly interactive analysis procedure, requiring well-founded expertise. While advances in e-VLBI technology promise to considerably cut the latency, automatic VLBI analysis tools have still to be developed to obtain VLBI results in near real-time. The concept and implementation of a system to automate the entire VLBI analysis procedure is presented. To achieve the automation, knowledge-based methods from the field of research of artificial intelligence are used. An Intelligent Assistant for Data Analysis in VLBI {IADA} is developed as an embedded expert system. Expert systems are software systems that are designed to reproduce the special knowledge and the expert's capability of reasoning within a narrow application area. Thus, a so-called structured model is defined to describe the VLBI data analysis procedure with all the required knowledge and analysis strategies. Based on the explicit utilization of this knowledge the automation of the analysis procedure can be realized. The term "embedded" is of particular interest, because embedding expert systems in the existing data processing environment is critical for the success of such a system. Embedding IADA in the Mark 4 data analysis software CALC/SOLVE by building a powerful interface guarantees the automation of the whole VLBI analysis procedure. The successful application of IADA in the analysis of about thirty 24 h geodetic VLBI experiments validates the presented approach. IADA is the first system that allows the automation of the entire VLBI analysis procedure for any geodetic VLBI experiment. The results can be compared to those obtained by manual analysis by an expert.

**5-09P Towards an Operational Automatic VLBI Data Analysis Tool for INTENSIVE Sessions**

Wolfgang Schwegmann, Volkmar Thorandt, Gerald Engelhardt, Bundesamt für Kartographie und Geodäsie

Currently the delay between the time of observation and availability of UT1 results from the INTENSIVE sessions is 2-5 days. Advances in e-VLBI technology promise to considerably shorten the latency resulting from the shipment of the tapes or discs from the VLBI stations to the correlators. To avoid the additional delay caused by the standard VLBI data analysis procedure the existing highly interactive analysis tools have to be automated to guarantee the availability of VLBI results in near real time. Thus, an automatic VLBI data analysis tool is developed by the VLBI group of the Federal Agency for Cartography and Geodesy (BKG). It is realized as a new tool within the Mark 4 data analysis software CALC/SOLVE and based on a software system for the automation of any geodetic VLBI experiment (cf. poster presentation: "An Embedded Expert System for the Automation of the VLBI Data Analysis: Concept, Implementation and Results"). The system reads a database with correlator output, sets appropriate parameterization, eliminates outliers, solves the LSQ problem and generates a detailed report on the data analysis. The time needed to generate UT1 results starting from the correlator output is less than 10 minutes. 50 intensive experiments have been analyzed and the results are comparable to the EOP-I products available at the IVS data centers.

**5-10P Simultaneous Estimation of a TRF, the EOP and a CRF from VLBI Observations - First DGFI Results using OCCAM**

Volker Tesmer, Hansjoerg Kutterer, Hermann Drewes, DGFI

Simultaneously estimated station positions, Earth orientation parameters (EOP) and quasar positions are computed using the modified least-squares approach of the VLBI software OCCAM. The procedure provides an unbiased solution by choosing an appropriate datum definition, e.g., by including the no net rotation (NNR) and no net translation (NNT) conditions for station positions and velocities w.r.t. ITRF2000, and NNR conditions for source positions w.r.t. ICRF. The paper presents the analysis strategy and first results using 2230 VLBI sessions between 1984 and 2001. Discrepancies between the solution and the a-priori values from ITRF2000, ICRF and EOP C04 are discussed.

# Session 6. Results and Geodetic/Geophysical/Astrometric Interpretation

## 6-01 Refinement of the ICRF

Chopo Ma, NASA Goddard Space Flight Center

The analysis and data used for the ICRF represented the state of the art in global, extragalactic, X/S band microwave astrometry in 1995. Since 1995 there have been considerable advances in the geodetic/astrometric VLBI data set and in the analysis that would significantly improve the systematic errors, stability, and density of the next radio-frequency realization of the ICRS. In particular, data acquired since 1990, including extensive use of the VLBA, are of higher quality and astrometric utility because of changes in instrumentation, schedule design, and networks as well as specifically astrometric intent. Sufficient data distribution exists to select a better set of defining sources. Improvements in troposphere modeling will minimize known systematic astrometric errors while accurate modeling and estimation of station effects from loading and nonlinear motions will permit the reintegration of the celestial reference frame, terrestrial reference frame and Earth orientation parameters though a single VLBI solution.

## 6-02 Status of the International Celestial Reference Frame

Alan Fey, U.S. Naval Observatory

At the XXIII General Assembly of the IAU held on 20 August 1997 in Kyoto, Japan, the International Celestial Reference Frame (ICRF) was adopted as the fundamental celestial reference frame. The ICRF is currently defined by the radio positions of 212 extragalactic objects obtained using the technique of Very Long Baseline Interferometry at frequencies of 2.3 and 8.4 GHz over the past 20+ years. Since its inception there have been two extensions to the ICRF. The history of the development of the ICRF and its adoption by the IAU will be briefly discussed. Emphasis will be placed on the second extension, ICRF Ext.2, which is being prepared for publication. The primary objectives of the two extensions were to provide positions for new sources and to refine the positions of candidate and other sources using additional observations. A brief overview of the current observing programs contributing to the maintenance and extension of the ICRF will also be presented.

## 6-03 VLBA Impact on Geodesy and Astrometry

David Gordon, Raytheon/Goddard Space Flight Center

VLBA antennas have been used in geodetic/astrometric sessions since 1988. Beginning in 1995, correlation of VLBA geodetic/astrometric sessions has been performed on the VLBA correlator, and then post-processed using AIPS and Calc/Solve. Earlier problems in AIPS fringing now appear to have been solved. Three main groups of geodetic/astrometric sessions have been run on the VLBA: the S/X RDV (and their predecessor) sessions, the S/X VLBA Calibrator Survey (VCS1 and VCS2) astrometric sessions (NRAO programs), and the K/Q astrometric sessions (K-Q Collaboration program). Data from VLBA sessions now comprises approximately 1/4 of the total number of S/X observations. The RDV sessions are providing the most precise reference frame connection in the northern hemisphere, the most precise EOP and nutation ever measured, and are significantly improving the CRF. The 12 VCS sessions have added some 1600 new calibrator sources to the geodetic/astrometric catalog. K/Q sessions are expected to lead to significant improvements in spacecraft navigation as well as to new avenues for geodetic measurements. Current and future contributions of VLBA sessions to the TRF and the CRF at S/X and higher frequencies (K, Q, Ka bands) will be presented and discussed.

**6-04 The VLBI Contribution to Precession (Present and Future)**

Nicole Capitaine (1), Patrick Wallace (2), (1) Observatoire de Paris/SYRTE, France, (2) HM Nautical Almanac Office, Rutherford Appleton Laboratory, UK,

The IAU 2000A precession-nutation model provided by Mathews et al. (2002) was adopted by the IAU and implemented in the IERS Conventions 2003. The precession component of the IAU 2000 model consists only of VLBI estimated corrections to the precession rates in longitude and obliquity of the IAU 1976 precession. This paper investigates the possible present and future role of VLBI observations in identifying a replacement for the precession component of IAU 2000A, with improved dynamical consistency and a better basis for future improvement in the precession of the equator. We first present a realistic evaluation of the accuracy of three independent high precision solutions for precession that were published in 2003, describe tests of the solutions against VLBI observations and then show how future VLBI observations can provide significant progress in the precession model when a sufficient length of the VLBI series is available to discriminate between different solutions.

**6-05 Ring Downs of Free Core Nutations in the GSFC and USNO VLBI Nutation Series** *(Invited)*

Douglas Smylie, Andrew Palmer, York University

The VLBI nutation series from GSFC and the USNO, now in excess of 23 years in length, allow the exploration of the temporal behaviour of both the retrograde and prograde free core nutations. Our analysis implements Singular Value Decomposition to solve the least squares problem of fitting the Discrete Fourier Transform to the non-equispaced VLBI nutation observations. A novel feature of our procedure is to use the Parseval relation to determine the number of singular values of the coefficient matrix to be eliminated. We report the observation for the first time of the prograde mode predicted by Jiang (1993). We find periods of -417 and -413 days for the retrograde mode and 388 and 387 days for the prograde mode. Spectral analyses at 500 day intervals down the two records show the RFCN in both the GSFC and USNO data to be in free ring down. The PFCN in the GFSC series appears to be a similar free ring down. The PFCN in the USNO series does not show similar behaviour, possibly because it is at the noise level. Free decay of the nutation modes allows the direct measurement of the viscosity at the top of the core. The motion with respect to the mantle is nearly pure rotational shear, and simple Ekman layer theory allows the ring down to be related to viscosity there. We find a value there of 4000 Pa s in contrast to the commonly cited value of 0.008 Pa s found by Gans (1972).

**6-06 Viscosity of the Earth's Fluid Core from VLBI Data**

George Krasinsky, Institute of Applied Astronomy, RAS

Recently adopted Nutation 2000 provides better presentation of coordinates of the Celestial Pole obtained by VLBI geodetic programs but depends on a number of empirical parameters that have no clear physical meaning. We show that the most noticeable observed peculiarities of precessional and nutational motion of the Celestial Pole (the secular rate in the obliquity and the large out-phase nutational amplitudes) may be explained as arising due to viscosity of the Earth's fluid core. These effects are expressed in terms of the lag of tides in the fluid core. The value of the lag is estimated from the VLBI based positions of the Celestial Pole.

**6-07 Contribution of VLBI to Earth Orientation Monitoring: State-of-the-Art and Future Prospects**

Daniel Gambis, Christian Bizouard, Observatoire de Paris

The Earth Orientation Center of the IERS is making use of the different astro-geodetic techniques, SLR, GPS and VLBI to derive optimal combined time series of Earth Orientation Parameters (EOP). VLBI as the only inertial astro-geodetic technique is essential for UT1 and nutation offsets variabilities determination in addition to pole coordinates. In the presentation we discuss the weaknesses and the strengths of VLBI contributions for EOP time series combinations, and present the evolution and the state-of-the-art of the contribution in the IERS analyses with respect to the other techniques. A fundamental issue is the consistency of long-term EOP with respect to both terrestrial and celestial reference frames, ITRF and ICRF. We present the various methods currently applied at the IERS to check and monitor it. Future prospects are finally presented. They concern rigorous methods based on a simultaneous estimation of the terrestrial frame and EOP and which are now being implemented within the IERS.

**6-08 UT1 Intensive Series Using K4 Technology**

Dorothee Fischer (1), Richard Kilger (2), Shinobu Kurihara (3), Axel Nothnagel (1), Wolfgang Schlüter (2), Kazuhiro Takashima (3), (1) Geodetic Insitute of the University of Bonn, (2) Bundesamt für Kartographie und Geodäsie, (3) Geographical Survey Institute of Japan

The new short duration observing series for UT1 determination using K4 technology started in July 2002 using the Wettzell - Tsukuba baseline. The joint IVS project organized by the Bundesamt für Kartographie und Geodäsie (BKG) (Germany), the Geographical Survey Institute (GSI) (Japan) and the Geodetic Institute of the University of Bonn (GIUB) (Germany) aims at independent monitoring of UT1. In 2002 the first pilot series contained 20 experiments and since April 2003 observations are carried out on a regular weekly basis. In view of combining the UT1 results of the new series with those of existing observing series some questions on reference frames and analysis strategies have to be discussed. Differences in setup, analysis and results of both Intensive series as well as comparisons with results of 24 hour experiments will be presented.

**6-09 Considering a priori Correlations in the IVS Combined EOP Series**

Christoph Steinforth, Axel Nothnagel, Geodetic Institute of the University Bonn

The current combination strategy actually implies a violation of the basic rule that the same data cannot be used twice in an adjustment process. This fact is presently neglected by treating the input data of the IVS Analysis Centers as "new" data. However, this deficiency can be mitigated by introducing proper correlation coefficients between the Analysis Centers. Different approaches for deriving such correlations as well as results are presented in this paper.

**6-10 CONT02 campaign - Combination of VLBI with GPS**

Volker Tesmer (1), Manuela Kruegel (1), Detlef Angermann (1), Daniela Thaller (2), Markus Rothacher (2), Ralf Schmid (2), (1) DGFI, (2) Technische Universitaet Muenchen

The IVS campaign CONT02 provides 15 days of continuous high quality VLBI observations during October 16-31, 2002, with eight telescopes participating. These sessions are highly valuable for research on various topics, among them the rigorous combination with solutions of a global GPS network. Unconstrained daily normal equations of both techniques were generated using OCCAM and the Bernese GPS software for the VLBI and GPS analysis, respectively. Much care was taken to use identical models (solid Earth tides, ocean loading, a priori tropospheric delays, a priori nutation model, ...) in the solution setups. Furthermore, the common parameters, i.e., site coordinates, Earth orientation parameters and tropospheric zenith delays and gradients were identically defined for both techniques. This paper reports about investigations on the impact of local tie information on a combined solution, and studies towards a rigorous combination of troposphere parameters together with station coordinates and EOP. The results can contribute to an identification of systematic technique-related problems and to an understanding the origin of remaining discrepancies.

**6-11 First Results of SINEX Combinations**

Markus Vennebusch, Geodetic Institute of the University Bonn

Up to now combinations of VLBI sessions have been performed on the level of results, i.e. different analysis centers generate series of earth orientation parameters and compute terrestrial reference frames. These series are collected and combined by computing weighted means. This kind of combination is done routinely and the results are official IVS products. A new approach uses datum-free normal equation matrices of VLBI sessions which are provided as SINEX files. Using this kind of strategy a common reference frame can be introduced which is likely to be a reason for offsets in current EOP series. Within this paper first results of EOP combinations will be presented.

**6-12 Evaluation of Global Ionosphere TEC Map by Comparison with VLBI Data** *(invited)*

Mamoru Sekido, Tetsuro Kondo, Eiji Kawai, and Michito Imae, Communications Research Laboratory

Precise ionospheric total electron content (TEC) map of the earth is useful, if it is available for calibration of ionospheric dispersive delay for space measurement techniques using microwave such as GPS, VLBI, and spacecraft navigation. Recent rapid development of GPS techniques is making it more realistic that earth's ionosphere TEC

map measured by GPS observation is practically applicable in those space measurements. We chose global ionosphere maps (GIMs) generated by the Center for Orbit determination in Europe (CODE) as a sample of GPS-based ionospheric map. And for the purpose to evaluated accuracy of the GIM/CODE, we compared them with dual band (S/X) VLBI experiment data from short up to intercontinental baselines. The group delay computed by using the GIM data of the GIM/CODE had about 90 % correlation with VLBI data. Then it was found that more than 90 % of ionospheric TEC could be predictable with that TEC map. Through further statistical analysis of TEC comparison data, error spectrum of GIM/CODE data was computed. Comparing the obtained error spectrum with error of spherical harmonics component of GIM/CODE data, latter was always smaller than the former, and the error of GIM/CODE data is suspected to be underestimated, especially at low spatial frequency. It was inferred from the spectrum that more than 0.8 TECU of ionosphere perturbations remain in higher spatial frequency region, which is not covered by GIM/CODE model. Total accuracy of GIM/CODE data was evaluated around 3.7 -- 3.9 TECU. Also phase delay rates derived from the GIM/CODE were compared with VLBI data. It indicated correlation around 0.6 -- 0.8 on intercontinental baseline, but it is not enough accuracy for practical use in phase delay rate correction in VLBI observation. The reason of low coincidence is understood by lack of small scale and short time scale TEC variation information in that TEC map model.

**6-13 How VLBI Contributes to Ionospheric Research**

Thomas Hobiger, Harald Schuh, Vienna University of Technology

In order to determine ionospheric delay corrections geodetic VLBI observations are carried out at two distinct frequencies. Each ionospheric delay corresponds to the total electron content (TEC) along the ray path through the ionosphere. Because VLBI is a differential technique the observed ionospheric delays represent the differences of the behavior of the propagation media above each two stations. Additionally, there is an instrumental delay offset per baseline that contributes to the observed ionospheric delay by a constant value. This instrumental offset is independent of azimuth and elevation in which the antennas point what allows to separate it from the variable ionospheric parameters for each station which can be represented by different functional approaches. If we neglect horizontal gradients in the ionosphere above the stations we are able to separate the instrumental offsets from the ionospheric parameters by a least-squares fit. A weakness of this approach is the assumption that the TEC values are assigned to the station coordinates but not to the geographical coordinates of the intersection point of the ray path and the infinitely thin ionospheric layer. The precision of the values determined by VLBI is about +/- 2 to +/- 3 TEC units (TECU). These results agree within 3 to 5 TECU with results of other techniques like GPS.

**6-14 Limitations to Dual Frequency Ionospheric Corrections for Frequency Switched K-Q Observations with the VLBA**

Gabor Lanyi (1), David Gordon (2), Ojars Sovers (3), (1) Jet Propulsion Laboratory, (2) Raytheon/GSFC, (3) Remote Sensing Analysis Systems

A series of VLBA experiments were carried out at K and Q bands for astrometry and imaging within the K-Q VLBI Survey Collaboration. The paired K and Q observations of each source are separated by approximately 3 minutes of time. We investigate the delay effect of the ionosphere between K and Q bands involving the interscan separation. This differential delay effect is intermixed with the differential fluctuation effect of the troposphere.

**6-15 Tropospheric Parameters Estimated by Geodetic VLBI Data**

Monia Negusini, Paolo Tomasi, Istituto di Radioastronomia, Bologna, Italy

The Institute of Radioastronomy (IRA) joined since the beginning the IVS TROP project providing regular submission of tropospheric parameters (wet and total zenith delays, horizontal gradients) for all IVS-R1 and IVS-R4 sessions since January 1st, 2002. In order to determine reliable time series of tropospheric parameters, we analyzed all the 2000-2003 databases available on the IVS data centers. Some of the tropospheric results are presented here. We have also compared the VLBI tropospheric estimates and the GPS-derived troposphere, provided by IGS (International GPS Service), for the co-located sites. Post-processing analysis have been carried out on the time series and trends and seasonal signals are highlighted. Constant biases are found between the zenith delays derived by VLBI and GPS, although the same effects should affect both techniques. Moreover, we started to test the implementation of combined wet zenith delay estimates into VLBI data analysis in order to improve the repeatability of stations baselines.

**6-16 Mass Loading Effects on Crustal Displacements Measured by VLBI**

Daniel MacMillan, NVI, Inc./GSFC

Observed VLBI site position variations contain significant contributions at seasonal frequencies. The annual site vertical amplitudes are mostly 3-6 mm compared with a wrms vertical precision of 8-14 mm. We determine the extent to which seasonal and non-seasonal site variations can be explained by atmospheric loading, hydrologic loading, and nontidal ocean loading. We also examine effects on site vertical variation due to tropospheric delay hydrostatic mapping function mismodelling and antenna thermal deformation.

**6-17 First Results of the IVS Pilot Project "Time Series of Baseline Lengths"**

Axel Nothnagel, Geodetic Institute of the University of Bonn

In summer 2003 a call for proposals was issued for an IVS Pilot Project "Time Series of Baseline Lengths". Six IVS Analysis Centers responded positively and regular submissions are expected to start soon. The input of the first submissions has been analyzed providing the basis for some initial conclusions.

**6-18 Preliminary Results of the IVS Gravity Experiment grav01**

Leonid Petrov, NVI, Inc./GSFC

On September 8, 2002 the Jupiter has passed in 3.7 arcmin from the quasar 0836+182. Three dedicated IVS experiments were performed: one during this event, another experiment two weeks before and the third experiment 6 months before. The purpose of the experiments was to measure the term in the time delay which is proportional to (v/c)**3, where v is the velocity of the gravitating body. This term originates from the non-stationary component of the gravitational potential and has not yet been measured directly. Design of the experiment, technology of data analysis and preliminary results are discussed.

**6-01P Stability of the VLBI-Derived Celestial Reference Frame**

Martine Feissel-Vernier, Observatoire de Paris and IGN

We present background information of a paper published in Astronomy and Astrophysics that investigated several stable source selection processes and proposed a list of 199 stable sources that could be used for a future improvement of the ICRF. Their performance in maintaining the direction of the ICRF axes is better by a factor of four or five than that of the current 212 ICRF defining sources.

**6-02P Southern Hemisphere Astrometry**

Alan Fey (1), Roopesh Ojha (2), et al., (1) U.S. Naval Observatory, (2) Australia Telescope National Facility

The United States Naval Observatory and the Australia Telescope National Facility are leading a collaboration in a continuing Very Long Baseline Interferometry research program in Southern Hemisphere astrometry and source imaging. The goals of this program are to increase the sky density of International Celestial Reference Frame (ICRF) sources in the Southern Hemisphere by adding new sources with milliarcsecond accurate positions and to image all Southern Hemisphere ICRF sources at least twice for structure monitoring. Milliarcsecond accurate radio positions for 22 Southern Hemisphere extragalactic sources are reported. These positions are derived from Mark III Very Long Baseline Interferometry observations made between 2003 February and 2003 August. The positions for all 22 sources are south of -30 degrees declination and represent the largest group of new milliarcsecond accurate astrometric positions for sources in this declination range since the initial definition of the ICRF. The reported positions have average formal uncertainties of 0.5 milliarcseconds in right ascension and 0.6 milliarcseconds in declination. A brief overview of the initial imaging results will also be presented.

**6-03P Extending the ICRF to Higher Radio Frequencies – Imaging and Source Structure**

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We present imaging results and source structure analysis of extragalactic radio sources observed using the Very Long Baseline Array (VLBA) at 24 GHz and 43 GHz as part of an ongoing NASA, USNO, NRAO and Bordeaux Observatory collaboration to extend the International Celestial Reference Frame (ICRF) to higher radio frequencies. The long term goals of this program are a) to develop higher frequency reference frames for improved deep space navigation, b) to extend the VLBA calibrator catalog at 24 and 43 GHz, c) to provide the benefit of the ICRF catalog to new applications at these higher frequencies and d) to study source structure variation at 24 and 43 GHz in order to improve the astrometric accuracy. The K/Q-band image database now includes images of 108 sources at 43 GHz (Q-band) and images of 230 sources at 24 GHz (K-band). Preliminary analysis of the observations taken to date shows that the sources are generally more compact as one goes from the ICRF frequency of 8.4 GHz to 24 GHz. This result is consistent with the standard theory of compact extragalactic radio sources

and suggests that reference frames defined at these higher radio frequencies will be less susceptible to the effects of intrinsic source structure than those defined at lower frequencies.

**6-04P Investigation of Nutation Beyond the IAU2000 Model**

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Precession and nutations are mainly generated by the luni-solar attraction. Diurnal variations in the atmospheric and oceanic angular momenta in an Earth-fixed reference system induce additional constant corrections to some nutation motions. Observed precession and nutations are derived from Very Long Baseline Interferometry (VLBI) data, assuming that the directions of observed quasars are fixed in space. In this study, we consider the effects of two possible causes for explaining discrepancies between the observed nutations and those modeled in MHB2000 (model adopted by the International Astronomical Union), (1) the temporal variations in the atmospheric (and potentially oceanic) forcing of nutations, of the Free Core Nutation (FCN) and of the Free Inner Core Nutation (FICN), and (2) the possible contamination of VLBI-derived nutation amplitudes by apparent changes in the directions of the extragalactic radio sources.

**6-05P A New FCN Model with Variable Period and Amplitude**

Zinovy Malkin (1), Toshimichi Shirai (2), (1) Institute of Applied Astronomy RAS, (2) Goldman Sachs (Japan) Ltd.

Results of analysis of differences between observed nutation series and IUAU2000A model are presented. The differences are analyzed by means of both wavelet and short-time periodogram with Gabor function methods. Both methods reveal variability of the FCN period and/or phase. Variations of the FCN amplitude are also obtained. Based on these results, a new FCN model with variable period (phase) and amplitude is constructed. Using this model allows us to significantly reduce the differences between observations and model. Accuracy of the FCN prediction with AR(I)MA and Neural Networks methods is analyzed.

**6-06P Analysis of the VLBI Intensive Sessions**

Karen Baver (1), Dan MacMillan (2), Leonid Petrov (2), David Gordon (1), (1) Raytheon/GSFC, (2), NVI, Inc./GSFC

Intensive sessions were designed to determine UT1 with minimum latency. Therefore these sessions are the highest priority service which IVS provides to a wide community of users. We have analyzed the NEOS (KOKEE-WETTZELL) intensives and the IVS-INT2 (TSUKUB32-WETTZELL) intensives. Here we present results of our analysis of the performance of these two intensive series, and we compare them to other UT1 series. We investigate the precision of the intensive UT1 series and possible seasonal variation of the precision. We also examine the dependence of session performance on the selection of observed sources, and we discuss strategies for improving the observing schedules.

**6-07P Investigations of High-Frequency Earth Rotation Variations from VLBI CONT Observations**

Raymundo Del Cojo Lopez, Juan Mata Lozano, Rüdiger Haas, Onsala Space Observatory

Several theoretical models exist that predict high-frequency earth rotation variations for example induced by variations in the atmospheric and ocenic angular momentum. We use observational results from the continuous VLBI series CONT94, CONT95 and CONT02 to investigate these phenomena. The VLBI results are compared to the theoretical models and the signals are analyzed using periodogram and wavelet analysis.

**6-08P High Resolution Earth Rotation Parameters Determined During the CONT02 Campaign**

Jolanta Nastula (1), Barbara Kolaczek (1), Robert Weber (2), Johannes Boehm (2), Harald Schuh (2), (1) Space Research Center PAS, Warsaw Poland, (2) Vienna University of Technology

Over the two weeks of the CONT02 campaign in October 2002 the Earth rotation parameters (xpol, ypol, UT1-UTC) were determined with a resolution of one hour by VLBI and also by GPS. Analyses of these two very precise polar motion series reveal an oscillation with a period of 8 hours. Rapid oscillations of polar motion with periods of 8 and 5-6 hours were already found in the two-hourly polar motion series determined by GPS (CODE) in the period 1997.5 through 2001.0 but in that time it was unclear whether these are phenomena connected with the observational technique, e.g. with effects of the satellite orbits. Analyses of the data of the CONT02 campaign do not reveal a 6-hour oscillation. However, the detection of an 8-hour oscillation in polar motion independently determined by two accurate space geodetic techniques is a first evidence for a real sub-semidiurnal variation of the ERP. On the other hand the oscillations might be still an artifact stemming from similar methods of data sampling or from un-recovered diurnal drifts in the time series. The UT1-UTC (and lod in the case of GPS) time series were also analyzed with respect to sub-diurnal variations.

**6-09P Ionospheric Parameters Obtained by Different Space Geodetic Techniques During CONT02**

Thomas Hobiger, Sonya Todorova, Harald Schuh, Vienna University of Technology

The goal of the CONT02 campaign was to acquire the best possible state-of-the-art VLBI data over a period of more than two weeks to demonstrate the highest accuracy of which VLBI is capable. In addition to the estimation of station coordinates, EOPs and tropospheric parameters this campaign provides us the chance to study the ionosphere by means of VLBI. Vertical total electron content (VTEC) values above the contributing stations were determined and further studies were made. It is possible to investigate the periodic behavior of the VTEC values and by comparison with results from other techniques, like GPS, systematic differences could be detected of which the reasons are still unclear. Anyway, generally there is a very good agreement between the parameters derived by VLBI and the results from other space geodetic techniques.

**6-10P Comparison of Ionospheric Activity Derived from GPS and Different VLBI Networks**

Sten Bergstrand, Rüdiger Haas, Onsala Space Observatory

GPS is currently the space geodetic technique most widely used for ionospheric studies, and provides broad coverage with high spatial and temporal resolution. Global maps of total electron content are produced daily by several research groups. Due to the dual frequency receivers, VLBI is also capable of sensing the total electron content of the ionosphere. We make a comparison of the ionospheric activity derived from different VLBI networks to global GPS results.

**6-11P IVS Tropospheric Parameters**

Harald Schuh, et al., Vienna University of Technology

In April 2002 the International VLBI Service for Geodesy and Astrometry set up the Pilot Project - Tropospheric Parameters, and the Institute of Geodesy and Geophysics (IGG), Vienna, was put in charge of coordinating the project. Seven IVS Analysis Centers have joined the project and regularly submitted their estimates of tropospheric parameters in terms of wet and total zenith delays and horizontal gradients for all IVS-R1 and IVS-R4 sessions since January 1st, 2002. The individual submissions are combined by a two-step procedure to obtain stable, robust and highly accurate tropospheric parameter time series with one hour resolution. The internal VLBI accuracy is about 2-4 mm. The zenith delays derived by VLBI are compared with those provided by the International GPS Service (IGS). At sites with co-located VLBI and GPS antennas biases are found between the GPS and VLBI derived zenith delays, although the short-term variabilities generally show a good agreement. Possible reasons for these biases are discussed. Since July 1st, 2003, the tropospheric parameters are determined as operational products within the IVS. The poster also includes the VLBI CONT02 campaign of 15 days of continuous observations in the second half of October 2002.

**6-12P Long Time ZTD Series for Some Stations**

Elena Skurikhina, Institute of Applied Astronomy

Long time ZTD series for selected stations were obtained from all 24 h series VLBI data processing with OCCAM package using Kalman filter technique for estimation of stochastic parameters (clock offset and ZDT). One ZTD value for each 24 h session is computed. Long time ZDT behavior can be described as combination of seasonal part and linear trend. Parameters of linear trend (bias, rate) and seasonal harmonic (amplitude, phase) for 20 VLBI stations with long observational history are presented. The comparison with mean diurnal values of meteodata is made.

**6-13P Calculating Mapping Functions from the HIRLAM Numerical Weather Prediction Model**

Bisser Stoyanov, Rüdiger Haas, Lubomir Gradinarsky, Onsala Space Observatory, Chalmers University of Technology

Modelling of tropospheric effects in space geodetic techniques like VLBI and GPS requires the use of mapping functions. Several different mapping functions are presently in use, some of them based on numerical weather models. We have applied the HIRLAM 3D-VAR numerical weather prediction model for a direct calculation of mapping

functions via raytracing. The advantages of this approach are the high spatial resolution (0.2 degrees x 0.2 degrees) of this model as well as its capability to provide data every 3 hours in a prediction mode. Mapping functions were fit down to a 2.5 degrees elevation angle. The new mapping functions were tested on VLBI measurements including Onsala, Sweden and Wettzell, Germany.

**6-14P Relative Deformations Between Collocated VLBI Stations and Comparisons with VTRF2003**

Zhigen Yang, (1), Mario Berube (2), Anthony Searle (2), (1) Shanghai Astronomical Observatory, Chinese Academy, (2) Geodetic Survey Division, Natural Resources Canada

Accurate determination of station positions and velocity vectors for the realization and maintenance of the International Terrestrial Reference Frame (ITRF) are among the contributions of global VLBI stations. ITRF solutions, such as ITRF2000, are combination solutions using different space geodetic techniques and could have potential “inconsistencies” between different realizations. At present, the estimated average uncertainty on regularly observed baselines for VLBI determined baseline length change is better than ±1.0 mm/yr. This study discusses results of the relative deformations between nearby stations in global collocated VLBI sites based on the ITRF2000 and using the NNR- NUVEL-1A model to calculate the modeled horizontal motions. Some international VLBI stations, which, in this method, have large vertical deformations relative to previous solutions, are also discussed. Comparisons of the results with those of the VTRF2003 solution (Ma et al, 2003) are addressed. The technique uses the observed baseline rates as constraints to quantify regional/local deformations relative to the NUVEL-1A model solution and obtain the relative deformations between two closely spaced VLBI stations separated by a few hundred to few thousand meters, and determines improved deformations at a regional or local spatial scale, isolating the “inconsistencies” from the TRF solutions. The approach is introduced and preliminary comparisons are made.

**6-15P Postseismic Transient After the 2002 Denali Fault Earthquake from VLBI Measurements at Fairbanks**

Daniel MacMillan, NVI, Inc./GSFC

The VLBI antenna at Fairbanks observes in networks routinely twice a week and on additional days with other networks on a more uneven basis. The Fairbanks antenna position is about 150 km north of the Denali fault and from the earthquake epicenter. Time series of the VLBI horizontal position at Fairbanks show that over the first 6 months after the earthquake, the rate of change of position primarily in the northerly direction was about 20-30 mm/yr less than the long-term rate prior to the earthquake. We examine the transient behavior during the year following the earthquake to determine how the rate of change of postseismic deformation has decreased. We compare the VLBI time series with the GPS time series, which also shows a similar transient after the earthquake. We also compare the rate of transient decay from Fairbanks with decay from other examples of transient behavior following earthquakes that have been monitored by continuous GPS measurements.

**6-16P Post-Seismic Motion of Gilcreek Geodetic Sites Following the November, 2002 Denali Earthquake**

Oleg Titov (1), Paul Tregoning (2), (1) Geoscience Australia, (2) Research School of Earth Sciences, ANU

We have detected post-seismic motion of the Gilcreek observatory in Fairbanks, Alaska after the Denali earthquake from an analysis of VLBI and GPS data recorded at the site in the 12-month period following the event. The motion is non-linear, indicating that either a relaxation process or afterslip on the fault is occurring. The co-seismic estimate of displacement from VLBI measurements agrees well with those from GPS analysis in all components.