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The 5th General Meeting of the International VLBI Service for Geodesy and Astrometry

MEASURING THE FUTURE

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This book contains the abstracts of papers presented at the 5th General Meeting of the International VLBI Service for Geodesy and Astrometry «Measuring the Future» which is held on March 2–6, 2008 in the Institute of Applied Astronomy of the Russian Academy of Sciences (St. Petersburg, Russia). These abstracts are devoted to modern aspects of astrometry, geodesy and geodynamics including theories of Earth rotation, plate tectonics and crustal deformations, Celestial and Terrestrial reference frames, VLBI observations and e-VLBI.

This book is of interest for specialists in astrometry, geodesy, geodynamics and related fields.

Edited by
Dirk Behrend and Andrey Finkelstein

Session 1: VLBI – A Vital Player in Global Observing Systems

1-01 IVS Report 2006-2008
Dirk Behrend (NVI, Inc./GSFC), Harald Schuh (Vienna University of Technology)
We will review and discuss the projects and activities of the IVS over the past two years. The report will also include the activities of the Coordinating Center as well as a review of meetings and publications.

1-02 IVS Plans and Perspectives
Harald Schuh (Vienna University of Technology), Dirk Behrend (NVI, Inc./GSFC)
We will present and discuss plans and future perspectives of the IVS. This includes ongoing activities within VLBI2010 but also future technological developments, new tasks and goals and the general strategies of the service. Its role with respect to GGOS will also be described.

1-03 Synergies between VLBI and GNSS *(invited)*
Urs Hugentobler (FESG Munich)
The two microwave techniques VLBI and GNSS observe common geodetic and atmospheric parameters. The comparison of time series of site positions, Earth rotation parameters, and troposphere or ionosphere delays allows investigating technique specific differences and problems. Assuring a consistent modeling the mutual strengths of the two techniques can be exploited by a combination at the parameter level. Estimation of subdaily Earth rotation parameters based on GNSS observations, affects, for instance, the orientation of satellite orbits. The introduction of VLBI data into the GNSS analysis should help to cure this deficiency.

Both techniques are one-way measurement systems that are based on the synchronization of distant clocks. VLBI uses hydrogen masers as a very stable frequency standard whose behavior is modeled by a few parameters of a low degree polynomial, while for GNSS receiver clock offsets are commonly determined independently for each epoch. For GNSS receivers connected to hydrogen masers (e.g., at VLBI stations), positioning results may gain by exploiting the high stability of the frequency reference. On the other hand, VLBI might profit from frequency transfer based on GNSS measurements. The potential of combining the two techniques at the observation level remains to be exploited.

1-04 Combining VLBI Intensive with GPS Rapid Solutions for Deriving a Stable UT Time Series
Daniela Thaller (GFZ Potsdam), Volker Tesmer (DGFI Munich), Rolf Dach (University of Berne), Manuela Krügel (DGFI Munich), Markus Rothacher (GFZ Potsdam), Peter Steigenberger (GFZ Potsdam)
Recently, the IVS started to provide SINEX files for the intensive sessions, containing station coordinates, polar motion, polar motion rates, universal time (UT) and length of day (LOD). In standard solutions for the intensive sessions, all EOP except for UT are to be fixed on or tightly constrained to predicted values. As the datum-free normal equation systems are provided in SINEX, we have the possibility to rigorously combine the intensive sessions with other data in order to have more reliable information than the predictions, especially for polar motion. In view of a short latency, it is of special interest to combine the intensive sessions with the rapid GPS solutions. Based on the SINEX files provided by the IVS and datum-free normal equations derived from the rapid GPS analysis we perform daily combinations and assess the benefit for the estimation of UT. On the other hand, for GPS the combination

with VLBI intensive sessions will allow to derive daily rapid solutions with a correct alignment of UT. In general, if a combination of GPS-derived LOD and VLBI-derived UT and LOD time series should be performed, the intensive sessions play a very important role. Using only the 24-h VLBI sessions and GPS solutions for every day, there are many epochs in the time series of UT that have no contribution from VLBI and, thus, suffer from the systematic drift that is induced by integrating GPS-derived LOD over longer time spans. This deficiency can be overcome if the intensive sessions are included. The benefit of such a procedure will be quantified in this presentation as well.

1-05 How Can the Wettzell "G" Ringlaser Improve VLBI Measurements of Subdiurnal Earth Rotation Variations?

P.J. Mendes Cerveira (Vienna University of Technology), H. Schuh (Vienna University of Technology), T. Klügel (BKG Wettzell), A. Velikoseltsev (FESG Munich), U. Schreiber (FESG Munich)

Very Long Baseline Interferometry (VLBI) resolves daily to hourly geodetic polar motion (PM) and Universal Time (UT1) to a precision of better than 100 µas. Ringlasers are instruments that are senstive to Earth rotation parameters by measuring relative Sagnac frequency variations without any relation to a celestial reference frame. However, these instruments are confronted with the problem of instrumental drift. This drift is unstable and unpredictable for periods longer than two days. A joint analysis of VLBI and ringlaser observations could provide information of the high-frequency Earth rotation spectrum, i.e. at the poorly resolved subdiurnal periods. After presenting the mathematical background and the relevant equations we will give some first results of an inter-technique combination on the normal equation level. As these first tests with a one hour resolution are still unsatisfactory, we simulated VLBI

observations from a realistic eleven stations network, as well as ringlaser observations for station Wettzell, Germany. The simulations included the effect of ocean tides on PM and UT1 for both techniques. The goal was to check the improvement of hourly VLBI parameters (PM and UT1) when additionally accounting for 1-minute synthetic ringlaser observations.

1-06 The Role of VLBI in GGOS *(invited)*

Markus Rothacher (GFZ Potsdam)

The presentation will describe the role of VLBI in GGOS.

1-07 Search for VLBI-compact Extragalactic Radio Sources

Yuri Kovalev (MPIfR Bonn)

We discuss a new method and results, current activities and plans to find more new extragalactic radio sources with bright components compact at milliarcsecond scales between 2 and 43 GHz. We analyze continuum spectra observed with RATAN-600 or available from literature and predict flux density of VLBI-compact jets. In addition, fring-search experiments with short on-source scans are conducted with VERA and EVN to preselect sources detectable at VLBI spacings. As a result of this effort, efficiency of successful candidate selection has been significantly improved. More than 1000 new VLBI-compact sources were found in recent VLBA experiments. Their positions are determined with high accuracy. Characteristics of these objects suitable as phase calibrators are studied at mas-scale.

1-08 Multi-step VLBI Observations of Weak Extragalactic Radio Sources to Align the ICRF and the Future GAIA Frame

Géraldine Bourda (Bordeaux Observatory), Patrick Charlot (Bordeaux Observatory), Richard Porcas (MPIfR Bonn), Simon Garrington (Jodrell Bank Observatory)

The space astrometry mission GAIA will construct a dense optical QSO-based celestial reference frame. For consistency between the optical and radio positions, it will be important to align the GAIA frame and the International Celestial Reference Frame (ICRF) with the highest accuracy. Currently, it is found that only 10% of the ICRF sources are suitable to establish this link, either because they are not bright enough at optical wavelengths or because they have significant extended radio emission which precludes reaching the highest astrometric accuracy. In order to improve the situation, we have initiated a VLBI survey dedicated to finding additional high-quality radio sources for aligning the two frames. The sample consists of about 450 sources, typically 20 times weaker than the current ICRF sources (down to the 20 mJy flux level), which have been selected by cross-correlating optical and radio catalogues. This paper presents the observing strategy to detect, image, and measure accurately the astrometric position of these sources. It will also include the first results of observation of these sources with the European VLBI Network in June and October 2007.

1-09 Multi-Source VLBI: A New Geodetic VLBI Observing Technique

Victus N. Uzodinma (University of Nigeria)

The "single-source" geodetic VLBI (Very Long Baseline Interferometry) observational technique widely used at present measures the positions of radio sources and the motions of points on the surface of the Earth by observing sources (one at a time) simultaneously from the two ends of a baseline. For a successful simultaneous determination of parameters, observations must be distributed correctly over a minimum of three sources otherwise singularity will occur. To achieve accuracies exceeding one mas (0.001") such observations are usually made over a time span of one or more days and spread over more than one baseline. However, if a VLBI technique is developed for observing five or more radio sources simultaneously (i.e., a 'multi-source' technique) instead of one at a time, the above accuracies can still be realized even from a single observation (one epoch) and on a single baseline. This paper describes the concept, mathematical formulation, potentials and strategies for the practical realization of the new technique. A software (MULTIQAS) for the new technique has been developed and simulation studies show that the technique meets most of the goals of the IVS (International VLBI Service) vision for future geodetic VLBI (the "VLBI 2010" project). Results obtained from the studies indicate that the technique is capable of achieving accuracies exceeding 1 mas for polar motion and quasar positions; 1 mm for lengths of global baselines; one nanoarcsecond (1×10^{-09}") for precession-nutation and 1×10^{-13} radians/second for the instantaneous rotation rate of the earth.

1-01P High Resolution Atmosphere Angular Momentum Time Series for Continuous VLBI Campaigns

Johannes Böhm (Vienna University of Technology), Paulo Jorge Mendes Cerveira (Vienna University of Technology), Sigrid Englich (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

We determine axial and equatorial effective atmospheric angular momentum functions (EAAMF) from data of the European Centre for Medium-Range Weather Forecasts (ECMWF). The horizontal spatial resolution is decreased down to 0.5 degrees, and the 6-hours temporal resolution is reduced to 3-hours steps from forecasting data. In terms of the ocean response to pressure variations, we compare both, IB

and non-IB approaches. We derive these sets of EAAMF for the time period of continuous VLBI campaigns (CONT02 in October 2002 and CONT05 in September 2005). Geophysical EAAMF are compared to the geodetic ones which are obtained from time series of polar motion and dUT1 with a temporal resolution of 3 hours. The characteristic frequencies in both types of functions will be investigated.

1-02P Astrometry of the Solar System Bodies with VLBI Radar

Igor Molotov (Central Astronomical Observatory at Pulkovo), Maria Nechaeva (Radiophysical Research Institute, Russia), Igor Falkovich (Institute of Radio Astronomy, Ukraine), Vladimir Agapov (Keldysh Institute of Applied Mathematics, Russia), Gino Tuccari (Istituto di Radioastronomia), Giuseppe Pupillo (Università di Bologna), Stelio Montebugnoli (Istituto di Radioastronomia), Gennadiy Kharlamov (Special Research Bureau, Russia), Lance Benner (Jet Propulsion Laboratory), Viacheslav Fateev (International Vimpel Corporation, Russia), Alexander Volvach (Crimean Astrophysical Observatory), Xiang Liu (Urumqi Astronomical Observatory), Ivars Shmelds (Institute of Astronomy, Latvia), Alexander Dementiev (Radiophysical Research Institute, Russia), Nikolay Dugin (Radiophysical Research Institute, Russia), Vladimir Jazykov (Central Astronomical Observatory at Pulkovo)

Three VLBI sessions of LFVN were carried out in 2006-2007 (VLBR06.1, VLBR07.1, VLBR07.2) having the main goal to adjust the application of the VLBI radar method for astrometry of the solar system bodies. The transmitter of Evpatoria RT-70 provided the radio sounding of the Venus, 2004 XP14 and 2007 DT103 asteroids, and space debris objects at 6-cm wavelengths. The echo-signals were recorded by array of the radio telescopes including Kalyazin RT-64, Noto RT-32, Medicina RT-32, Urumqi RT-25, Simeiz RT-22 using NRTV, Mk-5 and Mk-2 terminals. Zelenchukskaya RT-32 participated in VLBR06.1. Also LFVN joined to the radar experiments of Goldstone RT-70 at 3.6 wavelengths for NEA in the time of VLBR06.1 and VLBR07.1 sessions. Irbene RT-32 was equipped with 6-cm feed-horn and receiver, NRTV recording terminal in order to arrange the VLBI tests during VLBR07.2.

The recorded data were processed with NIRFI-3 correlator in N. Novgorod, Russia. New Vimpel-1 processor was developed in order to correlate NRTV and Mk-5 format VLBI data. The precise Doppler shifts were measured and analyzed for echo-signals of 2004 XP14. The VLBI fringes were obtained for the echo-signals of Venus. The echoes of space debris fragments with high area to mass ratio were detected under international observing campaign coordinated Inter-Agencies Space Debris Committee.

Session 2: Network Stations, Operation Centers, Correlators

2-01 The QUASAR Network: 2008, 2009, 2010 *(invited)*

Andrey Finkelstein (Institute of Applied Astronomy RAS), Alexander Ipatov (Institute of Applied Astronomy RAS), Sergey Smolentsev (Institute of Applied Astronomy RAS)

1. 2008—The QUASAR network is being equipped with Mark 5B and RDR-1 terminals for registration of signals in the VSI-H and S2 formats, respectively. The Mark 5B terminals make it possible to carry out the domestic EOP determination programs RU-E and RU-U two times per week. The RDR-1 terminals will be used for supplying observational programs for the RADIOASTRON space mission. Preliminary processing of the data obtained within the domestic programs will be done by the 3-station MicroPARSEC correlator at IAA RAS, whereas RADIOASTRON data processing will be performed at the Astronomical Space

Center correlator. International IVS programs will be carried out with the data recording in Mark 5A format at Svetloe and Zelenchukskaya observatories as well as Mark 5B format at Badary station with preliminary data processing in Bonn, Washington, and Haystack. The Correlation Center in St. Petersburg will be equipped with a remote control system, which will allow an observer to monitor the receiving and recording devices online.

2. 2009—The Quasar network will be equipped with the new generation hydrogen masers CH-175A and combined geodetic and timing GLONASS/GPS receivers. The new generation 6-station ARC correlator will be developed for processing the observations carried out in the frame of the domestic EOP programs once per week. The e-VLBI regime with 100 bps rate will be introduced into the domestic RU-U Intensive programs for UT determination (1-hour session every day).
3. 2010—The RT-70 radio telescope in Ussurijsk will be equipped with the Mark 5B receiving and recording system for joining the Quasar network to carry out both astrometric and astrophysical programs and deep space missions.

2-02 Equipment Failures, Chronic Station Problems, and RFI: Their Effects on Geodetic VLBI Data as Seen at the Correlator

Kerry Kingham (U.S. Naval Observatory), David Hall (U.S. Naval Observatory)

In the course of processing routine IVS sessions, several common station problems reoccur. We present some of these problems as they are seen at the correlator, point out their deleterious effects on the integrity of the observations, and discuss mitigation actions. In addition, some problems external to the stations will be discussed because of their potential impact on VLBI2010.

2-03 Effects on the Geodetic-VLBI Measurables due to Polarization Leakage in the 2.3 GHz and 8.4 GHz Receivers *(invited)*

Alessandra Bertarini (IGG Bonn), Walter Alef (MPIfR Bonn), Brian Corey (MIT Haystack Observatory), Axel Nothnagel (IGG Bonn), Craig Walker (NRAO)

Geodetic VLBI delivers baseline length and Earth orientation parameter measurements, which offer the most viable and precise way to study Earth crustal and core dynamics and to support space navigation. Polarization leakages are one of the instrumental errors that decrease the precision of the measurements, but can be removed from the data. In this study we present the observation strategy used to measure the leakages, the correlation process and some preliminary results.

2-04 Twin Telescope Wettzell: a VLBI2010 Radio Telescope Project

H. Hase (BKG TIGO), G. Kronschnabl (BKG Wettzell), W. Schlüter (BKG Wettzell), W. Schwarz (BKG Wettzell), R. Dassing (BKG Wettzell), R. Kilger (FESG Munich), P. Lauber (FESG Munich)

BKG Wettzell is realizing with its Twin Telescope Wettzell project a radiotelescope system based on the specifications of the IVS VLBI2010 vision. It consists of a pair of identical fast moving radiotelescopes of the 12+ m class observing with a wide spectrum receiver up to at least 12 GHz (covering S/X band), allowing 24h/d observations plus an array mode for higher sensitivity. The project is scheduled to be executed at the Geodetic Observatory Wettzell during 2008-2011. A status report on the project and some technical features will be presented.

2-05 Space Geodesy at KASI

Younghee Kwak (KASI, Ajou University), Jungho Cho (KASI), Jonguk Park (KASI)

The Korea Astronomy and Space science Institute (KASI) intends to analyze geodetic VLBI data and to generate several products: Terrestrial Reference Frame (TRF), Earth Orientation Parameters (EOP), and tropospheric delay. For that, KASI has been establishing the infra-facilities for geodetic VLBI analysis in the last two years—including two data processing servers and a database (DB) server with HDD-storage. All available IVS data are archived in the DB server. Our first analysis results closely agree with results from IVS ACs in some cases. As a next step, we intend to further investigate the mitigation of systematic errors in our products and to analyze products specifically. Based on our VLBI experiences and infra-facilities, KASI will also start research work in the combination of the major space geodetic techniques: VLBI, GNSS, and SLR. In this presentation, we report the status and progress of our geodetic VLBI activities.

2-06 Comparisons of Correlations Using Disk Transfer and e-VLBI Transfer

A. Nothnagel (IGG Bonn), A. Bertarini (IGG Bonn), C. Dulfer (IGG Bonn), T. Artz (IGG Bonn), J. Wagner (Metsähovi Radio Observatory), G. Molera (Metsähovi Radio Observatory), J. Ritakari (Metsähovi Radio Observatory)

In May 2007 in the EURO87 session, the station at Metsähovi recorded the VLBI data in parallel on a Mark 5A disk module and on a Linux Raid system (PC-EVN). The Mark 5A disk module was shipped to the correlator and the data from the Raid system were transferred to a Linux Raid system in Bonn by e-VLBI using the UDP-based protocol Tsunami. In Bonn the data were then copied onto a Mark 5A disk module for correlation. Both data streams were correlated as if they came

from different sites. In this presentation we will show the level of agreement and its consequences for the results of a standard VLBI solution.

2-07 Ultra-rapid UT1 Measurements with e-VLBI

Shigeru Matsuzaka (GSI), Kozin Wada (GSI), Shinobu Kurihara (GSI), Yasuhiro Koyama (NICT), Mamoru Sekido (NICT) Rüdiger Haas (Onsala Space Observatory), Jan Wagner (Metsähovi Radio Observatory)

Earth orientation parameters are a fundamental link to the transformation between the CRF and the TRF. Especially, rapid and unpredictable changes of dUT1 require frequent observations with fast turn-around times. Currently three so-called IVS-Intensive observing sessions (INT1, INT2 and INT3) are carried out. However, it takes at least about 5 hours to release available databases. So, in cooperation with Sweden, Finland and Japan, we have been carrying out ultra-rapid dUT1 experiments to obtain dUT1 within 30 minutes after the end of the session. On November 22, we succeeded in the real-time data transfer and automatic data processing of the Onsala–Tsukuba baseline. The details of the ultra-rapid dUT1 sessions and future plans will be presented.

2-08 The EVN MkIV Data Processor at JIVE and e-VLBI Developments in the EVN

Bob Campbell (Joint Institute for VLBI in Europe), Arpad Szomoru (Joint Institute for VLBI in Europe)

We will review the capabilities of the European VLBI Network (EVN) MkIV Data Processor at JIVE, briefly touching on operations for EVN/global observations and the context within European radio astronomy and beyond. We will focus on correlator/network developments that expand the kinds of experiments that users can conduct. The greatest strides in the past two years have been made in establishing an operational real-time e-EVN facility. We have had 15 proposal-driven real-time science experiments since 2006. The current 6-station e-EVN network can now reliably sustain 512 Mbps data rates, and towards the end of 2007 a 5-station network sustained real-time fringes at 920 Mbps for an hour. We anticipate more stations joining the e-EVN in the next year. In different tests we have obtained real-time fringes at JIVE on Sheshan-Mopra-European baselines at 256 Mbps and inter-Australian baselines (3 stations) at 512 Mbps. We are investigating at the EVN level various operational issues that would allow fuller exploitation of the rapid-response nature of e-VLBI for studying transient sources. Part of the e-VLBI development process has included work on a grid-based software correlator; we currently use this running on multiple local nodes for processing the pre-session ftp fringe-tests.

2-09 The IAA RAS 6-station VLBI Correlator

Igor Surkis (Institute of Applied Astronomy RAS), Andrey Bogdanov (Institute of Applied Astronomy RAS), Artemiy Fateev (Institute of Applied Astronomy RAS), Alexey Melnikov (Institute of Applied Astronomy RAS), Violet Shantyr (Institute of Applied Astronomy RAS), Vladimir Zimovsky (Institute of Applied Astronomy RAS)

The development of the 6-station hardware XF correlator at IAA RAS has almost been completed. The correlator will be used for national geodetic VLBI sessions. The correlator simultaneously processes VLBI signals from 6 stations (15 baselines) with 16 frequency channels on each baseline. The correlator accesses two-bit VLBI signals with 32 MHz maximum tact frequency. The maximum data range from each station is 1 Gigabit per second. The correlator requires VSI-H VLBI input signals and is going to be equipped with Mark 5B playback terminals. The correlator hardware consists of 15 BMC (Base Modules of Correlator) and SDSS (Signals Distribution and Synchronization

System). The SDSS generates DPSCLOCK and DPS1PPS synchronization signals for Mark 5B terminals. The SDSS transfers data stream from each station to 5 BMCs. The BMCs carry out all hardware data processing. Each BMC receives a data stream from two stations and processes 16 frequency channels for this baseline. BMCs are based on FPGA technique. It has been developed as a Compact PCI 6U device. A BMC contains 16 correlation units. Each unit is a single-baseline, single-channel XF correlator for calculating 64 complex delays and picking out calibration signals. Each unit consists of 2 FPGA chips and 2 RAM chips for baseline or station delay mode realization. The data processing algorithms are implemented as FPGA programs. The correlator software is installed on a desktop computer and 4 Compact PCI 6U crates with BMC. Mark 5B terminal control, crate coordination, and data transfer are realized through the correlator local net. The NGS file format is the main output correlator format at the moment. The prototype of the BMC has been developed at IAA RAS from 2002–2004. This small device processes two frequency channels simultaneously. It is connected to the S2-PT terminal working in VSI-H mode. From 2004–2006 the 3-station correlator based on these devices has been developed. It is used now for the processing of the S2-terminal national VLBI sessions. At the present time, the pilot batch of the BMC devices has been produced. The production of the correlator prototype has been started. We plan to complete and to test the full scale correlator in 2009.

2-10 Bonn Correlator Status Report

Arno Müskens (IGG Bonn), Walter Alef (MPIfR Bonn), Alessandra Bertarini (IGG Bonn)

The Bonn Mark IV correlator is jointly operated by the Max Planck Institute for Radio Astronomy (MPIfR), Bonn Germany, the Institute of Geodesy and Geoinformation of Bonn University

(IGG), and the Federal Agency for Cartography and Geodesy (BKG), Frankfurt. In 2007 correlation using electronically transferred VLBI data (e-VLBI) has become routine, especially for the geodetic experiments. It has permitted correlation and submission of the database for the geodetic Intensive series INT3 within 7 hours of observation.

In early 2007 the MPIfR and BKG decided to install a sizeable computer cluster at MPIfR for installing the DiFX software correlator. DiFX is envisaged as a mid-term to long-term replacement of the Mark IV hardware correlator, although the two will coexist until validation tests of the DiFX correlator are concluded. We describe the correlator status, software and hardware upgrades and give an overview of its operation in 2007.

2-11 CVN Software Correlator Development and Applications in the Chinese Lunar Exploration Mission

Weimin Zheng (SHAO CAS)

Being able to achieve very high angular resolution, the VLBI synthetic telescope is widely used in the deep-space explorer tracking. The Chinese lunar exploration project also used the Chinese VLBI Network (CVN) to track the Chang'E-1 (CE-1) satellite besides the traditional Unified S-Band (USB) system. Based on the commercial multiple processor servers, the CVN software correlator can work in near real-time and post processing modes. Besides the normal VLBI data correlation function, it has the abilities of fast fringe search and multi-channel phase calibration abstraction, which are especially useful in spacecraft tracking. It was the main VLBI correlator of and played an important role in the one-month critical near real-time tracking mission of the CE-1 satellite from the phase orbit to the circumlunar orbit procedure in 2007. Before this mission, it was used to determine the precise positions of the two new VLBI stations of Beijing and Kunming. Because the software

correlator using parallel computation technology may be widely applied in the next generation VLBI observation, we constructed another high speed prototype correlator using threads and an MPI (Message Passing Interface) parallel algorithm running on a small Beowulf cluster platform to explore its feasibility. This correlator has 10-station data processing ability and can process wide-band observation data. Operation results indicated that the software correlator has the characteristics of flexible structure, reliability, and scalability. The software correlator will be used in geodesy and astronomy observations, as well as further deep-space exploration projects in the near future.

2-01P Single Dish Radiometric Observations of Geodetic Sources on Radio Telescopes of the QUASAR Network

Mikhail Kharinov (Institute of Applied Astronomy RAS), Andrey Mikhailov (Institute of Applied Astronomy RAS)

The radio telescopes of the QUASAR network are equipped with a control system integrated with the Mark IV Field System (FS) software that is used for radio interferometric observations. A software package was developed at IAA RAS in order to perform single dish radiometric observations. This package consists of FS extensions, scheduling, and data processing software components. Different methods of antenna beam scanning required for single dish observations are implemented in the control system. A complete set of software support for radiometric registration devices used at IAA was developed. It provides device control, graphical visualization, and data recording in special compressed file format. All these capabilities are controlled by the commands added to the FS SNAP language. Two special software packages, SchedMaker and Class Visual, were developed for observation scheduling and radiometric data processing, respectively. The scheduling uses the SNAP language with additional non-standard commands. These observation facilities are used for regular monitoring of the flux density of the sources from the four lists, which are used in the following IVS programs: 1) Intensives INT1 and INT2, 2) CRF, 3) ICRF, and 4) Geodesy (R1, R4, T2). The complete list of sources consists of 128 sources. The observations are carried out every month on X-band. Each time from 30 up to 50 sources are being observed. The program of monitoring was started in July 2005. There are 1782 single source sets observed for the period up to May 2007.

2-02P An Automatic System for Monitoring Hydrogen Standards in the QUASAR VLBI Network

Dmitriy Ivanov (Institute of Applied Astronomy RAS), Aleksandr Vytnov (Institute of Applied Astronomy RAS)

The accuracy of a VLBI network is substantially defined by the characteristics of hydrogen frequency standards, which provide functioning the spatially separated radiotelescopes with independent local oscillators as a phase measurement radio system. All VLBI observatories of the QUASAR network are equipped with a set of three hydrogen standards. For remote monitoring and testing of hydrogen standards the software and hardware systems are being developed at IAA. This automatic system provides internal comparisons between hydrogen standards and external comparison of the basic standard by GPS/GLONASS signals. The data measured are transmitted in quasi-real-time mode to IAA for processing and analysis. The adjustment of standards is made by the results of processing. The equipment allows also a monitoring of the stability of the basic standard during a VLBI session. The data of stability can be used while processing the observations.

2-03P Local Ties Between Co-located Space Geodetic Instruments at the QUASAR Network Observatories

Iskander Gayazov (Institute of Applied Astronomy RAS), Elena Skurikhina (Institute of Applied Astronomy RAS)

The 32-m radio telescopes and dual frequency GPS receivers with choke ring antennas are the main co-located space geodetic instruments at the QUASAR network observatories. The geocentric coordinates of the reference points of these instruments at the Svetloe and Zelenchukskaya observatories have been determined in the ITRF2005 within the framework of IERS, IGS, and EPN activities. The ITRF2005 coordinates of the Badary observatory reference point have been obtained at the IAA Analysis Center by processing VLBI and GPS observations. Local ties between the radio telescope reference points and GPS antenna markers at the observatories have been derived by means of classical geodetic measurements in 2005-2006. The consistency of the ITRF2005 coordinates with the local tie results has been analyzed. The analysis has shown that the eccentricity vectors obtained from geocentric coordinates and transformed to the local systems are in agreement with the parameters of the local ties within 2 cm. The description of local data and the results of the analysis are presented.

2-04P Australian–New Zealand Geodetic VLBI Network Project

Oleg Titov (Geoscience Australia), Sergei Gulyaev (Auckland University of Technology), Jim Lovell (University of Tasmania), John Dickey (University of Tasmania)

Geodetic Very Long Baseline Interferometry (VLBI) is a technique that maintains the International Celestial Reference Frame (ICRF) and contributes significantly to the International Terrestrial Reference Frame (ITRF) and Earth Orientation Parameter (EOP) service. Currently in Australia only the Hobart (Tasmania) radio telescope is involved in geodetic

VLBI observations on a regular basis. A new VLBI network is planned which will consist of five new antennas (three Australian and two New Zealand), each comparatively small (12 meters in diameter) with fast slew rates (5 degrees per second in azimuth) and equipped with Mark 5B data recorders. All VLBI sites will be co-located with permanent GPS receivers, and some of them with SLR facilities to facilitate the frame-tie and to verify the inter-technique performance. We present computer simulations that demonstrate that this network will have the potential to significantly improve the accuracy of the ICRF and hence of the ITRF in the Southern Hemisphere (to sub-mas and sub-cm levels, respectively). The first 12-m antenna of this series will be installed near Auckland, New Zealand in April 2008.

2-05P The CVN in Geodesy: Experiments, Results and Activities in the Near Future

Guangli Wang (Shanghai Astronomical Observatory)

The Chinese VLBI Network (CVN) is comprised of four domestic VLBI stations, and two new of them are operated in China since the year of 2005. To date, three geodetic VLBI experiments have been carried out. In this report we will introduce the experiments and results. And then we will report briefly on the CVN activities in geodesy for the coming years.

2-06P Status of the Setup of the New 40-m Radiotelescope at Yebes (Spain) for Geodetic VLBI

F. Colomer (OAN Yebes), J. Gómez-González (Instituto Geográfico Nacional), J.A. López-Fernández (OAN Yebes), P. de Vicente (OAN Yebes), R. Bachiller (OAN Yebes), S. García-Espada (OAN Yebes)

The National Geographic Institute of Spain (IGN) has built a new 40-m radiotelescope at Yebes. After the commissioning is finished, it will operate at frequencies between 2 and 115 GHz,

including the geodetic S/X frequency bands, for which a receiver is to be installed in February 2008. All the VLBI equipment is ready, including a VSI-compatible DAR and Mark 5B recorder, H-maser, GPS, and weather station. The determination of the local tie to the old 14-m radiotelescope is expected in early 2008. The antenna will join some IVS campaigns in tagalong mode, with the aim of becoming fully involved in 2009.

2-07P Onsala Space Observatory – IVS Network Station

Rüdiger Haas (Onsala Space Observatory), Gunnar Elgered (Onsala Space Observatory), Tobias Nilsson (Onsala Space Observatory)

The Onsala Space Observatory is active in VLBI since the mid-1960ies and regularly contributes to the IVS observing sessions. We describe the current status and the future plans of this IVS network station.

2-08P VLBI Activities of Tsukuba 32-m Station and Tsukuba Correlator

Shigeru Matsuzaka (GSI), Kozin Wada (GSI), Etsurou Iwata (GSI), Hiromi Shigematsu (GSI), Shinobu Kurihara (GSI), Morito Machida (GSI), Kensuke Kokado (GSI), Daisuke Tanimoto (AES/GSI), Kentarou Nozawa (AES/GSI)

We present an overview of the VLBI activities of the Tsukuba 32-m station and the Tsukuba correlator of the Geographical Survey Institute (GSI), Japan.

- In 2007, the station succeeded in the introduction of the K5/VSSP32 sampling/recording system and we conducted regular observations with e-VLBI transfer technology, which we had been in operation since 2006.
- According to an agreement with the University of Tsukuba, a K-band (22 GHz) receiver was installed at the Tsukuba 32-m antenna.

- As the antenna and observation equipment has shown some wear and tear after 10 years in operation, we are planning a special maintenance period for the summer of 2008.
- From 2005 to 2007, we had developed the Parnassus software at the Tsukuba Correlator, which is an intelligent application with graphical user interface to aid the operation of K5 kernel programs. It can process data automatically, and the efficiency of work has improved significantly. In the future, we would like to make all processes automatic and more rapid.
- In addition, with the prospect of becoming an IVS Analysis Center in the future, we are putting the global analysis into practices experimentally.

2-09P The Past Decade of Tsukuba 32-m VLBI Station

Shigeru Matsuzaka (GSI), Kozin Wada (GSI), Etsurou Iwata (GSI), Hiromi Shigematsu (GSI), Shinobu Kurihara (GSI), Morito Machida (GSI), Kensuke Kokado (GSI), Daisuke Tanimoto (AES/GSI), Kentarou Nozawa (AES/GSI), Kazuhiro Takashima (College of Land, Infrastructure and Transport), Yoshihiro Fukuzaki (GSI)

The Tsukuba 32-m VLBI station began operation in June 1998 as a successor to the Kashima 26-m station, which had contributed to the progress of the Japanese VLBI technique since 1968. In this presentation, we will look back on the past decade of the Tsukuba 32-m VLBI station. Tsukuba 32-m VLBI station is equipped with a 32-m diameter Cassegrain main dish, which can slew at 3 degrees per second in both azimuth and elevation. Initially, it has been started with a K4/Mark-IV-type backend and data acquisition system; however, to lead the times of e-VLBI, we replaced them with the K5/VSSP, which is a PC based sampler and data acquisition system, and a high speed network for e-VLBI in 2005. At present, over 150 sessions are carried out annually at

Tsukuba, and it will continue to keep its activities and performance high in the future.

2-10P Geodetic VLBI Prospects for Irbene Station

Karlis Berzins (University of Latvia)

First I will report on the current status of the Irbene 32-m antenna VLBI station of VIRAC, Latvia. Then I will sketch the planned joint activities of VIRAC and the University of Latvia in the field of geodetic research.

2-11P Matera Site Survey and VLBI Invariant Point Determination

Roberto Lanotte (CGS/Telespazio), Giuseppe Bianco (CGS/ASI)

The role played by CGS (Centro di Geodesia Spaziale) as geodetic fundamental station, hosting the main space geodetic technique systems SLR, VLBI, and GPS, makes the whole survey theme (measurements, related corrections and processing) of great importance for the CGS activities. The last survey at CGS was performed in February/March 2004 and involved measurements connecting seven IERS geodetic reference points and 14 additional reference points in the local network. During July 2005, a measurement campaign was carried out to estimate the VLBI IVP from the geometrical surface described by four optical retro-reflectors mounted on the antenna structure. New software (GSMAT) for the analysis of the survey raw measurements was developed. The main characteristics of this software are:

- atmospheric effects removed using continuously measured values of local temperature, pressure and humidity provided by the meteorological sensors operating at ASI CGS;
- rigorous network adjustment (weighted least squares method) with minimal inner constraints (via SVD), using

the whole covariance matrix at each step of the computation;
- outlier detection/rejection;
- designed to keep the human intervention on the data processing at a minimum;
- the VLBI invariant point is estimated by modeling the geometrical figure described by the retro-reflectors located on the antenna;
- production of the SINEX file with coordinates of the IERS reference points and VLBI IVP.

2-12P Space Geodesy at Yebes: Station Motion from VLBI and GPS

S. García-Espada (OAN Yebes, Onsala Space Observatory), R. Haas (Onsala Space Observatory), F. Colomer (OAN Yebes)

The National Astronomical Observatory (OAN Yebes) is active in space geodesy with geodetic VLBI and GPS observations. Between 1995 and 2004 the Yebes 14-m radio telescope was used successfully in 32 geodetic VLBI experiments, mainly in European sessions. Since 2004, the 14-m telescope is not in use any longer, but it is going to be replaced by the newly constructed 40-m radiotelescope. This new large telescope at Yebes will be used for geodetic VLBI starting in 2008. Additional to the geodetic VLBI data, there are GPS data available since 1999. We present the results of a re-analysis of the geodetic VLBI data using the best available a priori geophysical models, and compare in particular the time series of station coordinates with the results from an analysis of the Yebes GPS data. This work is, together with planned local tie measurements, of major importance for the combination of the historic VLBI observations performed with the 14-m radio telescope and the future observations with the new 40-m radio telescope.

2-13P Variations in the Integral Fluxes and Parsec-Scale Structure of Geodetic VLBI Sources

A.E. Volvach (Crimean Astrophysical Observatory), A.B. Pushkarev (MPIfR, Crimean Astrophysical Observatory, MAO), L.N. Volvach (Crimean Astrophysical Observatory), H.D. Aller (University of Michigan), M.F. Aller (University of Michigan)

We present the analysis of VLBI imaging at 2 and 8 GHz for 34 active galactic nuclei together with the results of 4.8-36 GHz integral flux density monitoring. The character of the multi-frequency flux variations is similar to that predicted by expanding source models. In the latter case the multi-frequency light curves track each other with no time delays and similar amplitudes, the outbursts are likely to be followed by an ejection of the new cm-VLBI components from the core.

Session 3: VLBI Data Structure, Analysis Strategies and Software

3-01 VLBI as a Tool to Connect Astrometry and Astrophysics *(invited)*

Yury Gnedin (Central Astronomical Observatory at Pulkovo RAS)

VLBI is the most powerful instrument for astronomical investigations and especially for determination of the scale of the Universe. Namely, the culmination of this millennium of astronomy is a tremendous growth in our understanding of the scale of the Universe and the range of astrophysical phenomena which underlies its apparent structure. Another important field of astronomical research is observation of quasars. Evidence has been accumulating for several decades that quasars, the most luminous objects in the Universe, are powered by accretion of

matter onto massive black holes. I will review the following most important topics of VLBI in modern astrophysics: (1) determination of cosmological parameters; (2) probes of super massive black holes (SMBH); (3) high-resolution observations of spatial regions of relativistic jets of active galactic nuclei and trace their evolution and interaction with the nuclear environment; (4) VLBI as the instrument for research of effects of new physics and vacuum polarization; (5) new fields of VLBI: Space Polarization INterferometry (SPIN) and X-ray Interferometry--MAXIM Project. Possibilities of using the IVS network to solve various astronomy problems will be discussed.

3-02 IVS Working Group 4 on VLBI Data Structures

John Gipson (NVI, Inc./GSFC)

The IVS Directing Board established the IVS Working Group IV on VLBI Data Structures at its September 15, 2007 meeting. The chair of the working group is John Gipson. Although the VLBI database system has served us well over the last 30 years, it is time for a new data structure that is more modern, flexible and extensible. The goals of the working group are to 1) assess current and future VLBI needs; 2) design a system which meets these requirements; and 3) design and implement a transition plan to take us from the current database format to the new format. I will discuss how the working group hopes to achieve these goals. I will also indicate how IVS members can provide feedback to the working group and contribute to its progress. Lastly I will present a timeline giving important milestones and dates.

3-03 Effects of Surface Pressure and Temperature on the VLBI Reference Frame

Robert Heinkelmann (Vienna University of Technology), Johannes Böhm (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

For the analysis of space geodetic techniques at radio wavelengths (GNSS, VLBI, DORIS, etc.) usually meteorological quantities such as surface pressure and temperature at each site are needed. While the surface pressure is necessary to separate hydrostatic and wet tropospheric delays, the thermal deformation of a VLBI antenna depends on temperature. In this study we quantify and compare the effects on the VLBI reference frames and tropospheric parameters obtained by VLBI if meteorological input data from various sources were applied: in situ measurements at the VLBI sites, interpolated values from the numerical weather model of the European Centre for Medium-Range Weather Forecasts (ECMWF), theoretical values from Berg's model of the atmosphere, and empirical values obtained from the global pressure and temperature model (GPT) developed at the Institute of Geodesy and Geophysics of the Vienna University of Technology.

3-04 The Chinese VLBI Network and its Contribution to the Chinese Lunar Exploration Project Chang'E-1

Jinling Li (SHAO CAS)

In this report we present the current status of the Chinese VLBI network (CVN), the results of satellite tracking experiments in the past few years as related to the real-time processing of the CVN dataflow and the reliability and precision of the CVN measurements, especially, we report the real-time monitoring of the orbit of the Chang'E-1 satellite by CVN.

3-01P Improved Estimation in VLBI through Better Modeling and Analysis

John Gipson (NVI, Inc./GSFC), Dan MacMillan (NVI, Inc./GSFC), Leonid Petrov (NVI, Inc./GSFC)

We report on three different ways of modifying the analysis of VLBI data. The first method is to include station dependent noise which is proportional to the mapping function. Such a term would arise, for example, if the atmosphere was mis-modeled. The second method is to include the effects of correlation between observations in a scan due to station dependent noise. The third method is to include additional second order spherical harmonics in the modeling of the atmosphere. Using the CONT05 and other data sets, we demonstrate that all three methods improve the analysis. Specifically, including these effects: 1) Improves chi-square of single sessions, i.e., makes them more realistic; 2) reduces baseline scatter and 3) improves agreement between VLBI and IGS estimates of EOP.

3-02P Data Analysis at BKG in the Frame of IVS

Volkmar Thorandt (BKG Leipzig), Gerald Engelhardt (BKG Leipzig)

The VLBI group of the Federal Agency for Cartography and Geodesy (BKG) in Leipzig is part of the jointly operated IVS Analysis Center of BKG and the Institute for Geodesy and Geoinformation of the University of Bonn (IGGB). BKG is responsible for the computation of time series of Earth orientation parameters (EOP) and tropospheric parameters, the generation of SINEX (Solution INdependent EXchange format) files for 24 hours VLBI sessions and 1 hour Intensive sessions, and quarterly updated global solutions for terrestrial reference frame (TRF) and celestial reference frame (CRF) realizations. The data processing steps are explained and also some problems in the procedure of data analysis are discussed.

3-03P The GSFC VLBI Analysis Center

David Gordon (NVI, Inc./GSFC), Chopo Ma (GSFC), Dan MacMillan (NVI, Inc./GSFC), Leonid Petrov (NVI, Inc./GSFC), John Gipson (NVI, Inc./GSFC), Karen Baver (NVI, Inc./GSFC)

We present the data processing, analysis, and research activities of the NASA Goddard Space Flight Center VLBI Analysis Center. The GSFC Analysis Center processes all available geodetic/astrometric VLBI sessions, including the 24-hr and 1-hr Mark 4/5 sessions, the 1-hr K-4 sessions, the 24-hr RDV VLBA sessions, and other occasional special VLBI sessions. Updated EOP files for the 24-hr and 1-hr sessions are promptly submitted to IVS for each new session. We also make quarterly EOP, TRF, and CRF updates to IVS and to our own web pages. We maintain and regularly update the Calc/Solve system, an analysis package of several dozen programs and more than one million lines of code. The GSFC Analysis Center also engages in all aspects of VLBI research and development activities, such as: source monitoring, source stability studies, ICRF-2 preparation, improving VLBI modeling and analysis, source calibrator surveys, K/Q band reference frame development, VLBI2010 simulation studies, VLBI network design, and many other areas.

3-04P WEB Service and Interactive Tools of the IERS Earth Orientation Center

Christian Bizouard (Paris Observatory), Oliver Becker (Paris Observatory), Daniel Gambis (Paris Observatory)

We present the WEB service and the panel of interactive tools — developed at IERS Earth Orientation Center (Paris Observatory) — for selecting, downloading, and analyzing the Earth Orientation Parameters.

3-05P The Virtual Observatory in Geodesy and Earth's Sciences: The French Activities

Florent Deleflie (Observatoire de la Côte d'Azur), Sébastien Lambert (Observatoire de Paris), Philippe Berio (Observatoire de la Côte d'Azur), Anne-Marie Gontier (Observatoire de Paris), Christophe Barache (Observatoire de Paris)

The International Virtual Observatory Alliance (IVOA) was formed in 2002, and now comprises more than a dozen of VO projects attached to various countries. The mission of the Virtual Observatory (VO) is to facilitate the international coordination and collaboration needed for the development and deployment of the tools, systems, and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory. The French geodetic community recently gathered around the project to extend the VO activities (originally dedicated to astrometry and astrophysics) to geodesy and Earth's sciences, especially to release all the products transiting within our hosted international services (VLBI data from the IVS, EOP and reference frame data from the IERS, ILRS data...). We mainly act in the frame of the VO-France and VO-GAFF (Géodésie et Astronomie Fondamentale Françaises). Our tasks are to (i) provide the geodetic data and products in the VO (XML) format, and (ii) develop tools for treating/visualizing/analyzing these data, with an emphasis on the interoperability with other existing or to be developed VO tools enabled by other VO communities.

3-06P MK3TOOLS: Seamless Interfaces for the Creation of VLBI Databases from Post-Correlation Output

Thomas Hobiger (NICT), Yasuhiro Koyama (NICT), Tetsuro Kondo (NICT)

A set of programs, summarized under the name MK3TOOLS, allow to create MK3 databases from post-correlator output without any dependency on CALC/SOLVE libraries. NetCDF files are utilized as intermediate data-storage and either MK3 compatible databases or NGS files are generated for follow-on analysis. Since all routines can be controlled from the command-line, MK3TOOLS enables the realization of a processing chain without human interactions and allows to generate databases for applications with a high demand on low latency (e.g., e-VLBI). Currently, only the K5 post-correlation format is supported by MK3TOOLS, but other correlators can be interfaced when needed.

3-07P VLBI Baseline Length Repeatability Tests of IVS-R1 and IVS-R4 Session Types

Kamil Teke (Vienna University of Technology), Robert Heinkelmann (Vienna University of Technology), Johannes Böhm (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

Very Long Baseline Interferometry (VLBI) has reached sub-centimeter precision for baseline lengths and station coordinates determined in a global terrestrial reference frame. However, future expectations are to improve the precision of these parameters to the millimeter level. The VLBI baseline length and station coordinate repeatabilities depend on the amount of observables and the lengths of the baselines, but also on the accuracy of reduction models, e.g., the tropospheric delay model. There is a trade-off between smaller correlations of zenith delay, clock, and station height parameters, when using low elevation observations on the one hand and mapping function errors, which become larger at low elevations, on the other hand. In this study, the effects of cut-off elevation angles on the baseline length repeatabilities are investigated with various troposphere mapping functions like NMF, GMF, and VMF1. We investigate cut-off elevation angles between 3° and 30° for IVS-R1 and IVS-R4 session types.

3-08P Influence of the Cut-off Elevation Angle and Elevation-dependent Weighting on Parameter Estimates: A Case of CONT05

Zinovy Malkin (Central Astronomical Observatory at Pulkovo RAS)

Proper weighting of the observations made at low elevations is important to obtain most precise and unbiased estimates of the geodetic parameters from processing of all types of space geodesy observations. Several studies on this subject were performed, sometimes with contradictory results. In this paper, I present results of processing of the CONT05 observations aiming at the investigation of the impact of the cut-off elevation angle (CEA) on the EOP estimates, and baseline length and station height repeatability. For this test, CONT05A observations were processed with different CEA from 3 to 25 deg, keeping all other options the same as used during the routine processing. The case of using elevation-depending weighting instead of CEA is also included in the test. Uncertainties and biases, as well as correlations between estimated parameters are investigated.

3-09P Physical Characteristics of Astrometric Radio Sources

Zinovy Malkin (Central Astronomical Observatory at Pulkovo RAS), Oleg Titov (Geoscience Australia)

A new list of physical characteristics of 3915 astrometric radio sources, including all 717 ICRF-Ext.2 sources, observed during IVS and NRAO VCS sessions have been compiled. The list includes source type, red-shift, and visual magnitude when found. In case of doubt, detailed comment is provided. Source list and positions were taken from the Goddard VLBI astrometric catalog with addition of two ICRF-Ext.2 sources. At this stage, source characteristics were mainly taken from the NASA/IPAC Extragalactic Database (NED). Characteristics of gravitational lenses were checked with the CfA-Arizona Space Telescope LEns Survey (CASTLES) data. We also used the HyperLeda database for physics of galaxies for supplement check. A comparison of our list with the IERS shows significant differences for about half of the common 667 sources, which shall be discussed and investigated. Based on this work, a list of frequently observed sources without known physical characteristics is proposed for urgent optical identification and spectrophotometric observations with large telescopes. The presented list of physical characteristics of astrometric radio sources can be used as a supplement material for the ICRF-2, as well as a source of information for kinematic studies and other related works, including scheduling of dedicated IVS programs.

3-10P Real-time Ray-tracing through Numerical Weather Models for Space Geodesy

Ryuichi Ichikawa (NICT), Thomas Hobiger (NICT), Yasuhiro Koyama (NICT), Tetsuro Kondo (NICT)

Numerical weather models have undergone an improvement of spatial and temporal resolution in the recent years, which made their use for GNSS applications feasible. Ray-tracing through such models permits the computation of total troposphere delays and ray-bending angles. At the National Institute of information and Communications Technology (NICT), Japan the so-called KAshima RAy-tracing Tools (KARAT) have been developed, which allow to obtain troposphere delay corrections in real-time. Together with fine-mesh weather models from the Japanese Meteorological Agency (JMA) huge parts of the East Asian region, including Japan, Korea, Taiwan and East China, can be covered. Thus we will introduce KARAT and its features and give an outlook on how ray-traced delays can be utilized within VLBI analysis.

Session 4: Interpretation of VLBI Results in Geodesy, Astrometry and Geophysics

4-01 Secular Decrease of the Earth's Ellipticity from the Analysis of VLBI Data of 1984-2006, and the Long-term Systematic Errors of the Precession-Nutation Models IAU 2000 and IAU 2006 *(invited)*

George Krasinsky (Institute of Applied Astronomy RAS)

At present, the available VLBI-based Celestial Pole offsets of the time-span 1984-2007 become sensitive to the secular decrease de/dt of the Earth's ellipticity e (the effect of the so-called post-glacial rebound). This effect was detected experimentally from the analysis of the laser ranging data of the geodetic satellites Lageos 1,2 in a number of works. The adopted value of de/dt should manifest itself in the VLBI data as a negative quadratic trend about –8 mas/cy^2 in the Earth's precession angle. For the available 25-year time-span of the VLBI data, the effect reaches 0.5 mas which value is quite detectable. Unfortunately, such study cannot be carried out making use of the standard models of the precession-nutation motion either IAU 2006 or IAU 2000. Our analysis of the VLBI data has revealed that in the precession angle of these models there exist the significant quadratic errors: –30 mas/cy^2 in IAU 2006 and -23 mas/cy^2 in IAU 2000. Processing the VLBI data with these models leads to the large positive value of the rate de/dt = $(27 \pm 4)\cdot 10^{-9}$ /cy that is incompatible with the satellite-based estimate $-7.9\cdot 10^{-9}$ /cy of de/dt. On the other hand, by processing the VLBI data with the numerical theory ERA of the Earth's rotation, the estimate de/dt = $-(14 \pm 4)\cdot 10^{-9}$/cy have been obtained which is statistically in accordance with the adopted value of de/dt. As the error of the VLBI estimates of de/dt falls as $1/T^2$ for the time interval T while that of the SLR estimates falls only as 1/T, the VLBI technology may provide most

accurate value of this important geodynamic characteristic in near future. For that, however, usage of a more adequate Earth's rotation theory than the adopted IAU 2006 model is indispensable.

4-02 Comparisons of Precession-Nutation Models *(invited)*

N. Capitaine (Paris Observatory), P.M. Mathews (University of Madras), V. Dehant (Royal Observatory of Belgium), P.T. Wallace (Rutherford Appleton Laboratory), S. Lambert (Paris Observatory)

In this presentation, we first summarize the key characteristics of the IAU 2000/2006 models, i.e. the IAU 2000 nutation and the P03 precession. Then, we report on recent comparisons of those models with VLBI observations (with and without removal of an FCN model) and with the INPOP06 numerical integration. We finally discuss some aspects of the numerical ERA model in comparison with the semi-analytical IAU models, considering the centrifugal perturbation and Love number formalism, the modeling of the dissipative phenomena, the Earth model and the estimation of parameters.

4-03 Astrophysical Stability of Radio Sources and Implication for the Realization of the Next ICRF *(invited)*

Patrick Charlot (Bordeaux Observatory)

This presentation will review the current state of knowledge about the VLBI properties of the extragalactic radio sources that form the International Celestial Reference Frame (ICRF). A large fraction of these sources has now been imaged, sometimes at many epochs, whereas only a handful of them had known VLBI properties at the time the ICRF was built in 1995. Based on the several thousands of such images now available, we assess source compactness and astrometric suitability, and the variation of these with time, on a statistical basis. We also discuss the implications in terms of source position stability from analysis of time series of images and compare the findings with actual source position variations measured in the framework of the realization of the next ICRF.

4-04 Some Challenges in Developing the Second ICRF

Chopo Ma (Goddard Space Flight Center)

VLBI data and analysis have both improved significantly since the first ICRF, which was completed in mid 1995. However, difficulties remain because of the inhomogeneity of the data distribution spatially and temporally, in particular the relative dearth of observations in the southern hemisphere and the two-order range in the number of observation epochs by source. The data set is still dominated by the ~100 sources observed regularly in EOP and TRF sessions, some of which are not ideal in terms of astrometric stability. The IVS program to monitor stable, potentially stable, and ICRF defining sources since 2004 should allow a somewhat larger, better observed set of defining sources for the second ICRF, and extensive source structure information is now available to supplement the identification of stable and unstable sources from position time series. It still may be necessary for the criteria for defining sources to have some flexibility in order to have more uniform spatial distribution. In the analysis for the second ICRF it will be necessary to improve the estimation of gradients, correlated noise, source position variations and observation weighting. As there will be many catalogues generated by the various analysis groups, methods for selecting the “best” solution among several or for combining solutions will be needed.

4-05 On Source Selection for the ICRF-2

Zinovy Malkin (Central Astronomical Observatory at Pulkovo RAS)

It is suggested that the ICRF-2 should comprise two source lists. The first list may be called the ICRF Core and will include about 400 sources, in average near one source per 100 sq. deg, and the

second list, the ICRF Supplement, will include about 3600 sources, which gives in total about 4000 ICRF sources, on average near one source per 10 sq. deg. The suggested total number of sources is close to the number of sources already observed during IVS and VCS sessions, and for most of them reliable positions are derived, mostly for declinations > –40 deg. It seems to be reasonable to schedule in 2008 several dedicated IVS sessions to obtain positions for 300–500 sources in the southern hemisphere to complete the ICRF Supplement list. An important issue is how to select ICRF-2 Core sources. Several strategies to select the most reliable ICRF sources based on observational history and statistical analysis of source position time series have been proposed. These criteria as well as modifications were applied to the time series submitted by IVS Analysis Centers to the ICRF-2 data pool. In result, updated stability indices are computed and compared for several hundreds sources, and a strategy for compilation of a core source list is considered.

4-06 Selection of ‘Defining’ Sources for ICRF2

David Gordon (NVI, Inc./GSFC), Chopo Ma (Goddard Space Flight Center), John Gipson (NVI, Inc./GSFC), Leonid Petrov (NVI, Inc./GSFC), Dan MacMillan (NVI, Inc./GSFC)

Generation of the second realization of the ICRF catalog is scheduled for the end of this year. Selection of a subset of so-called ‘defining’ sources with small systematic errors is desirable in the next few months. Towards this goal, eight institutions have generated source position time series files using thousands of VLBI databases. We will discuss our work towards categorizing the systematic behavior of each source, the requirements for 'defining' sources, and what possible minimal criteria a source must meet in order to be designated as a defining source. Lists of possible defining sources, selected using time series files from the 8 institutions will be compared.

4-07 Systematic Effects in Apparent Proper Motions of Radio Sources

Oleg Titov (Geoscience Australia)

The galactocentric rotation of the Solar system generates the systematic effect in proper motions known as 'secular aberration drift'. This tiny effect (about five microseconds per year) in the quasar proper motions can be measured by VLBI. However, the motions of relativistic jets from the active extragalactic nuclei can reach several hundred microseconds per year and mimic the proper motion of the observed radio sources. These apparent motions exceed the secular aberration drift by a factor of 10–100. In this paper we search for ways to overcome the difficulties and discuss our estimates of the secular aberration drift using the OCCAM software.

4-08 Extending the ICRF to Higher Radio Frequencies: X/Ka-band Global Astrometric Results

Christopher S. Jacobs (JPL), Ojars J. Sovers (RSA Systems)

In order to extend the International Celestial Reference Frame from its S/X-band (2.3/8.4 GHz) basis to a complementary frame at X/Ka-band (8.4/32 GHz), we began an ongoing series of X/Ka observations starting in mid-2005 using NASA's Deep Space Network DSN) radio telescopes. This paper will report global astrometric results from the first 36 sessions. These sessions covered right ascension over the full 24 hours and declination down to a southern limit of –45 degrees. Our analysis produced a radio frame of 316 sources with median formal position uncertainties of approximately 0.25 mas. A comparison of our X/Ka-band frame against S/X-band shows WRMS differences of approximately 0.25 mas. These differences include zonal errors the largest of which is a trend in Declination difference vs. Declination. We will discuss the frame's error budget including systematic errors from the geometric weakness of using just two baselines, mis-modeling of the troposphere, and uncalibrated instrumental effects. We will discuss our plan for addressing the current limiting errors and the resulting prospects for improved accuracy over the next few years.

4-09 The Impact of Source Structure on the Celestial Reference Frame at Higher Radio Frequencies

David Boboltz (U.S. Naval Observatory), Alan Fey (U.S. Naval Observatory), Patrick Charlot (Bordeaux Observatory)

During the last 10 years the NRAO Very Long Baseline Array, and up to ten additional stations, have been used by groups at NASA, NRAO, and USNO in a collaborative program of geodetic and astrometric research. Because the resultant data from this program, hereafter referred to as the VLBA RDV program, are of such high quality and are so prolific, we show that it is now possible to produce a celestial reference frame based solely upon the VLBA RDV experiments, at least for sources with positions north of about -40 degrees declination. We will present a set of astrometric positions estimated solely from VLBA RDV data and evaluate their quality with respect to ICRF-Ext.2. This has important consequences for, and will be crucial in, the construction of ICRF-2, the second realization of the ICRF.

4-10 Results from K-band Geodetic VLBI Using VERA

Takaaki Jike (Mizusawa VERA Observatory, NAOJ), Seiji Manabe (Mizusawa VERA Observatory NAOJ), Yoshiaki Tamura (Mizusawa VERA Observatory, NAOJ)

VERA is a VLBI array to achieve precise astrometry on the order of 10 micro-arc-seconds. Monitoring the positions and movements of the VERA stations, is one of the purposes of the VERA internal 1-Gbit geodetic VLBI observations. Regular geodetic VLBI observations started in 2004 November and supply coordinates of VERA stations with several millimeters accuracy to observations and analyses of VERA astrometry. VERA observation system demonstrates best performance in K-band. We started experimental geodetic VLBI observations on K-band in January 2006, aiming at obtaining more accurate geodetic solutions and confirmation of the feasibility of geodetic VLBI using new frequency bands that replace S/X bands. From the analyses of these experiments, we obtained geodetic solutions with higher precision than S/X bands observations.

4-11 Comparison of Radio Source Positions from Individual Solutions

Sergei Bolotin (MAO NASU), Svitlana Lytvyn (MAO NASU)

Various VLBI analysis centers which participate in ICRF-2 IVS/IERS Working Group provided their results of source coordinates estimation as well as time series of sources positions variations. In this presentation we discuss results of a comparison of these catalogs.

4-12 The Large Quasar Astrometric Catalog and the Radio-Optical Link

J. Souchay (Paris Observatory), S. Bouquillon (Paris Observatory), C. Barache (Paris Observatory), A.-M. Gontier (Paris Observatory), S. Lambert (Paris Observatory)

We present the LQAC (Large Quasar Astrometric Catalog); i.e., a compiled catalog containing 113,653 quasars, which has just been achieved. We discuss the homogeneity of the information (magnitudes, radio fluxes), the coherence of cross-identifications, the way of estimation of absolute magnitudes, and the radio-optical link.

4-13 The Effect of Nuclear Opacity in Radio Sources on Astrometric Applications

Andrei Lobanov (MPIfR Bonn)

Nuclear opacity in compact jets of extragalactic radio sources due to synchrotron self-absorption and external free-free absorption may lead to changes in their observed absolute positions depending on the frequency of observation (the “core shift” effect, well-known in radio astronomy). This effect is broad-band and can be variable in time, which may reduce the accuracy of the radio reference frame determination. We present here the core shifts measured in a sample of 29 bright compact extragalactic radio sources observed with VLBI at 2.3 and 8.6 GHz. The magnitude of the measured core shift reaches 1.4 milliarcseconds, with a median value of the sample 0.44 milliarcseconds. We argue that systematic measurements of the core shift should be conducted in a representative sample of radio sources in order to take this effect into account and increase accuracy of various astrometric applications.

4-14 Atmospheric Loading Coefficients Determined from Homogeneously Reprocessed Long-term GPS and VLBI Height Time Series

V. Tesmer (DGFI Munich), J. Böhm (Vienna University of Technology), B. Meisel (DGFI Munich), M. Rothacher (GFZ Potsdam), P. Steigenberger (GFZ Potsdam)

In this investigation, we compare harmonic annual signals, mean annual patterns, and episodic events in homogeneously reprocessed VLBI (OCCAM6.1e, at DGFI) and GPS (Bernese, at GFZ) long-term height series. Furthermore, we estimate atmospheric loading coefficients from these height time series using ECMWF pressure data assuming a simple linear regression. The VLBI and GPS data analysis was done using fully homogenized models in both software packages and the solutions were run twice, once with simple tropospheric modeling (NMF as mapping function and constant a priori zenith delay) and once with advanced approaches (VMF1 and a priori zenith delay derived from ECMWF). Thus, the results will give a clear insight into the level of similarity one can reach with both techniques in terms of station position time series. A comparison of the VLBI- and GPS-derived atmospheric loading coefficients and a comparison of the signals derived from these coefficients with existing time series of atmospheric loading deformation signals will allow an assessment of how well the effect can be modeled by such a simplified approach.

4-15 Re-assessment of Ocean Tidal Terms in High-Frequency Earth Rotation Variations Observed by VLBI

Sigrid Englich (Vienna University of Technology), Robert Heinkelmann (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

Periodic changes in the ocean heights and currents, driven by the tidal acceleration due to the Moon and Sun, are the main cause for diurnal and semi-diurnal variations in polar motion and dUT1. It has been shown, e.g. by Gipson in 1996, that VLBI observations can be used for the derivation of high-frequency Earth rotation variations and hence for the determination of ocean tidal terms. In this study we present a re-processing of 24 years of VLBI observational data with the purpose of obtaining high-resolution Earth rotation parameters (ERP). The potential of VLBI to estimate precise and robust short-period ERP variations is investigated. The time series with a length of more than 20 years allows for the separation of tidal terms, which differ by only one cycle in 18.6 years. We solve for all terms (including their side lobes) of the diurnal and semi-diurnal frequency band, to gather a VLBI-based empirical model of ERP variations induced by ocean tides.

4-16 Comparison and Validation of VLBI Derived Polar Motion Estimates

Thomas Artz (IGG Bonn), Sarah Böckmann (IGG Bonn), Axel Nothnagel (IGG Bonn), Volker Tesmer (DGFI Munich)

For a rigorous combination of Very Long Baseline Interferometry (VLBI) and Global Positioning System (GPS) data, they should not be subject to systematic differences. Nevertheless, such systematic differences with the order of magnitude up to 0.2 mas are present between the official polar motion time series of the International VLBI Service for Geodesy & Astrometry (IVS) and the International GNSS Service (IGS). At first glance, this is not astonishing since these solutions were not computed with homogenized models and parameterization. However, such differences also exist between VLBI and GPS solutions, where a detailed adaptation of the different software packages has been performed. In a careful analysis of VLBI sessions we try to relate these systematic differences in polar motion to various possible causes. We therefore examine the VLBI solution setup and the data itself regarding network changes, analysis options, and observation schedules.

4-17 The Variance Component Approach in the IVS Combination

Sarah Böckmann (IGG Bonn), Axel Nothnagel (IGG Bonn)

Within the IVS, datum-free normal equations have been combined and long time series of Earth Orientation Parameters (EOP) calculated. Contributions were submitted by five IVS Analysis Centers covering data since 1984. In order to account for the different levels of variance of the individual contributions to the combination process, relative weighting factors should be determined for example by means of variance component estimation method. In this presentation the corresponding results within the IVS combination will be discussed. Furthermore, the IVS combined long time EOP series and station positions calculated with and without variance component estimation are compared with GPS and SLR series.

4-18 Combination of Nutation Time Series Derived from VLBI and GNSS

Maria Kudryashova (Vienna University of Technology), Kristyna Snajdrova (Vienna University of Technology), Robert Weber (Vienna University of Technology), Robert Heinkelmann (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

VLBI is the unique space geodetic technique which allows estimating nutation offsets with a long-term stability. Nevertheless, GNSS (Global Navigation Satellite System) observations can contribute essentially to the determination of nutation parameters in the high frequency domain (periods from 5 to 20 days). In this work we concentrate on the combination of 2-years (2005-2006) series of nutation offsets from VLBI and nutation rates from GNSS obtained w.r.t. the IAU 2000 nutation model. In order to take advantage of both series the combined smoothing method introduced by Vondrac and Cepek has been used. From the combined series, amplitude corrections to the IAU 2000 model at selected frequencies have been estimated.

4-19 Outer and Inner Core Parameters from Joint Analysis of Superconducting Gravimeter and VLBI Data

Severine Rosat (EOST-IPGS Strasbourg), Sébastien Lambert (Paris Observatory)

We analyze VLBI delays back to 1984 from the permanent geodetic network, and ten superconducting gravimeter records from the Global Geodynamic Project spanning more than 7 years. From the former data, we deduce station displacements and nutation offsets, and from the latter we get gravimetric factors. Comparison of these observed quantities against theoretical expressions of the core and mantle admittance to the

tidal potential allows us to estimate Love numbers and resonant frequencies and quality factors of the core and the inner core. We finally point out strengths and deficiencies of each technique in their ability to retrieve the Earth's interior parameters.

4-01P QUASAR National Programs of EOP Determinations

*Andrey Finkelstein (*Institute of Applied Astronomy RAS*), Elena Skurikhina* (Institute of Applied Astronomy RAS*), Igor Surkis (*Institute of Applied Astronomy RAS*), Alexander Ipatov (*Institute of Applied Astronomy RAS*), Ismail Rahimov (*Institute of Applied Astronomy RAS*), Sergey Smolentsev (*Institute of Applied Astronomy RAS*)*

Regular determinations of Earth orientation parameters have been done by the QUASAR VLBI network since August 2006. The observations are carried out in the framework of two national programs: (1) 24-hour sessions for the determination of the five EOP parameters using all three network observatories (RU-E program) and (2) 8-hour sessions for the determination of Universal time using the Zelenchukskaya and Badary observatories (RU-U program). Each of these two session types are observed twice per month. We present the analyses of the observations. The mean RMS EOP deviations from the IERS C04 series in the RU-E program are 1.10 mas for Xp and 1.13 mas for Yp, 37 µs for UT1-UTC, and 0.75 mas and 0.63 mas for Xc and Yc, respectively. The RMS deviations of the Universal time values from IERS C04 series for the RU-U program are 146 µs. In the near future, it is envisaged to improve the EOP determination accuracy for the 24-hour sessions and to determine Universal time using e-VLBI in the QUASAR network.

4-02P Analysis of Source Motion Using Source Position Time Series

Zinovy Malkin (Central Astronomical Observatory at Pulkovo RAS), Oleg Titov (Geoscience Australia)

An accurate determination of radio source proper and apparent motions is important for many astrometric and astrophysical tasks, such as stable celestial reference frame, kinematics and evolution of the Universe, and so on. In this paper, an attempt is made to evaluate the source motions from the analysis of the source coordinate time series submitted to the IERS/IVS project on the ICRF-2. Several IVS Analysis Centers provided their time series obtained using different software and analysis strategies. The influence of these factors on the result is investigated. Finally, the combined velocity field for several hundred sources is derived, and possibilities of its application to problems of the Universe kinematics and the study of cosmological parameters are considered.

4-03P The Phase Variations of Retrograde Free Core Nutation

Vadim Gubanov (Institute of Applied Astronomy RAS)

The evenly sampled precession-nutation offsets dX_i, dY_i taken from the EOP(IERS) time series [1] within the span of 1985.3-2007.8 were adjusted by moving LSQ-filter with a view to study of the RFCN phase variability. At first so much offsets in numbers N_k in range [400,500] are chosen at the beginning of the EOP series and the amplitudes and phases of sinusoidal harmonics are obtained by LSQ-fit. Shifting trial time interval N_k step by step along the data series we can obtain some sequence estimates of phase φ_k that in turn may be presented in the following linear model: $\varphi_{jk} = \varphi_0 - d\omega_k \times t_j + d\varphi_k$, where t_j is the middle time of shifted interval counted from the same epoch t_0, $d\omega_k \times t_k$ — linear path of phase trend and $d\varphi_k$ — are residuals. The parameters of this model were obtained by LSQ-fit. It is evident that some time interval N_k is equal to

module of period of RFCN if, and only if the associated parameter $d\omega_k$ is equal to zero. In practice this criterion gives $P_0 = -444$d for both dX_i and dY_i series instead standard value $P_{RFCN} = -430.2$d adopted in the MHB theory [2] and recent IERS Conventions (2003) model [3]. In addition, the residuals $d\varphi_0$ decrease from the beginning of EOP series up to 5 July 1998 and increase after it. The linear parts of these trends give two periods $P_1 = P_0+26 = -418$d and $P_2 = P_0 - 29 = -437$d, which can be seen in amplitude spectrum calculated by the complex FFT [4]. The results obtained after identical analysis of EOP(NEOS) [5] are in close agreement. Thus, the phase variation of RFCN during 1985.3-2007.8 is valid. Similar conclusion was drawn in [6]. In this connection, the stability of RFCN period has become problematic. Moreover, is it really true that the Free Core Nutation is free? It can be shown that the precise period of RFCN is not necessary for the estimation, filtering, and prediction of this stochastic signal. All these problems have been solved successfully by means of the Least-Squares Collocation (LSC) technique [7]. The standard RFCN model [2, 3] that uses amplitude as piecewise linear function have need for only rough period. At present, the most precise have the estimate of standard RFCN period ($P_{RFCN} = -430.2 + -0.2$d) derived by indirect route, namely, fitting MHB transfer function [8] to resonance effects for 21 main nutation terms. However, it is not clear why this result and classical one are so different?

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4-04P A Postseismic Relaxation Model for the 2002 Denali Earthquake from GPS Deformation Analysis Applied to VLBI Data

Robert Heinkelmann (Vienna University of Technology), Jeff Freymueller (University of Alaska), Harald Schuh (Vienna University of Technology)

Five years after the 2002 Denali, Alaska, earthquake an optimized postseismic deformation model based on GPS time series analysis is available. The deformation model includes a logarithmic and an exponential term and considers poroelastic rebound and stress driven afterslip as well as viscoelastic relaxation. It is derived fitting both, near-field and far-field observations at ten GPS continuous as well as at about 100 campaign sites during 2002 and 2005. In our investigations we compare postseismic GPS and VLBI coordinate time series, i.e. the latter for station Gilmore Creek. The GPS derived deformation model is applied to the analysis of VLBI data and its effects are quantified in terms of residual analysis.

4-05P A Tropospheric Correction Approach for VLBI Phase-Referencing Using GPS Data

Bo Zhang (Nanjing University, Shanghai Astronomical Observatory), Xingwu Zheng (Nanjing University), Jinling Li (Shanghai Astronomical Observatory), Ye Xu (Purple Mountain Observatory, Nanjing)

We compare tropospheric zenith delays, which were derived from VLBI and GPS data at the VLBA stations that are co-located with GPS antennas. Both the systematic biases and the standard deviations are at the sub-centimeter level. Based on this agreement, we suggest a new tropospheric correction method in phase-referencing using combined VLBI and GPS data.

4-06P Using Singular Spectrum Analysis for the Investigation of Troposphere Parameters

Natalia Miller (Central Astronomical Observatory at Pulkovo RAS), Zinovy Malkin (Central Astronomical Observatory at Pulkovo RAS)

In this paper, the method of Singular Spectrum Analysis (SSA) is applied to investigation of the zenith troposphere delay time-series derived from VLBI observations. With the help of this method we can analyze the structure of time-series and separate the harmonic and irregular (trend) components. One of the main features of the SSA method is the opportunity of detecting even weak, but meaningful trends. Combined IVS time-series of zenith wet and total troposphere delays, obtained at IGG, were used for analysis. For this study, several VLBI stations with the most long and dense time series of troposphere zenith delays were selected, also taking into consideration the geographic region where the station is located. The investigations were carried out using both one-dimensional SSA and multidimensional MSSA modes. As a result, trends and seasonal components (with annual and

semiannual periods) were obtained for all the stations. Using of SSA enabled us to determine nonlinear trends in zenith delay, and also to study variations in the amplitude and the phase of the seasonal components with time.

4-07P Comparison of the Prediction Force of the Nutation Theories IAU2000 and ERA2005

Sergey Pasynok (All-Russian Research Institute of Physical-Technical and Radio-Technical Measurements)

A comparison of the nutation theories IAU2000 and ERA2005 has been carried out on the efficiency of their use in a nutation angles prediction program. As a result, the used prediction procedure yielded similar results for ERA2005 and IAU2000 to within the uncertainties of the measurements. The author thanks G. A. Krasinsky for the ERA2005 nutation angles series. This work was supported by the Russian Foundation for Basic Research under Grant No. 05-02-17091.

4-08P Precise Astrometry with the Very Long Baseline Array

Alan Fey (U.S. Naval Observatory), David Boboltz (U.S. Naval Observatory)

During the last 10 years the NRAO Very Long Baseline Array, and up to ten additional stations, have been used by groups at NASA, NRAO, and USNO in a collaborative program of geodetic and astrometric research. Because the resultant data from this program, hereafter referred to as the VLBA RDV program, are of such high quality and are so prolific, we show that it is now possible to produce a celestial reference frame based solely upon the VLBA RDV experiments, at least for sources with positions north of about –40 degrees declination. We will present a set of astrometric positions estimated solely from VLBA RDV data and evaluate their quality with respect to ICRF-Ext.2. This has important consequences for, and will be crucial in, the construction of ICRF-2, the second realization of the ICRF.

4-09P Astrometry from VLBA Observations at 24 and 43 GHz

G. Lanyi (JPL), D. Boboltz, (U.S. Naval Observatory), P. Charlot (Bordeaux Observatory), A. Fey (U.S. Naval Observatory), E. Fomalont (NRAO), B. Geldzahler (NASA), D. Gordon (NVI, Inc./GSFC)), C. Jacobs (JPL), C. Ma (GSFC), C. Naudet (JPL), J. Romney (NRAO), O. Sovers (RSA Systems), L. Zhang (JPL)

Astrometric results are presented from a collaboration formed to study extragalactic objects at radio frequencies between 20 and 50 GHz: The K-Q VLBI Survey Collaboration. We analyzed ten 24-hour observing sessions at the Very Long Baseline Array (VLBA) interferometer over a 5-year period, including nearly three hundred radio sources. Our analysis indicate reduction in source structure effects on source positions. The median formal uncertainties of right ascension and declination are 0.08 and 0.15 milliarcseconds, and the average absolute difference between the K-band (24 GHz) and the S-X estimated source positions are 0.17 and 0.23 milliarcseconds, respectively. These differences are partly due to absent or inadequate modeling of physical effects.

4-10P The Astrometric Feasibility and Accuracy of VERA

Tomoaki Oyama (Mizusawa VERA Observatory), Akiharu Nakagawa (Mizusawa VERA Observatory), Hideyuki Kobayashi (Kagoshima University) and the VERA team

VERA (VLBI Exploration of Radio Astrometry) is a Japanese VLBI array dedicated to VLBI astrometry. VERA telescopes are uniquely equipped with a dual-beam system, which enable us to observe simultaneously a target and a reference source within 2.2 degrees. To verify the capabilities of the VERA system, test observations of QSO pairs were conducted

between 2004 and 2007. We will report on the results of the test observations, outline a future upgrade plan, and briefly discuss a demonstration of joint VERA and OCTAVE (Optical fiber Connected real Time Array for VLBI Exploration) observations.

4-11P Source Selection for NNR Constraints from Source Position Time Series

Sergey Kurdubov (Institute of Applied Astronomy RAS), Elena Skurikhina (Institute of Applied Astronomy RAS)

Time series for more than 600 sources were calculated using the QUASAR software for VLBI data processing. Source positions for every source were obtained from single series analysis by fixing coordinates of all another sources. A-priory source positions were used from the ICRF-Ext.2 radio source positions catalogue. Time series analysis is performed with covariation analysis technique. The global solutions with different sets of sources for NNR constraints were obtained. Transformation parameters between obtained source catalogues were calculated and compared.

4-12P Comparison and Combination of CRF Catalogues

Julia Sokolova (Pulkovo Observatory RAS), Zinovy Malkin (Pulkovo Observatory RAS)

In 2007, a joint IERS/IVS Working Group has been established to consider practical issues of creating the next ICRF generation, ICRF-2. The goal of the WG is to seek after ways to improve the existing ICRF. In this study we investigate a possibility of ICRF improvement by means of using combined ICRF catalogue instead of a catalogue computed in a single analysis centre, even though using most advanced models and software. In this work, we present a new version of Pulkovo combined catalogue of radio source positions computed using the method proposed in (Sokolova & Malkin, 2007). Radio source catalogues that were submitted in 2007 in the framework of the WG activity were used as input for mutual comparison and combination. Two combined catalogues have been calculated: the first one provides a stochastic improvement of the ICRF, and the second one allows us to account also for systematic errors in the current ICRF version.

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4-13P Analysis of Radio Source Coordinate Variations

Julia Sokolova (Pulkovo Observatory RAS), Zinovy Malkin (Pulkovo Observatory RAS), Robert Heinkelmann (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

It is well known, that the selection of reference sources affects the precision and accuracy of the CRF derived from the VLBI observations. Therefore, it is important to select the most stable sources to be used as reference. Some of the radio sources are known to have apparent motions at the sub-milliarcsecond level. At present, there are four approaches to select stable radio sources, but significant inconsistencies of source lists obtained using these methods exist. So questions still are: What is the source stability? Which radio sources can be considered as stable? In our study, we analyze the causes, which can lead to radio source apparent coordinate variations in time. The effects of changes in radio source structure, changes in observation programs, observing network, etc. are discussed.

4-14P Measuring the Relativistic Parameter γ Using the Current Geodetic VLBI Data Set

Sébastien Lambert (Paris Observatory), Christophe Le Poncin-Lafitte (Technical University Dresden)

We investigate the possibility of measuring the gravitational deflection of the light emitted by extragalactic radio sources by the sun by VLBI. This deflection, giving rise to the so-called gravitational delay, is characterized in the parameterized post-Newtonian formalism by the parameter γ, which is equal to 1 in General Relativity. We make use of all available geodetic VLBI databases since 1984 to investigate how to obtain the most interesting constraint on γ.

Session 5: Progress in Technology Development and the Next Generation VLBI System

5-01 Modeling Tropospheric Delays with Atmospheric Turbulence Models *(invited)*

Tobias Nilsson (Onsala Space Observatory), Rüdiger Haas (Onsala Space Observatory)

Atmospheric turbulence causes fluctuations in the atmospheric delay of the signals used in VLBI. These fluctuations limit the accuracy of the parameters estimated in a VLBI analysis. This will be important for the next generation VLBI system VLBI2010 that aims at an accuracy of 1 mm. To assess the impact of atmospheric turbulence on the VLBI results we can use simulations in which simulated atmospheric delays are used. In order to simulate realistic delays we need to know how turbulent the atmosphere is. This can be described by the refractivity structure constant C_n. One way to estimate C_n is to use high resolution radiosonde data. We use data from a number of high resolution radiosonde stations around the world to determine the variability of C_n as function of time and space. The temporal aspect includes the variability on different time-scales (sub-diurnal to seasonal), and the spatial aspect includes variability in 3-dimensions (with respect to height and climate regions). The effects of different modeling approaches on the VLBI results will be investigated.

5-02 VLBI2010 Broadband Delay Demonstration *(invited)*

Arthur Niell (MIT Haystack Observatory) and the BBDev Team

The major innovation for the VLBI2010 concept that allows the use of relatively small antennas is the proposal to observe in four bands, instead of the two currently used, in order to gain the delay precision of phase delays compared to the group delay. The other advance that enables the use of small antennas is the significant increase in data acquisition rates that has been made possible by the development of the Mark5B+ recorders and the Digital Back Ends (DBE). To evaluate the concept, a prototype of the feed-to-recorder system has been implemented on the 5 m MV-3 antenna at the Goddard Geophysical and Astronomical Observatory near Washington, D.C. First VLBI fringes were obtained 2007 Nov 19 at X-band using the Westford 18 m antenna as the other element of the interferometer, using the standard geodetic feed and receiver. Recently a six-hour session was recorded and processed to investigate the system performance over a longer time. In this talk the system will be described and results of the recent test will be reported.

5-03 Progress Report on Developing Eleven Feed for VLBI2010 and SKA Frequency Bands *(invited)*

Per-Simon Kildal (Chalmers University of Technology)

The Eleven feed is a new dual-polarized, low-profile feed for reflector antennas, offering efficient aperture illumination, constant phase center and polarization control over more than a decade bandwidth. The feed is of interest for scientific applications such as SKA and VLBI. The present paper will give an overview of the models developed so far as well as ongoing projects aiming at a coolable version operating up to 15 GHz or higher.

5-04 Composite Applications to Radio Telescopes

Dean Chalmers (DRAO Penticton), Gordon Lacy (DRAO Penticton), Peter Dewdney (DRAO Penticton), Gary Hovey (DRAO Penticton), Bill Petrachenko (Natural Resources Canada)

Composite materials offer a range of benefits over traditional metal structures in the construction of large (> 10m diameter) radio antennas. The high specific modulus of composites results in lighter and stiffer reflectors and their low CTE yields thermally stable structures. For a VLBI2010 antenna, a lighter reflector has the benefit of allowing higher slew accelerations while greater stiffness reduces elevation dependent gravitational deflections. If the antenna tower were also fabricated of composite materials, the resulting thermal stability would greatly reduce the temperature induced annual signature of the VLBI reference point. Development of composite reflectors is an active R&D focus at the National Research Council's Dominion Radio Astronomical Observatory (DRAO), near Penticton, Canada. DRAO constructed and tested its first 10-m diameter prototype reflector in 2007 and is currently incorporating improvements in performance and manufacturability for the next prototype to be built in the spring of 2008. New developments in composite manufacturing processes have the potential to make composites a cost effective alternative for VLBI2010 antennas.

5-05 DBBC Development Status

G. Tuccari (IRA-INAF), W. Alef (MPIfR Bonn), A. Bertarini (IGG Bonn), S. Buttaccio (IRA-INAF), G. Nicotra (IRA-INAF), A. Roy (MPIfR Bonn), M. Wunderlich (MPIfR Bonn)

More DBBC units of version 1 have been built. DBBC version 2 has reached an advanced stage of development and realization. The detailed status of the project is presented including: the existing hardware versions and their layout, the main differences between DBBC.1 and DBBC.2, the new elements which are

under development, the implementation timing for DBBC version 2, and observational tests. Moreover possible uses of the DBBC hardware as a general purpose backend for VLBI and radio astronomy are presented.

5-06 Progress of Wideband VLBI Digital System Development at SHAO

Xiuzhong Zhang (Shanghai Astronomical Observatory)

There are several wideband VLBI devices, such as wideband dBBC and a 5-station correlator, that are being developed at Shanghai Astronomical Observatory (SHAO). The design concept and the applications of these devices will be reported in the paper.

5-07 The Mark 5C VLBI Data System

Alan Whitney (MIT Haystack Observatory)

The Mark 5C VLBI data system is being developed as the next-generation Mark 5 system built on the same basic platform as the Mark 5A, Mark 5B and Mark 5B+. The Mark 5C will have the following characteristics: - Dedicated 10 Gigabit Ethernet data-input port - Recording rates to 4096 Mbps using two Mark 5 modules (16 disks) - Full compatibility with existing Mark 5 modules - Playback will be through a high-performance motherboard and 10GigE NIC - Targeted for use on software-correlator systems Data sources for the Mark 5C system will be based on new digital backends now being developed, specifically the DBE2/DDC in the U.S. and the dBBC in Europe. Mark 5C data formatting is organized as one-frequency-channel per Ethernet packet, which supports an arbitrary number of frequency channels and allows fine increments in tuning aggregate data rates for better matching with available e VLBI network bandwidths. A data mode which writes a disk module in a format compatible with playback on a Mark 5B system is planned. Mark 5C system specification and development is

being supported by Haystack Observatory, NRAO, and Conduant Corporation. Prototype Mark 5C systems are expected in mid 2008.

5-08 Mark 5C Software Development Program

Chester Ruszczyk (MIT Haystack Observatory)

The product road map for Mark5C software development will be presented, including support of the DBE v2 digital backend hardware that will act as a 4Gbps data source over a 10GigE data connection.

Mark5C software development is being staged as a three phase project. The first phase of the project will create a 10GigE packet emulator to aid in the debug of the DBE v2 and Mark5C hardware. The second phase of the project, dubbed 'Mark5C-', will accept data stored in shared memory from a standard network interface card, and will have the capability to store the data in Mark5B format to either standard Mark 5 disk modules or to a standard file system (perhaps at a reduced data rate). This second phase will allow other software applications to communicate with the Mark5C interface, with the aim to reducing the time to deliver/debug the software, and to help facilitate the burst-mode development effort. The final phase of the program will be the Mark5C application itself that will configure, control and manage the actual Mark5C hardware.

All phases of the Mark 5C software development effort will be tracked by standard version-control software with full accountability for all changes and revisions.

5-09 Development of a Compact VLBI System for Providing over 10 km Baseline Calibration

R. Ichikawa (NICT), A. Ishii (NICT), H. Takiguchi (NICT), H. Kuboki (NICT), M. Kimura (NICT), J. Nakajima (NICT), Y. Koyama (NICT), T. Kondo (NICT), M. Machida (GSI), S. Kurihara(GSI), K. Kokado (GSI), S. Matsuzaka (GSI)

We are developing a compact VLBI system with a 1.6 m diameter aperture antenna in order to provide reference baseline lengths for calibration baselines. The calibration baselines are used to validate surveying instruments such as GPS and EDM and maintained by the Geographical Survey Institute (GSI). To perform short-term (about one week) measurements at several calibration baselines in Japan islands, the most important concept in developing the VLBI system is transportability. Thus, the VLBI system is designed to be assembled with muscle power only. In fiscal 2007, we have evaluated a front-end system with a wide-band quad-ridged horn antenna by installing it on the 2.4 m diameter antenna at Kashima. On December 5, 2007 we successfully detected fringes of the 3C84 signal for both S and X bands. In addition, we have tested a capability of an LD-pumped Cesium gas cell atomic frequency standard for geodetic VLBI measurements. An analyzed baseline length is well consistent with those obtained by previous VLBI measurements using a hydrogen frequency standard.

5-10 Developments of an Automated Data Processing System for Ultra Rapid dUT1 e-VLBI Sessions

Yasuhiro Koyama (NICT), Mamoru Sekido (NICT), Thomas Hobiger (NICT), Hiroshi Takiguchi (NICT), Tetsuro Kondo (NICT)

In June 2007, we made a proposal to the IVS Observing Program Committee to perform several UT1-intensive style e-VLBI sessions on two Europe-Japan baselines, namely Onsala-Tsukuba and Metsähovi-Kashima. In the proposal, we planned to transfer data observed at Onsala and Metsähovi stations to Tsukuba and Kashima, respectively, in real-time during the observations. The transferred European data are then correlated with the Japanese data observed at Tsukuba and Kashima. We have been developing a system to generate database files from the session and analyze the data to obtain the dUT1 estimation from the session as soon as possible. As of December 2007, several sessions have been carried out and we succeeded to run the automated system for a session performed on November 22. The details of the system and results from actual observation sessions will be presented.

5-11 VLBI2010 Antenna Slew Rate Study

Bill Petrachenko (Natural Resources Canada), Johannes Böhm (Vienna University of Technology), Daniel MacMillan (NVI, Inc./GSFC), Andrea Pany (Vienna University of Technology), Toni Searle (Natural Resources Canada), Jörg Wresnik (Vienna University of Technology)

The slew rate specification for VLBI2010 antennas has proven to be difficult to define. There are two competing tendencies. Since geodetic performance improves as observation rate increases, antennas with higher slew rates are desirable. This is offset by the fact that higher slew rates also lead to higher capital and operating costs. The optimization process is complicated by the fact that conclusions are dependent on scheduling strategy, analysis strategy, axis configuration, slew limits, the ratio of azimuth to elevation slew rate and the fact that slew accelerations also have an impact. In this study, the optimization process is broken down into two steps. In the first step, four schedules are generated and analyzed. The schedules are designed to achieve a reasonably uniform sky coverage for every group of 12 sources observed. In the second step, antenna drive systems are analyzed to see which can achieve these schedules. Two axis configurations are considered along with a wide

variety of combinations of slew parameters, including the impact of multiple antennas at a site.

5-12 Simulation Analysis of the Geodetic Performance of Networks of VLBI2010 Stations

Daniel MacMillan (NVI, Inc./GSFC)

As part of the design of a future geodetic VLBI network, we studied the performance of networks of new-generation (VLBI2010) stations. We ran simulations for 8, 16, 24 and 32-site networks with a fairly even distribution of sites between hemispheres. To determine the repeatability of estimated geodetic parameters from a given network, we performed Monte Carlo simulations of VLBI analysis solutions with the same 24-hour observation file but with different input simulated noise. The simulated noise consists of tropospheric, clock, and observation noise delay contributions, where the troposphere noise is based on a realistic model of atmospheric turbulence. Since one of the critical design specifications for the VLBI2010 antennas is slew rate, we examined the improvement of baseline length and station position repeatabilities on increasing azimuth and elevation slew rates. We also determined the improvement of the reference frame scale and EOP repeatabilities resulting from (1) increasing network size and (2) increasing the data recording rate.

5-13 VLBI2010 Simulations at IGG Vienna

Jörg Wresnik (Vienna University of Technology), Johannes Böhm (Vienna University of Technology), Andrea Pany (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

To support the design of a new geodetic Very Long Baseline Interferometry (VLBI) system, VLBI2010, simulations are carried out at the Institute of Geodesy and Geophysics (IGG), Vienna. The main part of these simulations is a Monte Carlo simulator which produces artificial group delays by modeling the stochastic processes caused by the station clocks, the wet zenith delays and additional system errors. The clocks are simulated with a random walk plus integrated random walk, the wet zenith delays are derived from a turbulence model and the system errors are represented by white noise. For the analysis of the simulated data, the Monte Carlo simulator is implemented in a modified version of the software package OCCAM. Because of limitations due to the huge number of observations in the OCCAM Gauß-Markov algorithm, the Kalman Filter approach of OCCAM was applied. Different variance rates for the stochastic parameters in the Kalman Filter solutions are tested and the best values are used for antenna slew speed tests. Different schedules with antennas of different slew speeds (from 1.5 °/sec to 12°/sec in azimuth and 0.7°/sec to 3.1°/sec in elevation) are compared w.r.t. baseline length repeatabilities and rms values of station position residuals. The investigation shows that there is hardly any improvement with antennas faster than 6°/sec in azimuth and 2.1°/sec in elevation. Different scheduling strategies, such as achieving uniform sky coverage, are also tested.

5-14 Vienna VLBI2010 PPP Simulations

Andrea Pany (Vienna University of Technology), Jörg Wresnik (Vienna University of Technology), Johannes Böhm (Vienna University of Technology), Harald Schuh (Vienna University of Technology)

Within the frame of Vienna's contribution to VLBI2010 a precise point positioning (PPP) simulation software has been developed. Similar to the simulation studies carried out with OCCAM and Calc/Solve, a cumulative delay time series is determined, consisting of wet slant delays provided by a turbulence model, stochastic variations of station clock and delay measurement errors. In contrast to the simulations using

VLBI analysis software packages the delay time series are generated only for single stations. The cumulative delays are used as observations to perform a precise point positioning (PPP) – with the classical least-squares method as well as with Kalman filtering. Different parameterizations of zenith wet delay, i.e. gradients and spherical harmonics, are tested using different time intervals and constraints. Performing a PPP for all stations of a VLBI schedule allows comparing the performance of different station networks, antenna slew rates and scheduling strategies as well as comparisons to the results of OCCAM and Calc/Solve simulations in order to validate how close the results of PPP are to what can be expected from real VLBI data.

5-15 The Square Kilometre Array in the Context of IVS Science

Leonid Gurvits (Joint Institute for VLBI in Europe)

After its completion around 2020, the Square Kilometre Array will be the world leading radio telescope in metre to centimeter wavelengths. It will be the most sensitive and versatile radio astronomy facility for several decades to come. The SKA science case is formed around five Key Science Areas, ranging from topics of cosmology and fundamental physics to formation of habitable planetary systems. The engineering specification of the SKA defined by its Key Science Areas has a broad universal appeal to the entire radio astronomy. I will review those areas of possible SKA activities which are relevant to the scientific challenges of IVS in the coming decades. A special attention will be given to high resolution (VLBI) applications of the Square Kilometre Array.

5-16 VLBI Observation of SELENE (KAGUYA) with VERA and with an International VLBI Network

Hideo Hanada (NAOJ), Takahiro Iwata (JAXA), Nobuyuki Kawano (NAOJ), Norijuki Namiki (Kyushu University), Kazuyoshi Asari (NAOJ), Yoshiaki Ishihara (NAOJ), Toshiaki Ishikawa (NAOJ), Fuyuhiko Kikuchi (NAOJ), Qinghui Liu (NAOJ), Koji Matsumoto (NAOJ), Hirotomo Noda (NAOJ), Seiitsu Tsuruta (NAOJ), Sander Goossens (NAOJ), Natalia Petrova (NAOJ), Sho Sasaki (NAOJ), Kenzaburo Iwadate (NAOJ), Takaaki Jike (NAOJ), Osamu Kameya (NAOJ), Katsunori Shibata (NAOJ), Yoshiaki Tamura (NAOJ), Xiaoyu Hong (SHAO), Jinsong Ping (SHAO), Yusufu Aili (Urumqi Observatory), Simon Ellingson (University of Tasmania), Wolfgang Schlüter (BKG Wettzell)

KAGUYA (SELENE) is a Japanese lunar mission which was successfully launched from the Tanegashima Space Center on Sep. 14, 2007. KAGUYA consists of the main orbiter, and two small free-flying sub-satellites, called Rstar (OKINA) and Vstar (OUNA). We are observing OKINA and OUNA by differential VLBI observations with the aim of improving the lunar gravity field model. Our observations will particularly improve the accuracy to which the low degree gravitational harmonics and the gravity field near the limb can be measured, and when combined with Doppler measurements will enable three-dimensional information to be extracted. Differential VLBI will be used to accurately measure the trajectories of the satellites, both with the Japanese VERA (VLBI Exploration of Radio Astrometry) telescopes and an array of international VLBI international stations including Shanghai, Urumqi (China), Hobart (Australia), and Wettzell (Germany).

We are using multi-frequency VLBI to determine the angular distance between OKINA and OUNA using three frequencies in S-band, (2212, 2218 and 2287 MHz), and one in X-band, (8456MHz). Two periods of international observations, each one

month in duration, with the participation of VERA and the international stations, (in addition to normal observations by VERA only) are planned for the one year mission period. We are able to measure the phase delay to an accuracy of better than 0.17 radians (10 degrees) in X-band in these observations.

5-17 VLBI and Precise Navigation in Space

Vladimir Zharov (Sternberg State Astronomical Institute), Leonid Matveenko (Space Research Institute of RAS)

VLBI is one of the most powerful methods for precise positioning of spacecrafts. We discuss one of the first experiments of the VLBI application for tracking of the balloons in the atmosphere of Venus (project "VEGA").We also discuss prospects for VLBI tracking of future missions, in particular the Radioastron mission. A 10-m radio telescope will be launched into orbit to realize a space-ground interferometer. One of the goals of the mission is precise astrometry on the level of several microarcseconds. The possibility of tracking and prediction of the orbital motion of the Radioastron spacecraft is discussed.

5-18 On the Space VLBI Mathematical Model with Nutation Parameters

Erhu Wei (Wuhan University), Jingnan Liu (Wuhan University), Vincenza Tornatore (Politecnico di Milano), Chuang Shi (Wuhan University)

The most important and complicated mission of modern geodesy and geodynamics is definition, realization, and interconnection of different reference systems, which include the Conventional Inertial System (CIS) fixed in space and defined by radio sources, the Conventional Terrestrial System (CTS) fixed to the earth and defined by a series of observation stations on the ground, and the dynamic reference system defined by the movement of satellites. At present, the VLBI technique and several other techniques (such as SLR, LLR, GNSS) are jointly

used for indirect interconnection between CIS and CTS (e.g., Thaller, 2006; Altamimi, 2006). Space Very Long Baseline Interferometry (SVLBI) is the unique space technology that can directly interconnect the three reference frames above to a very high accuracy. There have been some studies (Adam, 1990; Kulkarni, 1992; Wei, 2006) on the mathematical model to estimate the parameters that can interconnect the reference frames by using SVLBI observations, in which nutation correction parameters are not included. With the development of technology, the life of satellite or detector designed for deep space exploration will last longer than before. The success of lunar exploration missions, such as the Chinese Chang'E and many other international missions, makes it possible to set VLBI antennas on the moon, which is quite favorable to estimate nutation with a longer-term observation than before. Therefore, it is very necessary to add nutation parameters in the mathematical model of space VLBI observations. In this paper, the nutation parameters will be added to the rotation matrix, and the mathematical model of SVLBI observations with the nutation parameters will be derived. Finally, the estimability of parameters in the mathematical model will be analyzed.

5-01P Mark 5 Disk Drive Performance and Reliability

Dan Smythe (MIT Haystack Observatory)

The performance of the Mark 5 VLBI data recording system is limited by three factors: 1) the disk drive, 2) the data bus, and 3) the StreamStor controller. This paper will examine each of these limits and demonstrate each of them with measurements showing how the record and playback data rates depend on the position of the record and playback pointers. We will also present a summary of disk drive failure statistics gathered at Haystack over the three years that the Mark 5 system has been in operation.

5-02P The Development and Performance of a New 4 Gbps Disk Recorder and e-VLBI Systems Using a 10 GbE Network

Tomoaki Oyama (Mizusawa VERA Observatory), Yusuke Kono (Mizusawa VERA Observatory), Tetsuya Hara (Mizusawa VERA Observatory), Noriyuki Kawaguchi (Mizusawa VERA Observatory)

The National Astronomical Observatory, Japan and Korea Astronomy and Space Science Institute are constructing the KJJVC correlator (Korea-Japan Joint VLBI Correlator) for the KVN (Korean VLBI Network), EAVN (East Asia VLBI network), and VSOP2. This correlator system consists of Raw VLBI Data Buffers (RVDBs) and a hardware correlator (16 stations, 120 cross, 8 Gbps with VSI-H data-input ports). The RVDB consists of one converter between one 10 GbE I/O port and four 2 Gbps I/O ports conformable to VSI-H, and new disk recorders enable us to simultaneously record and play at 2 Gbps using a 10 GbE network. We will report the detailed performance of the RVDB and results of successful test e-VLBI observations with 2 and 4 Gbps recording using the RVDB from December, 2007.

5-03P VLBI Terminal for Pushchino Radio Astronomy Observatory

*A.S. Berdnikov (*Institute of Applied Astronomy RAS*), L.V. Fedotov (*Institute of Applied Astronomy RAS*), K.G. Belousov (Astro Space Center), S.F. Likhachev (Astro Space Center), O.V. Dronova (Astro Space Center), A.V. Chibisov (Astro Space Center)*

The new VLBI terminal consists of 8-channels data acquisition system (R1001), which is developed at IAA RAS, and hard disks based data recorder system (RDR-1), which is developed at Astro Space Center of Physical Institute RAS. Input IF is from 100 MHz to 1000 MHz. Bandwidths are 2 MHz, 4 MHz, 8 MHz or 16 MHz. The rate of recording data is up to 256

Mbits/s with 16 active bit-streams. The terminal can register data in 16-bits S2 format or 8-bits "Radioastron" format with 32 MHz clock signals frequency. The time of record is up to 7 hours with four 200 GB HDD. The recorder errors are not worse then 10e-06. The terminal is controlled by computer. It is planned to use this terminal in ground complex of the instrumentation of "Radioastron" project.

5-04P Recent Progress Status of Korea-Japan Joint VLBI Correlator Development

Sejin Oh (KASI), Dukgyoo Roh (KASI), Jaehwan Yeom (KASI), Yongwoo Kang (KASI), Sunyoup Park (KASI), Bongwon Sohn (KASI), Doyoung Byun (KASI), Changhoon Lee (KASI), Hyunsoo Chung (KASI), Kwangdong Kim (KASI), Hyoryoung Kim (KASI), Hideyuki Kobayashi (NAOJ), Noriyuki Kawaguchi (NAOJ)

Korea Astronomy and Space Science Institute (KASI) and National Astronomical Observatory of Japan (NAOJ) are developing the Korea-Japan Joint VLBI Correlator (KJJVC) until the end of 2010 for the Korean VLBI Network (KVN), the Korea-Japan Joint VLBI Network (KJJVN), and the East Asian VLBI Network (EAVN) including the next generation space VLBI (VSOP2). It is being discussed mainly by the Korean and Japanese correlator teams and applied several new functions and ideas. It will be one of the most powerful VLBI correlators in the world, and it will become a hub of the international cooperative VLBI studies in East Asia. In this paper, we summarize the detail specifications and the recent progress status of KJJVC development.

5-05P Current Status of Korean VLBI Network Radio Telescope

Changhoon Lee (KASI), S.O. Wi (KASI), D.H. Je (KASI), D.Y. Byun (KASI), K.T. Kim (KASI), S.T. Han (KASI), M.H. Chung (KASI), S.J. Oh (KASI), B.W. Sohn (KASI), M.G. Song (KASI), J.H. Yeom (KASI), Y.W. Kang (KASI), D.G. Roh (KASI), H.S. Chung (KASI), H.R. Kim (KASI), S.H. Cho (KASI)

We present the current status and some future plans of the Korean VLBI Network (KVN) system such as 21-m antenna installation, multi-wavelength receiver, and data acquisition system.

5-06P Imaging Capabilities of the Next Generation VLBI System

Arnaud Collioud (Bordeaux Observatory), Patrick Charlot (Bordeaux Observatory)

The next generation VLBI system is being designed for a wide range of applications, including geodesy, astrometry as well as astrophysics. In this presentation, we explore the capability of the system for reconstructing VLBI maps of extragalactic sources from simulated radio interferometric data. We base our analysis on proposed VLBI 2010 network configurations and schedules, and discuss the impact of these on the resulting images. Our simulations confirm that the future VLBI system is well suited to produce high-quality images of reference frame sources.

5-07P First Considerations on the Feasibility of GNSS Observations by the VLBI Technique

Vincenza Tornatore (Politecnico di Milano), Gino Tuccari (IRA INAF), Erhu Wei (Wuhan University)

GNSS (Global Navigation Satellite System) has shown a rapid growth in the last few years. GPS (Global Positioning System) and GLONASS (GLObal NAvigation Satellite System) constellations have started an extensive modernization,

moreover there are plans to develop a European Galileo system and China is planning to have its own version called Compass. Since 2003 with the establishment of the IVS Working Group 3, VLBI is devoting several efforts to design the next generation geodetic VLBI system called VLBI2010 that would provide enhanced performances. In the meantime a demand of higher positioning accuracy for the global earth parameter estimation is growing, too. A combination/integration of different spatial geodetic techniques is the key to ensure the consistency and to improve the accuracy of the resulting geodetic products. The observation of GNSS satellites by the VLBI technique could give the opportunity to obtain a direct link between VLBI and GNSS reference systems. In this work the characteristics of the different GNSS systems are presented with the objective to evaluate if it is possible to observe any of these different constellations and obtain satellites orbits by using new VLBI 2010 antennas and data acquisition system. The present accuracies of GNSS satellites orbit will also be presented and the potential benefits of orbit determination by means of the VLBI technique will also be discussed.

5-08P New Approach to VLBI-GPS Combination

Younghee Kwak (KASI, Ajou University), Tetsuo Sasao (KASI, Ajou University), Jungho Cho (KASI), Tuhwan Kim (Ajou University)

Atmospheric parameters and clock offsets usually cause large difficulties in VLBI observations. To solve these difficulties, proposals have been made in the VLBI community to observe several sources at once. We suggest, as one of the solutions, to combine GPS and VLBI antennas located in the same site through VLBI-type observations, which would cut costs for constructing lots of radio telescopes at one site. With this type of observation, we assume that GPS signals at various sites can be recorded and correlated with VLBI correlators. This is a

kind of “multi-beam VLBI” with one beam observing a quasar and others GPS satellites. Correlator output would give us the phase delays of GPS satellites which can be analyzed together with the group delays of quasars obtained by VLBI antennas in the same sites. We expect that atmospheric parameters and clock offsets would be precisely determined since GPS receiver looks various directions at the same time and is connected to the same H-maser clock used by the VLBI antenna. We introduce simple phase delay model, where complicating but not very essential terms are neglected, for finitely distant GPS satellite to demonstrate this concept.

5-09P VSOP-2: An Orbiting Co-location Site Between VLBI, GPS and SLR

Hiroshi Takeuchi (JAXA), Yoshiharu Asaki (JAXA), Hiroo Kunimori (NICT), Hirobumi Saito (JAXA), Yasuhiro Murata (JAXA), Shinichi Nakamura (JAXA), Toshimitsu Otsubo (Hitotsubashi University), Makoto Yoshikawa (JAXA)

We present an overview of the VLBI Space Observatory Programme 2 (VSOP-2) and the precise orbit determination (POD) system for the VSOP-2. The VSOP-2 satellite, a next generation space VLBI satellite for radio astronomy, is expected to be launched in 2012. POD is a key factor to enable phase referencing VLBI observations with VSOP-2. Four GPS/Galileo antennas and a SLR retro-reflector array will be used for the POD. Local-ties between phase-centers of the GPS/Galileo antennas, reference point of the SLR retro-reflector, and satellite's center of mass position, which will be changed as fuel consumptions, should be maintained accurately. We describe the accuracy and possible by-products of the POD.

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