Abstract book
IVS General Meeting 2022

IVS IAG SUOMEN AKATEMIA

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

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Session-1: IVS Network Stations and Technical Developments

How much do satellite techniques depend on UT1?

R. Dach

Abstract The satellite-based techniques need to introduce UT1 when Earth rotation parameters and orbital elements shall be estimated in a global solution. The reason is the correlation between the ascending node of the satellite orbit ellipse with the UT1 parameter. In this context the satellite techniques depend on the UT1 results from VLBI. On the other hand, the estimated satellite orbits are typically transformed back into the Earth-fixed frame using the estimated Earth rotation parameters. In this sense the quasi-inertial frame for the satellite orbit determination can also be seen as an intermediate frame for a specific solution. The presentation will show to which extent the solutions of the satellite techniques really depend on UT1 provided by VLBI. It will also be discussed what happens if outdated UT1 values are used in a satellite orbit determination processes.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Invited

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The Global VLBI Alliance

F. Colomer

The GVA facilitates the flow of information between VLBI networks, including sharing strategies, technical developments for compatibility, logistics, operations, and user support. It also promotes, proposes and coordinates common observational campaigns with these existing networks. Moreover, with the advent of the Square Kilometer Array (SKA) and its precursors, such global coordination of the various networks and their participating telescopes will be required. The Next Generation Very Large Array (ngVLA) may also collaborate with a global VLBI array. In such scenario, the GVA will serve as contact point and framework of collaboration of the VLBI networks and these other facilities. Additionally, it can encourage and support new VLBI activities (like the African VLBI Network - AVN, Iniciativa VLBI IberoAmericana - IVIA, developments in India and southeast Asian countries, etc.).

The GVA will also facilitate that adequate information is provided to the users. For this, a unique common portal will explain the characteristics of the different networks, and the options for users to access them or in combination.

Since there is a big synergy of developments with geodetic VLBI, and many radio observatories share their facilities and equipment between different VLBI applications, the discussions in the GVA will be very relevant to the IVS.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Spectrum management for the VLBI Global Observing System observations (VGOS)

J. Kallunki, H. Hase, N. Zubko

Abstract The feature of a wideband receiving system for 2-14 GHz of the VGOS, set a challenge for the spectrum management and interference investigations. Unlike legacy S/X-band VLBI using allocated space communication bands, the VGOS frequency range is occupied with various active telecommunication services. The VGOS idea to use this wide spectrum 2-14 GHz in a flexible manner by changing the observation frequency channels to avoid RFI (Radio Frequency Interference) is not compatible to a frequency fixed allocation scheme by national spectrum authorities. The global VGOS network faces different national radio frequency allocations. This makes the quest for the "best" frequency setup more difficult. Without a consensus on the "final frequency setup", it is hardly possible to get legal frequency allocation to all VGOS frequency subbands, which by the way are already given to other services. The passive use (like in radio astronomy) is permitted, when no interference to the allocated services is produced. The only way to protect the VGOS sites against radio frequency interference is to claim some local protection like radio quiet zones or at least a coordination zone in which the VGOS observations are made. On the example of the new Metsähovi VGOS radio telescope station we explain, what is important to reach some protection: (1) a fluent dialogue between the VGOS operator and the national frequency administration is required; (2) the registration of the VGOS-site at the International Telecommunication Union (ITU) – Radio Section to get a legal position for a radio astronomy site is important, which (3) further improves possibilities to get protection for VGOS sites; (4) An interference monitoring system is needed to track the ongoing changes of the electromagnetic environment and eventually to protest at the national spectrum administration, if unwanted RFI is detrimental to VLBI observations. In this talk, we discuss on these aspects.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Large satellite constellations and their potential impact on VGOS operations

F. DiVruno, V. Tornatore

Abstract The industrialization of spacecraft construction, reaching throughputs of one satellite per day, and the lowering in costs of space launches has paved the way for big plans in Low Earth Orbit (LEO). Large satellite constellations like Starlink and OneWeb (with 4400 satellites and 620 satellites respectively) are already in the deployment phase, others like Kuiper (Amazon) or Guowang (China) are in their development phase and others with even larger numbers are being filled into the ITU system. With altitudes between 500 km and 1200 km, these new constellations will surround the planet almost homogeneously. From a radio telescope point of view, the situation in the sky will change considerably. From about 2000 active satellites in 2018, there are already more than 5000 in 2022, and the trend expects to reach tens of thousands in this decade at least. Until now, most of the satellites for internet communication were located in the geostationary belt, appearing fixed in the sky for a terrestrial observer. The new LEO satellites will orbit the Earth with a period of about 90 minutes and will be seen as hundreds of bright-fast moving radio sources in the sky. Several frequency bands under the Fixed Satellite Service (FSS) are envisaged for the satellite constellation, of special interest to us are the downlink frequencies that connect satellites and user terminals (the *user downlinks*). Some of these bands include the 10.7 to 12.7 GHz range, several bands between 17.7 and 20.2 GHz, 37 to 42.2 GHz and other bands above 50 GHz. We will concentrate here in the 10.7 - 12.7 GHz range, but this analysis can be extrapolated to the other bands too. Contrary to the situation with terrestrial radio frequency interference (RFI), it is not possible to build radio telescopes far away from satellites [1], the challenge is further increased due to the opposite pointing direction of radio telescopes and user downlink antenna beams. The 10.7-12.7 GHz user downlinks pose a risk of interference to the immediately adjacent primary radio astronomy service (RAS) band in 10.6-10.7 GHz, which includes a *passive band* in 10.68-10.7 GHz protected by the footnote RR No. 5.340. This interference can impact sensitive observations in the RAS band, but can also affect wideband receivers which include the frequency range of user downlinks. In the case of VGOS, the receivers 2 GHz - 14 GHz can be impacted by these satellite transmissions. The typical power flux density (PFD) of satellite constellations is in the order of $-146 dBW/m^2$ in 4kHz or an equivalent to $62 * 10^6 Janskys$, i.e. at least 7 orders of magnitude brighter than a strong radio source. These strong signals will require a radio astronomy receiver to have a large dynamic range to accommodate the RFI and still be able to detect faint cosmic sources in other frequency channels within the receiver band. This is normally true for modern radio astronomy receivers, but this can be different in some particular situations such as total power bolometric receivers or receivers with a low effective number of bits (ENB). The fast angular speed of these satellites combined with the narrow beams of radio telescopes, requires a transient-aggregated approach to consider their effect. While hundreds of satellites can be above the horizon at any given time, only a few will be close or in the main beam of the radio telescope antenna and that can last for a few seconds. To account for this, the ITU-R has developed a method called equivalent power flux density (epfd), which considers the effect of all visible satellites in a typical observation time of 2000 seconds [2]. In this paper we will study the potential effect of the user downlinks in 10.7-12.7 GHz on the VGOS 2 - 14 GHz band. Using a combination of simulation (and potentially measurements), the impact on single telescope observations and VGOS observations will be studied. It is expected that the correlation of RFI between VGOS antennas, being separated by several hundreds of kilometres, will be very low thus having a minimal impact. The simulation proposed will look at

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two VGOS stations performing a 2000s observation of several radio sources; as satellite constellations the first phase of Starlink and OneWeb will be considered separately and in aggregate. The effect on the single dish will be compared to the ITU-R RA.769 limits for VLBI and the interferometer response will also be estimated.

References:

[1] Report ITU-R RA.2295 Characteristics of *Radio Quiet Zones*

[2] Recommendation ITU-R SM.1586 Calculation of unwanted emission levels produced by a non-geostationary fixed-satellite service system at radio astronomy sites

[3] Starlink phase 1 FCC filing - https://fcc.report/IBFS/SAT-MOD-20200417-00037/2274316

[4] OneWeb phase 1 FCC filing - https://fcc.report/IBFS/SAT-MPL-20200526-00062/2379565

[5] Gouwang ITU-R filing in the Space Networks System - *GW-A59*

Session-1: IVS Network Stations and Technical Developments

Presentation type: Invited

Status at Ny-Ålesund Geodetic Earth Observatory

R. Bolaño González, S. Garcia-Espada, T. Gansmoe, G. Grinde, S.A. Grøslie Wennesland, R. Kleiven,
A. Meldahl, H.C. Munthe Kaas, L.M. Tangen

Abstract The current status of the Ny-Ålesund Geodetic Earth Observatory will be presented. Special focus will be placed on the status and future of the VGOS twin telescopes (Ns, Nn) and the legacy 20-meter antenna (Ny).

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Russian New Generation VLBI Network

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Abstract In 2012, the new generation VLBI system VGOS project was launched in Russia. At the end of 2015 the two-element interferometer with 13.2 –m multi-fast rotating antennas (RT-13) was completed at the Badary and Zelenchukskaya observatories. In 2020, the new generation VLBI network was replenished with the third antenna at the Svetloe observatory. Since then, observations have been regularly made on the VLBI network in the three bands (S, X and Ka) mode. Radio telescopes have identical equipment, except for the installed multifunctional digital backend system at the RT-13 in Svetloe. Additionally, the RT-13 is equipped with the ultra-wideband receiver to provide communication with international VGOS observations. The paper presents the current state and the first results obtained on the VLBI network. The nearest prospects for the expansion of the network to the east will also be considered, taking into account the start of construction of a new co-location station.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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The AuScope array - status and outlook

J. McCallum, L. McCallum, T. McCarthy, L. Chin Chuan, A. Jaradat

Abstract The AuScope array consists of three telescopes spread across the Australian continent (Hobart12, Katherine and Yarragadee) which started operating as S/X stations over a decade ago. Since then, both the Hobart12 and Katherine telescopes have been upgraded to use a wideband (2.2-14 GHz) feed and are equipped with DBBC3 samplers to support VGOS observations. A recent addition to the DBBC3 systems has now provided full VGOS-support at Hobart.
In this talk we outline our current status and observing programs, together with our future plans. This will touch on our experiences with mixed- mode observing, Southern-baseline intensive sessions, local-baseline VGOS tests and correlation.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Recent developments at the future GGOS core site Metsähovi, Finland

J. Näränen, N. Zubko, J. Eskelinen, U. Kallio, A. Raja-Halli, N. Kareinen, H. Koivula, M. Poutanen, M. Bilker-Koivula, J. Peltoniemi

Abstract Metsähovi Geodetic Research Station (MGRS), located at 60°N in Southern Finland, has been undergoing a major upgrade over the past several years. When completed, MGRS will be one of the northernmost GGOS core stations with a full suite of co-located space geodetic instrumentation and gravimeters. The station currently houses several GNSS receivers, including three IGS stations, an absolute gravimeter FG5-X, two superconducting gravimeters, and a DORIS beacon. A trihedral triangular corner reflector for geodetic SAR measurements was installed at MGRS already in 2013 and has been operational since. Geodetic VLBI sessions coordinated by IVS have been observed since 2005 in collaboration with close-by Metsähovi Radioastronomical Observatory. A new dedicated VGOS radio telescope system is being commissioned as well as a new 2kHz Satellite Laser Ranging system. Local tie measurements linking the different measurement systems are being done and research is carried out to improve the measurement methods. A high precision time and frequency link between MGRS and the Finnish metrology institute VTT MIKES responsible for the national time has been realized via commercial White Rabbit technology. A new optical fiber link with a capacity of 100 Gbit/s speed has been installed at Metsähovi, that will support the VGOS data transfer in the future. The station upgrade also includes a new office and instrumentation building that is being constructed. VGOS equipment and the backend will be relocated to the new building during this year. Special attention has been put into RFI protection of the building. We present recent developments at MGRS, with emphasis on the VGOS system, and introduce the instrumentation that already contribute and will contribute in the future to various IAG services.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Status update from Onsala Space Observatory

E. Varenius et al.

Abstract This talk is an update on the VLBI activities at the Onsala Space Observatory in Sweden. I present the current status, ongoing development, and future plans for the three Onsala VLBI telescopes; the legacy S/X antenna ONSALA60 as well as the VGOS antennas ONSA13NE and ONSA13SW.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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RAEGE Santa Maria: Station overview

J. Salmim Ferreira, A. García-Castellano, J. López-Pérez, M. Moreira, D. Avelar, V. Cuambe, F. Wallenstein Macedo, J. González-García, C. Albo-Castaño,

Abstract The RAEGE station of Santa Maria is part of the RAEGE network (Atlantic Network of Geodynamic and Space Stations), a cooperation project established between the National Geographic Institute of Spain (IGN) and the Regional Government of the Azores. It is a unique project at a geodetic and geodynamic level, in which it is committed to the construction and operation of four Fundamental Geodetic Stations, namely: Yebes and Gran Canaria stations in Spain, Flores and Santa Maria stations in the Azores, Portugal. Santa Maria station has a radio telescope equipped with a triband receiver (S, X and Ka bands) and operates as a regular station within the IVS R1 and R4 sessions, since May 2021. For the past two years, the radio telescope infrastructure and signal chain underwent a series of maintenance procedures and improvements that will be described in this contribution. Currently, the station has a team of ten people (and growing) distributed among IT, maintenance, administrative, science communication and R&D tasks. An overview of the state of the art of Santa Maria station and its plans, which includes the installation of a broadband VGOS receiver in the second half of 2022, will be presented.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Description of RAEGE Yebes VGOS receiver upgrades

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Abstract This presentation describes the upgrades to be implemented in the RAEGE Yebes VGOS receiver. Meanwhile, the Yebes radiotelescope is operating with the VGOS receiver designed for RAEGE Santa María station. The goal of these upgrades is to improve the overall receiver performance in terms of sensitivity, band-pass ripple and phase calibration stability. For these purposes, the following components have been redesigned and improved: 1) a new QRFH, with better input matching, 2) new balanced LNAs, with lower noise temperature and better input matching, 3) new cryogenic 30 dB directional couplers, more reliable that COTS units, 4) new CDMS, to improve the accuracy and stability of cable delay measurements, 5) new PhaseCal Antenna Unit, with new pulse generator and level control of calibration signals. Additionally, a new frequency converter is ready to be used with R2DBEs. It is expected to install the upgraded receiver in April 2022.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Examination of DiFX RDBE vs. R2DBE for upper vs. lower sidebands disambiguation

C. Ruszczyk, R. McWhirter, M. Titus, A. Burns, P. Elosegui

Abstract The DiFX community has been debating the ROACH2 generation-4 (gen4) complex VDIF output as to whether it is upper or lower sideband. This ambiguity presents a practical challenge for the correlation of VGOS sessions with the DiFX trunk. In this presentation, we will review the history behind the origin of this ambiguity, summarize the tests being designed and executed to resolve the output format of the gen4 as well as the former generation-3 (gen3) complex data. Testing involves using the the RDBE generation-1 personality, where the output unambiguously is real-VDIF data, as a control dataset. Testing also involves VGOS observations with a system that also generates real data but it is not an RDBE-based system. Finally, we will present correlation of these fringe tests using the DiFX trunk.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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GGAO Notch Filter at 20 K and other RFI mitigation work

D. Sullivan, D. Hudson, L. Hilliard

Abstract The faint radio signals from active galactic nuclei acquired in Very Long Baseline Interferometry (VLBI) measurements are easily corrupted by Radio Frequency Interference (RFI) from a variety of sources. Here we report on two milestones for mitigation of RFI due to a co-located radar system at the Goddard Geophysical and Astronomical Observatory (GGAO). Elimination of this RFI will increase the sky area available for observations by approximately 20%. We presented preliminary results for this work at the RFI2017 Conference in Yebes, Spain. The new developments are the commissioning of a dedicated VLBI test cryostat and experimental results for the performance of a High Temperature Superconductor (HTS) notch filter at the GGAO radar frequency of 9.41 GHz. The test cryostat is equipped with multiple stainless steel-beryllium copper (SS-BeCu) coaxial lines for the characterization of cryogenic signal chain components. The use of SS-BeCu signal lines greatly reduces the heat load on the 20 K sample stage, and with multiple lines we are able to measure system S-parameters at arbitrary points in the signal chain. We compare our S-parameter measurements for the HTS filter as a function of temperature and frequency with our design goals of rejection of -50 dB at 9.41 GHz $\pm$ 150 MHz inside the stop-band and around the radar center frequency, and low insertion loss ($\sim$0.5 dB) across the 2–14 GHz signal band. In the future we plan to use this cryostat to perform measurements of integrated high-performance signal chain components, including Low Noise Factory broadband amplifiers, other HTS notch filters, and commercial and custom-made HTS directional couplers.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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From BRAND to DBBC4

G. Tuccari, W. Alef, H. Rottmannn, S. Dornbush, A. Felke, M. Wunderlich

Abstract The BRAND project is now overlapping with the DBBC4 project. This is due to the fact that a number of technological solutions already developed and still under development for BRAND are being applied to the DBBC4 front-end.
The current status of the BRAND project with latest achievements will be presented, together with an overview of the new DBBC4 project which started this year. The DBBC4 is expected to provide new functionalities at the state-of-the art for the VLBI astronomy, geodesy and space science.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Oral

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Status of the VGOS Infrastructure Rollout

D. Behrend, C. Ruszczyk, P. Elosegui, S. Weston

Abstract The legacy S/X system has been the production system of the IVS since the inception of the service. However, in 2020 after many years of development the VGOS system was declared operational and the fledgling VGOS network (of 8–10 stations) started contributing with operational sessions to the determination of IVS products. The VGOS observing program was expanded in 2021 and it is anticipated to grow further in 2022. In order to extend the observing program, aside from the growing observing network other infrastructure components of the VLBI processing chain have been further developed. This includes the VGOS correlation and post-processing capabilities as well as VGOS data analysis. We will provide a status overview of the infrastructure realization efforts of the VGOS station network and the correlation centers. Further, we will outline the VGOS observing plan for 2022.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Poster [S1-P01]

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VGOS Station in the South of Thailand

P. Jaroenjittichai, N. Kruekoch, N. Thoonsaengngam, J.A. Lopez-Perez

Abstract Following the development of the 40m Thai National Radio Telescope and Thai VLBI Network, the project to build a VGOS station in the South of Thailand has been approved for the year 2022-2025 to probe tectonic activities in South East Asia region. The site is located in the vicinity of NARIT's Regional Observatory for the Public, Songkla. A wideband 2-14 GHz receiver system is being developed in a collaboration with Yebes Observatory.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Poster [S1-P02]

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Status of the Ishioka VLBI station for the past two years

S. Matsumoto, T. Nakakuki, T. Yutsudo, H. Ueshiba, Y. Takagi, K. Hayashi, K. Mori, Y. Sato, T. Kobayashi

Abstract The Ishioka 13-m VLBI telescope has participated in IVS sessions since 2015. From 2020 through 2021, it could not be involved in the scheduled sessions for several months because of the telescope driving system trouble. In June 2020, errors caused by the motor for elevation drive frequently happened. As a result of the investigation, it was revealed that the vibration generated by the worn teeth of the gear rim caused the motor over-torque and the telescope emergently stopped. After the threshold of the torque limiter was raised and the settings of automatic lubrication to the gear rim were changed, Ishioka resumed the observation at the end of November 2020. It means that the operation was interrupted for five months. However, the trouble on another motor for elevation drive happened six months later. This time, it was an error on servomotor amplifier, and some failure on the control board or electric contact failure were suspected. Once the motor was dismantled and reassembled by the manufacture, the error had never happened again. Thus, the error seemed to be caused by the contact failure of the motor encoder. It took more than five months to return to the observation completely. In this presentation, the process of the troubleshooting and our efforts to prevent the recurrence of these problems will be reported.

Session-1: Technical Developments at the Stations

Presentation type: Poster [S1-P04]

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Recent progress on the upgrade of the VERA for EAVN, GVLBI

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Abstract NAOJ has been operating the VERA for 20 years since we got first fringes. The first catalogue was prepared to reveal the dynamics of the Galaxy (VERA Collaboration, et al. 2020). At the same time, we have upgraded the VERA to get more higher sensitivity, dual polarizations and new frequency bands for EAVN and GVLBI. First upgrade is to have installed the new digital back-end system (OCTAVE-DAS) ,which enable us to sampling direct RF($\leq$ 26 GHz) signals and record VLBI raw data at a rate of 32 Gbps. Second is to have installed LNAs and DCs for right polarizations of K and Q-band on all the VERA stations. Third is to have installed low frequency broad-band receivers (1.4 $\sim$ 2.3 GHz) with the cooling super conducting filter to eliminate strong satellite RFIs at Mizusawa and Ishigaki satations. Fourth is to have upgraded the Mizusawa software correlator system with using GPU-technology. This paper shows the current status of upgrading the VERA and results of test observations.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Poster [S1-P05]

Tomoaki Oyama[1], Yusuke Kono[2], Takaaki Jike[1], Kazuhiro Hada[1], Tomoya Hirota 2, Mareki Honma[1], Osamu Kameya[1], Aya Yamauchi[1], Yu Asakura[1], Syunsaku Suzuki 2, Hiroshi Imai[3], Yoshiaki Hagiwara[4],
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IVS Seamless Auxiliary Data Archive and EVN Monitor

A. Neidhardt, Ch. Plötz, M. Verkouter, A. Keimpema, S. Weston

Abstract Continuous data in real-time offer a tremendous benefit. Operators get detailed information about system status and quality. External partners and companies can retrieve historic values for intervals of events and failure situations. Correlation and analysis can integrate highly-sampled correction parameters. These advantages were the drivers of an IVS Seamless Auxiliary Data Archive at Wettzell as well as the EVN Monitor at JIVE. The EVN Monitor has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730884. This presentations shows the current status, possibilities to participate, and first improvements.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Recorded presentation [S1-M06]

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Modernization of subreflector's reflective surface of radio telescopes RT-32

S. Serzhanov, A. Shamov, V. Olifirov

Abstract In order to improve the accuracy of VLBI observations in the high-frequency bands, subreflectors' reflecting surface of the Quasar network RT-32 radio telescopes were upgraded. The paper presents description of design, installation and alignment of new panels. This project was implemented in 2020-2021.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Poster [S1-P07]

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An agile method to detect deformations of the VLBI dish

U. Kallio, J. Eskelinen, J. Näränen, M. Poutanen

Abstract Gravity and temperature variations deform the radio telescope dish and structure during VLBI measurements, thus affecting the reference point determination. Full determination of the deformations is time consuming and requires a dedicated campaign to investigate the form of the full paraboloid surface of the VLBI antenna dish. In this paper we investigate a more agile method using spherical prisms attached to the dish structure and a robot tachymeter. We tested the method at Metsähovi Geodetic Research Station VGOS antenna and measured the angles and distances to the points in telescope and dish structure in different antenna elevation positions. The distances between the points were calculated and projected in each elevation position to the Cartesian system, axes of which are the pointing direction, elevation axis direction and the third one orthogonal to those. The projected distances were then analysed. In our experiment we detect mm-level changes at different dish elevation positions. The method could be used to complement the full determinations, even during VLBI-sessions.

Session-1: IVS Network Stations and Technical Developments

Presentation type: / Poster [S1-P08]

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Development of Wideband Antennas

H. Ujihara

Abstract Wideband Antennas have been developing for a next generation radiometer and wideband feed horn for upgrading of conventional Cassegrain antennas. This next generation radiometer uses 16 - 64GHz feed horn to observe spectrums of water vapor(22 GHz band), water in clouds (30GHz band) and oxygen(50GHz band) with two LNA. The OMT delivers one linear polarization to the LNA for 16 - 34 GHz, and the other to the LNA for 26 - 62 GHz. Both LNA can be cooled by a stirling cooler, but now they have been tested in room temperature with wideband horns at Kyoto University. This wideband feed system will be set on new portable 900 mm dish and MARBLE 2 at NICT Koganei to obtain fine resolution. The feed horn for upgrading of radio telescopes aims to recieve 1.5 - 15.5 GHz with narrow beam of 15 degree in subtended angle of sub reflector. Various types of feed were tested in simulation, the present models are arranged from original IGUANA feed design for Kashima 34 m antenna. They are coaxial multimode horns and they seems to have fine beam in 3.2 - 16 GHz. Development of the next generation radiometer is supported by JSPS Kakenhi Grant Number 18H03828 and 21H04524. Development of 1.5 - 15.5 GHz feed horn is suppered by a powerful computer of Max Plank Institute.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Poster [S1-P09]

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Using the Multifunctional Digital Backend System on Radio Telescopes of Svetloe Observatory

E. Nosov, D. Marshalov, L. Fedotov, Yu. Bondarenko, I. Rahimov

Abstract We present the results of using a new multifunctional digital backend (MDBE) on radio telescopes of the Quasar VLBI network. It is designed to form digital data streams from intermediate frequency signals (0–2 GHz) and supports both broadband and narrowband recording modes and is also compatible with domestic and foreign receiving systems. The system has a flexible architecture and supports up to 12 modules (channels) of digital signal processing, which can be remotely reconfigured. The input signals are converted with minimal distortion by using digital signal processing. Installing the system directly on the antenna eliminates distortion in the signal path between the receiver and MDBE due to the absence of moving cable loops. Experimental sessions of VLBI observations using MDBE on the RT-13 radio telescope confirmed the compatibility of MDBE with standard domestic and foreign systems. The MDBE has also been used to record echoes during radar observations of the Moon. At the end of 2020, the MDBE was commissioned at the RT-13 radio telescope at Svetloe Observatory and is currently used in all VLBI observations. We plan to equip all radio telescopes Quasar VLBI network with such systems starting from 2022.

Session-1: IVS Network Stations and Technical Developments

Presentation type: Poster [S1-P10]

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Session-2: Observations, Operation and Correlation

Current Status of the EU-VGOS Project

W. Alef, J. M. Anderson, S. Bernhart, J. Böhm, R. Bolaño González, Y. K. Choi, T. Gansmoe, S. García Espada, C. García Miró, A. Girdiuk, J. González García, S. A. Groøslie Wennesland, J. F. Gruber, R. Haas, R. Hammargren, F. Jaron, N. Kareinen, A.-S. Kirkvik, H. Krásná, E. Martinez, A. Meldahl, I. Martí-Vidal, A. Melnikov, S. Modiri, A. Neidhardt, A. Nothnagel, O. Panzenböck, L. Petrov, C. Plötz, H. Rottmann, T. Savolainen, M. Schartner, T. Schüler, H. Schuh, B. Soja, E. Varenius, P. de Vicente, J. Wagner, M. H. Xu, N. Zubko (The EU-VGOS Collaboration), M. Kettenis, S. Matsumoto, R. Porcas, D. Small, M. Verkouter (External collaborators)

Abstract The EU-VGOS project was started in 2018 with the aim of using the VGOS infrastructure in Europe to investigate innovative methods for VGOS data processing. The project is now structured into working groups dealing with operations (stations), e-transfer, correlation and post-processing, and analysis. I will give a report on the status of our work in progress and present results from our investigations.

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Session-2: Observations, Operation and Correlation

Presentation type: Oral

The Australian VGOS observing program

A. Jaradat, L. McCallum, J. McCallum, T. McCarthy

Abstract The AuScope VLBI array is entering the VGOS era; Hobart 12m and Katherine 12m stations have already been upgraded with VGOS systems and Yarragadee will follow soon. However, due to some technical differences, the AuScope stations have not routinely joined the IVS VGOS sessions yet. The AUV observing program is a series of VGOS sessions with fortnightly cadence, aiming eventually at achieving mm precision. The scheduling is being continuously enhanced, for example session duration has been adjusted to 12 hours on a single baseline to optimise for results versus total data volume. Additionally, source behavior is a concern, and we have already identified several unsuitable sources due to bad performance at higher frequency bands (10 GHz - 12 GHz). These sessions have been used to get feedback about baseline sensitivity across frequency bands, identify RFI and adjust the channels distribution accordingly. This talk will present the transition progress of the AuScope VLBI array towards VGOS era.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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The Australian AUM/AUA mixed-mode observing program

L. McCallum, L. Chin Chuan, H. Krásná, J. McCallum, T. McCarthy, M. Schartner

Abstract Australian mixed-mode sessions have been regularly observed since 2020. A legacy S/X-only mode is used in these observations, with the Hobart12 and Katherine telescopes contributing with their VGOS receiver and backend. Sessions are observed twice per month with a southern network of up to six telescopes, strongly continuing the previous AUSTRAL program. In this contribution we detail the aims and plans of this observing program and discuss the latest results. The mixed-mode technique allows a continuation of station time series for Hobart and Katherine, which would otherwise be interrupted until regular VGOS sessions begin. It further allows comprehensive testing and debugging of the receivers and recording systems as well as increasing our operational preparedness for VGOS in terms of the high data load for transport, storage and correlation. Until VGOS will be operating continuously, these AUA/AUM sessions will serve as link between the legacy and the VGOS network with the aim to increase the current regional network to a more global one in the near future.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Australian VLBI Correlation Centre

T. McCarthy, J. McCallum, O. Titov, L. McCallum

Abstract We outline the progress and current plan for development of an Australian VLBI correlation centre operated by the University of Tasmania. This centre will fill the gap in Australian VLBI capabilities and initially focus on the correlation of geodetic VLBI data from Australia and the Asia-Pacific region, with the ultimate goal of becoming recognised by the IVS as an international VLBI correlation centre. The centre will be designed from the ground up with the data volumes of VGOS in mind, and aims to address the current lack of correlation centres that are equipped to handle the routine correlation of VGOS experiments. We aim to transition from a local correlation cluster to an HPC environment, allowing us to overcome data I/O issues that are inherent to the high data rates of VGOS. This centre will allow for better utilisation of the Australian VLBI network, increasing cadence of observations with shorter turn around times on processing.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Bonn Correlator Status

Y. K. Choi, S. Bernhart, W. Alef, H. Rottmann, T. Schüler and J. Wagner

Abstract We report on the status of the Bonn Correlation Center focusing on geodesy over the period from 2018 to 2021. The correlation center is operated jointly by the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn and the Federal Agency for Cartography and Geodesy (BKG) in Frankfurt. Our duties include the correlation of the weekly INT3 and R1 series and as well as OHIG and T2 sessions. In March 2018, on initiantive of W. Alef of the Bonn Correlation Center, a collaboration with the three European stations of Wettzell, Onsala and Yebes, equipped with both standard S/X and VGOS systems, was launched to carry out a VGOS Proof-of-Concept study. The aim of the project is to verify the processing chain for VGOS experiments end-to-end, from the scheduling to the geodetic analysis of the derived observables. In addition to our EU-VGOS test correlations, we started correlating 24-hour IVS VGOS sessions in 2021. In August 2021, in order to regain a cross-site consistent DiFX-2.5 installation for VGOS correlation, as opposed to many local patches at correlator sites, Bonn gathered necessary patches and backported certain features from mainline DiFX-2.6, and together with Haystack-provided HOPS 3.22, released DiFX version 2.5.4 to the DiFX community. In October 2021, we upgraded our Internet connection for e-VLBI to a commercial 10 Gbps link (NetCologne), replacing our previous 2×1 Gbps NREN (DFN) links.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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VLBI correlator Wettzell - a new IVS component

C. Plötz, W. Probst, R. Wildenauer, B. Fischalek, A. Neidhardt, M. Seegerer, M. Schönberger, T. Schüler

Abstract The Geodetic Observatory Wettzell (GOW) in Germany was enhanced with a VLBI correlation facility. An initial DiFX-based correlator was operated between 2016 and 2020 for the evaluation of local VLBI baseline measurements between the three VLBI radio telescopes of the GOW (Wz, Wn and Ws). In December 2021, a high performance cluster (HPC-) based DiFX VLBI correlator replaced obsolete small hardware, which enabled also the necessary performance for handling VGOS observations. Additional correlation duties came along with serving the local VLBI observation program in Wettzell and a small VLBI network with BKG radio telescopes located in Argentina (AGGO) and O'Higgins (Antarctica). Since late 2021 the VLBI correlator at Wettzell was acknowledged as an official IVS correlation component in order to contribute to the IVS correlation resources. A special focus is on serving a timely deltaUT1 estimation with dedicated legacy S/X Intensive sessions between Wettzell and AGGO and with a newly established IVS VGOS Intensive observation program between Wettzell and MacDonald Observatory (MGO). Automation is an important aspect from provisioning the IT infrastructure towards an automatized correlation workflow, in particular the Intensive sessions. The new VLBI correlation facility has a close integration into the Geodetic Observatory Wettzell and its infrastructure as a geodetic fundamental station, as well as the other IVS components at Wettzell, namely the Operation Center (OC DACH) and the three VLBI network stations. These components are a valuable addition to the worldwide geodetic VLBI infrastructure.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Flux density monitoring of sources based on observations of the Quasar VLBI Network

A. Kudelkin, S. Kurdubov, V. Ken

The most popular approach for the SNR estimation is using sources flux densities catalogs. Depending on the catalog, flux density can be defined as a constant or as a function depending on the length of the baseline. However, this approach has some disadvantages. In particular, it does not take the structure of a source into account. Due to the structure of a source influence, SNR periodically depends on sidereal time with a period of 12 hours. An alternative approach for SNR estimation is the analysis of long-term regular observations of a source and statistical processing of the data obtained by appropriate methods like Kalman smoothing.

In this report, the set of observations was carried out from 2016 to 2020 on RT-13 VLBI antennas of the Quasar VLBI Network located in the radio astronomy observatories ”Zelenchukskaya” and ”Badary”. This set contains about 1 million observations in S/X bands in right (RCP) and left (LCP) circular polarizations. Using Kalman smoothing, this data was decomposed to the sum of a trigonometric polynomial and a stochastic part. The coefficients of trigonometric polynomials for 50 sources in channels 2164 MHz LCP, 2164 MHz RCP, 8080 MHz RCP, 7568 MHz RCP were derived. Finally, the result obtained was compared to ”VLBI Source Position Catalogue” by L. Petrov. The result obtained can be used to improve a priori estimation of SNR for future observation scheduling.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Monitoring source flux density and antenna sensitivity with improved feedback for the AUSTRAL VLBI sessions

L. Chin Chuan, L. McCallum, J. McCallum, G. Molera Calvés

Abstract In very-long-baseline interferometry (VLBI) observation, two or more telescopes observe distant quasars and record the radio signal of specific frequency ranges. VLBI experiments using dual frequencies at S- and X-band (2.3 GHz and 8.4 GHz, respectively) has been the standard for about six decades. In the fringe-fitting stage, the recorded signal needs to reach a theoretical minimum signal-to-noise ratio (SNR) of seven to be usable for geodetic analysis. The development of the next-generation VLBI system (VGOS) is ongoing, which is to replace the current S/X system in the next several years. The VGOS system uses four or more frequency bands between 2.3 GHz and 14 GHz. The move to replace the legacy S/X system with VGOS will require source flux and antenna sensitivity estimation in the additional frequency bands.
Although it has a long history, VLBI in the Southern Hemisphere is not as old as the Northern Hemisphere, with significantly fewer telescopes and observations. The Australian AuScope array, one of the major contributors to the Southern Hemisphere VLBI observations, strives to achieve better results through improved source flux density and antenna sensitivity monitoring with more automation. A new approach was investigated using 24-hour AUSTRAL sessions from previous years. We found that the Australian 12-metre telescopes have varying sensitivity in actual observations. The a priori SNR prediction for these sessions could have been improved by more than two standard deviations if we used locally monitored source flux densities together with the newly predicted antenna sensitivity. With automated feedback, we can quickly identify our system performance, generate improved source flux density information and create schedules with better SNR prediction for the AUSTRAL sessions.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Data Ingest at the IVS Data Centers

D. Behrend, M. Bérubé, J. Gipson, A. Girdiuk, M. Goltz, T. Yates, P. Michael, C. Barache

Abstract In 2021, the primary IVS Data Centers at BKG, CDDIS, and OPAR started to use a new data ingest software. The new software suite is modular in structure and replaced the original monolithic *ivsincoming2ivs* program. While the transition to the new ingest should be smooth and transparent for most data providers, there are significant updates in the processing that may impact the acceptance of files in the repository. In addition to the formerly used filename check, a validation step (QC) was introduced for each data type. This was realized in dedicated routines that are the same across all three data centers. That is, the validation routines plus the accompanying data description files (DDFs) are modular pieces that are exchanged one-to-one between the data centers. If a submitted file fails the filename check or the format validation check, it is being rejected. As at the CDDIS the ingest of VLBI data and products is part of a larger suite that supports all geodetic techniques, the realization of the main program at CDDIS differs from the main program used at BKG and OPAR. While the filename check done in this part of the software suite should yield identical results, there is the odd chance of a divergence. Once the ingest process gives the same results for all three data centers, the existing data holdings will be reprocessed and synchronized. Following this cleanup step, the mirroring among the data centers will ensure identical holdings going forward. We will provide an overview of the new ingest process and its current status.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Improving IVS communication through a VLBI Operating Center

M. Bérubé, J. Gipson, J. Lovell, D. Lakins

Abstract Since 2000, the International VLBI community has greatly invested in developing new hardware and software to improve data precision, processing, and latency. There is also a significant effort in automating observations and processes. Unfortunately, one element that has not been improved is how the different VLBI components, Operations Centers, stations, correlators, and analysts are communicating. The current VLBI communication system was developed 25 years ago and relies mainly on emails, archiving system, and the dedicated people monitoring the information relevant to them. This is not a suitable communication system for operational VLBI. To improve the actual system, the GSFC group at NASA has developed a VLBI Operating Center (VOC) and tools for near real-time, machine-to-machine, two-way communication between IVS components. The VOC is a web service supported by a database and a message broker using formatted information designed for access by computers. The database keeps up-to-date data on schedules, catalogs and all relevant information on various IVS components (station's availability, latest SEFDs, ...). The message broker is used to inform any IVS components that some data/information at the VOC are relevant for them. The VOC knows who acknowledges the message and uploaded the schedule, allowing full traceability of data/information exchanges. This presentation will show the limitations of the actual communication system, describe the various components of the VOC and how it could improve the communication and data exchange between IVS components. The tests done with the VOC hosted by NASA will also be presented.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Towards Automating Operations of SGP VGOS Stations

J. Lovell, D. Lakins

Abstract The NASA Space Geodesy Project (SGP) aims at establishing a network of up to 10 VGOS stations in the next several years. The goal is to have the network of stations be controlled and monitored from the Space Geodesy Network Operations Center (SGNOC) and having the local operations teams focus on safety, maintenance, and the technical aspect of operations. To attain this high level of automation, a set of use scenarios and requirements have been defined for the Next-Generation Field System (NGFS). The initial steps on the road to NGFS and automated operations have been made with additions to the current Field System (FS). Fesh2 is an automated schedule file management module that checks the IVS data repositories for current master and session schedule files, downloads updated versions, and prepares one or multiple stations for observing. In addition, work has been done on an SGP Automation module that will take over local operator hands-on FS tasks before, during, and after an observing session. We will describe the new modules as well as future steps.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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VGOS Technology RD Sessions

B. Petrachenko, M. Schartner, M. Xu

Abstract Initial VGOS development and testing focused on systems and processes that had the basic conceptual shape of VGOS but did not yet fully meet specifications. This basic form persisted for the better part of a decade and was still in use as VGOS entered operations at the start of 2020. Recent augmentation of VGOS correlator resources provided enough operational margin to put out a call for a series of VGOS Technology RD sessions. To date, within the scope of the VGOS Technology Committee (VTC), two sessions of 24-hours duration and two sessions of 1-hour duration have been carried out; five more of each duration are scheduled for the remainder of 2022. The overarching focus of these sessions is to move VGOS towards its final specifications, primarily an increase in maximum RF frequency to 14 GHz, an increase in data rate to 16 Gbps and an increase in scan rate to 1 scan every 30 seconds at each station. Unfortunately, hardware limitations make the former two goals difficult to achieve in 2022 so the main focus this year is to increase the station scan rates and at the same time to improve scheduling and analysis strategies to better match the higher rates. In recent years the critical role of source structure in limiting geodetic performance has become clear. Hence schedules will also emphasize good uv-coverage so that processes can be developed to better understand and correct structure errors. In the long term it is expected that VGOS data will be a valuable resource for astronomy as well as geodesy. Current state of the VGOS Technology RD sessions will be presented.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Radio telescope equipment signal propagation delay stability and its influence on scheduling of VLBI sessions

Yu. Vekshin, V. Ken, S. Mironova

Abstract Accuracy of UT determination is to a great extent dependent on group delay measurement accuracy of radio interferometer. Measurement error of group delay depends on signal delay instability in radio telescope equipment. We propose a technique for determining an optimal scan duration and its application to the processing of UT determination sessions. Fringe delay stability is determined by analyzing recording of the continuous 1-hour tracking of a source. Signal optimal accumulation time (which provides minimum error of delay measuring) is determined by calculating Allan deviation. Delay measurement error increases at longer accumulation time due to delay instability. Source scan duration is determined in such a way that the delay's calculated standard deviation is not less than the radio telescope equipment's delay instability Allan deviation. The results of measuring fringe delay stability on RT-13 radio telescopes of Quasar VLBI Network in S-, X-, Ka-bands were applied to R-X session postprocessing. We have recalculated some of previous sessions by changing the scheduled scan duration to an optimal one for a few most intense sources. The comparison of UT1-UTC determination and its formal errors obtained with current scheduling and based on optimal scan duration scheduling is presented.

Session-2: Observations, Operation and Correlation

Presentation type: Oral

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Alternative Frequency Setups for VGOS

H. Hase

Abstract The frequency setups for legacy VLBI have been almost never changed during decades providing a consistent time series. The VGOS concept introduces the broadband receivers covering a spectral range from 2-14 GHz. The highest accuracy will be achieved by maximizing the spanned observation bandwidth. Unlike in legacy VLBI where S-band observations are used for ionospheric calibration of X-band, the VGOS concept estimates the Total Electron Content values during the correlation process. This allows to extend to former X-band bandwidth of about 800 MHz to the range of 12 GHz between 2 and 14 GHz. In order to find the appropriate frequency setup for VGOS-observations the Golomb ruler of the order 22 can be applied. Simulations with new sequences including some RAS-frequencies have been analyzed by the delay resolution function and showing improvements compared to known VGOS-480 resp. VGOS-9923 setups.

Session-2: Observations, Operation and Correlation

Presentation type: Recorded presentation [S2-M01]

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Yebes Observatory and the future VLBI correlator for the RAEGE network

J. González, C. García-Miró, E. Martínez, J. A. López-Pérez, P. de Vicente

Abstract This contribution describes the VLBI geodetic activities carried out in the Yebes Observatory and gives an update about the status of the RAEGE project. The design of a VLBI correlator for the RAEGE network has just started based on the experienced gained with a prototype installed on site. The development of the correlator is part of the YNART project, co-funded with ERDF 2014-2020 funds, granted by the Spanish Ministry of Economy and Competitiveness.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P02]

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Obtaining Local-Tie Vectors from Short-Baseline Interferometry

R. Handirk, E. Varenius, T. Nilsson, R. Haas

Abstract With the VLBI Global Observing System (VGOS) being the next step in the development of geodetic VLBI, it is necessary to connect the new VGOS network to existing legacy S/X telescopes. At the Onsala Space Observatory (OSO), this is being done by short-baseline interferometry between the VGOS Onsala Twin Telescopes ONSA13SW and ONSA13NE, and the legacy antenna ONSALA60.
The main aim of these sessions, referred to as ONTIE, is to obtain local-tie vectors between these three OSO telescopes that all take part in regular geodetic VLBI observations. Each ONTIE session is about 24 h long, during which all three telescopes observe simultaneously the same sources at X-band. A total of 37 ONTIE sessions have been run since April 2019. In November 2021, the ONTIE sessions were for the first time run with alternative observation frequency setups in order to mitigate the influence of known RFI. Additionally, scheduling was done – also for the first time – with VieSched++ instead of sked.
Interesting findings of the ONTIE sessions include unexpected offsets in the results of group and phase delays, jumps in the coordinates of the Twin Telescopes, and apparent yearly trends that might be an artifact of unmodelled thermal expansion of the telescopes that are left in the data.
Future ONTIE sessions are envisioned to happen on a regular basis and could, as a by-product, also serve as quasar flux-monitoring sessions by investigation of the recorded system temperatures during observation.
The poster to be presented will summarise the current status and results of the ONTIE sessions.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P03]

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Quality Assessment of Mizusawa Software and GPU Correlator

T. Jike, T. Oyama, A. Yamauchi

Abstract The measurement accuracy required for the next generation of astronomical and spatial-temporal measurements is higher than 1 mm, 1 micro-arc-second, atto time-second level, and 1 micro Jy. It is an important issue to achieve accuracy if the receiving / transmitting system, digital system, and correlator guarantee 2 pico-seconds accuracy. As an investment in the future plan, we investigated the delay measurement accuracy guaranteed by the Mizusawa correlator. Accumulation of inspection technology that can also be used to investigate the performance of new radio interferometer equipment.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P04]

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Assessment of INT2 and INT3 sessions – current status and recent achievements

M. Schartner, C. Plötz, B. Soja

Abstract Under the supervision of the IVS, various Intensive observing programs exist that determine dUT1 on a regular basis. Within this work, we will present a detailed investigation of INT2 and INT3 session performance over the last five years. We will compare analysis results from various Analysis Centers (ACs) and also compare them with combined solutions such as the IERS C04 and the JPL EOP2 series.
In 2019, the scheduling strategy of the INT3 sessions was significantly changed, leading to a reduction of dUT1 mean formal errors by 25 % for 4-station sessions and 45 % for 5-station sessions based on the GSF-AC results. Mid-2020, the same scheduling adjustments were performed for INT2 sessions, also leading to a reduction of the average dUT1 mean formal error. For example, the mean formal errors were reduced by 44 % for baseline Mauna Kea to Wettzell.
Furthermore, the dUT1 latency of products obtained from INT2 and INT3 sessions is investigated. Thereby, it is revealed that the turnaround time of INT3 sessions, although observed with 1 Gbps and with up to five participating stations, is mostly below twelve hours. This indicates good cooperation between the participating stations, the BONN correlator, and the Analysis Centers.
Altogether, this highlights a strong positive trend in the performance of INT2/INT3 dUT1 measurements over the last years.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P05]

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Recent activities of VGOS data processing at Shanghai

F. Shu, X. He, D. Wu, Y. Huang, J. Gan, Z. Chen, C. Liu, J. Li

Abstract In addition to regular VGOS observing sessions, some geodetic experiments with participation of Shanghai VGOS station have been correlated in 2021. Among them, Shanghai VGOS station was scheduled to be tagged along to a VGOS or AOV session as listed in the IVS master files. The former is observed at 4 bands and dual linear polarization, while the latter is observed at X band only for legacy-to-VGOS local ties. We will report our experience with data playback and correlation as well as the evaluation of the station performance and preliminary solution of station coordinates.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P06]

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Coordinating Center Activities at GFSC

D. Behrend, C. Thomas, M. Bérubé, K. Baver, K. Armstrong

Abstract The IVS is a globally operating service that coordinates and performs VLBI activities through its constituent components, supporting geodetic and astrometric work on reference systems and Earth science research. Various component types specialize in given aspects of the VLBI technique. The service consists of over 80 components, which are supported by about 40 organizations in more than 20 countries. In order to be able to manage both the day-to-day work and the long-term activities of the IVS, a Coordinating Center (CC) was established at NASA Goddard Space Flight Center at the creation of the service in 1999. The CC provides the necessary fabric to enable a cohesive interaction of the individual components. Among its many activities, the CC coordinates the observing programs (creating and maintaining the master observing schedules), fosters communications among the IVS components, organizes workshops and meetings, produces and publishes reports, and provides a liaison with other organizations. In this poster we summarize the various aspects of the coordination work done at GSFC and outline some of the changes that have occurred over the last four years. Updates include a revamping of the session webpages, a migration to a new mailing list server, and a redesign of the logo and newsletter format (in close collaboration with the Office for Outreach and Communications).

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P07]

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IVS Data Center at BKG

A. Girdiuk, M. Goltz, D. Thaller

Abstract The three primary IVS Data Centers cooperate closely together to establish and maintain common data acquisition procedures. The IVS Components should be able to upload their data to the Data Center of their choice, while each Data Centers ensures data acceptance, storage, availability of the data and compatibility with the other Data Centers. We present here the current procedures of the data acceptance at BKG and our future plans to extend the data center infrastructure. The data center storage capacity covers the foreseen requirements to store vgosdb intuitively based on the expected rate of the data increase. We are also interested in the extension of the currently accepted IVS Data Center structure to additionally store the correlated data, however, the expected storage capacities need to be better defined and properly advocated. The approval process is expected to be considerable as well. While this work is in progress, the BKG's IVS Data Center uses its available capacities to serve as an exchange server for projects of relatively small disk space demands, namely TPWLO and EU-VGOS. The structure of the projects repeats the IVS Data Center structure, what facilitates the exchange internally. Also it means that the internal project would be possible to make available on the official data center once it is decided. The projects are maintained with restricted access, which allows us to learn the new routines to handle the data acquisition. The corresponding routines are planned to be in place for all our users once we switch to a secure protocol as it is demanded by our internal IT-Infrastructure requirements and EU-regulations on Data Security.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P08]

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VLBI Data Ingest Improvements at NASA CDDIS

T. Yates, J. Woo, N. Pollack, J. Ash, J. Roark, S. Blevins, P. Michael

Abstract NASA's Crustal Dynamics Data Information System (CDDIS) and the International VLBI (Very Long Baseline Interferometry) Service for Geodesy and Astrometry (IVS) have been collaborating for several years to identify and rectify issues including data and derived product collection completeness and availability. The issues identified include inconsistent quality assurance (QA) across data centers, fringe visibilities missing in the archive, latency in resolving data submission issues, and a reliance upon on-premises servers to provide these datasets to the community. In 2021 several improvements to address these issues were made. A new QA architecture has been introduced that utilizes common standards (Data Definition file Formats, or DDFs) provided by the IVS. This centralization of QA standards has proven to be vital in improving archive quality and consistency across the multiple data centers. SWIN data files contain raw output from the Distributed FX (DiFX) software correlator (Level 1 data) in Swinburne format. These files are large, compressed directories of the fringe visibilities. Adding SWIN files to the CDDIS archive increases their visibility and use in the community. Additional software has been written that informs data providers when an uploaded file is not recognized, greatly reducing the response time for any anomalies. Cloud deployment of the CDDIS archive will greatly increase data availability; therefore, steps are being taken to deploy CDDIS VLBI datasets to be available on Amazon Web Services without disrupting active use of the data by the community.

Session-2: Observations, Operation and Correlation

Presentation type: Poster [S2-P09]

Session-3: Data Structures, Scheduling and Analysis Strategies

VTEC estimates in the VGOS era: Quality assessment of VTEC derived with the use of the next-generation VLBI system

Mudathir Awadaljeed, Grzegorz Kłopotek, Benedikt Soja

Abstract Spatio-temporal modelling of the ionosphere helps us extend our knowledge concerning the dynamics and characteristics of the ionospheric processes. It is also beneficial for correcting ionospheric contributions as in the case of single-frequency GNSS measurements or other techniques operating in the microwave regime. These corrections can be derived from observations conducted with multi-frequency space-geodetic techniques including the next-generation very long baseline interferometry (VLBI) system, known as the VLBI global observing system (VGOS). As VGOS has already reached an operationally stable international network and continuously evolves into a truly global infrastructure, VGOS-derived vertical total electron content (VTEC) has the potential to complement local and global sources of ionospheric observations. We developed a Python package for automatically downloading VLBI/VGOS observations organized as 24-hour global sessions, deriving VTEC time series above VGOS sites from those observations, and analysing the derived VTECs, also in relation to external ionospheric products. In our approach, the VTEC time series are represented as a piece-wise linear (PWL) function to account for the temporal variability of the ionosphere above the geodetic stations. To consider the impact of the Earth's magnetic field on the ionosphere, the modified dip (modip) latitude is employed in relation to the ionospheric piercing points (IPP). In addition, the Sun-fixed coordinate system is used to account for the dependency of ionosphere on the position of the sun.
All publicly available 24-hour VGOS sessions were investigated, resulting in over seventy global sessions that were available for the analysis. The results indicate that VGOS-derived VTEC time series exhibit a similar temporal behavior as the VTEC time series obtained from observations made with the use of the legacy VLBI system or co-located GNSS stations. A similar pattern is visible when VGOS-derived VTEC time series are compared with VTEC time series extracted from external ionospheric products such as global ionosphere maps (GIMs) or Madrigal TEC maps (MTMs). An inter-technique VTEC bias exists between the different VTEC time series that were investigated, with its origin in modelling errors and the calibration uncertainty of both VGOS and GNSS instrumentation. However, the sources of inter-technique biases need further investigation. Interestingly, almost no discrepancies were found between VTEC time series derived for two VGOS stations located at Onsala Space Observatory, i.e., ONSA13NE and ONSA13SW. In general, the uncertainties of VGOS-derived VTECs are consistent across all of the currently operational VGOS stations.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Analysis of VGOS dTEC using global TEC maps

N. Zubko, M. Xu, N. Kareinen, T. Savolainen, M. Poutanen

Abstract The ionosphere causes an extra delay in radio signal propagation and this effect is taken into account in VLBI data analysis. The ionosphere contribution to the VLBI observable is characterised by the differential total electron content (dTEC) for each baseline. The estimation of the dTEC from VGOS data has different approach compared to the traditional geodetic S/X VLBI observations. In the current VGOS data processing the visibility data is used to estimate delay, delay rate residuals and simultaneously estimate dTEC. The formal errors of VGOS dTEC values are generally very small, on the order of 0.01 - 0.2 TECU. However, the analysis of VGOS data reveals that the estimated dTEC values contain some observational and instrumentation effects which are not reflected by the formal error values. To evaluate the effects, we use TEC global maps that model the global distribution of the TEC as a shell layer at height of 450 km, the models are based on GNSS observations. The use of the TEC map data for the comparison requires temporal and spatial interpolation, as well as the mapping of the vertical TEC to obtain the slant TEC values corresponding to each VGOS observation. The comparison of the TEC map data with VGOS is still suitable and useful to characterise some features seen in VGOS dTEC. We present our recent investigations and results on this comparison.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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VLBI data analysis at ESA/ESOC

S. Bruni, M. Otten, E. Schoenemann, T. Springer

Abstract ESA's Navigation Support Office is responsible for providing the geodetic reference for ESA missions. In this context, it has long established the analysis capability of the data provided by the three geodetic satellite techniques that contribute to the realization of the International Terrestrial Reference Frame (ITRF), namely GNSS, SLR and DORIS, in compliance with the latest updates to the IERS 2010 Conventions. For all of these techniques, ESA's Navigation Support Office acts as an official analysis centre (AC) for the respective Services of the International Association of Geodesy (IAG). All the relevant solutions are generated with the ESA's NAvigation Package for Earth Orbiting Satellites (NAPEOS). NAPEOS can also generate multi-technique solutions by Combining the relevant data On the Observation Level (COOL approach) and generating a single fully consistent solution.
The fourth space geodetic technique contributing to the ITRF realization is VLBI, that is fundamental to establish the link between the terrestrial and celestial reference frames. Therefore, to complement ESA's expertize and support its operational capability, NAPEOS has been recently extended to enable the processing of VLBI S/X observations according to the latest modelling standards. The analysis of rapid turnaround and intensive sessions is envisaged to be integrated in the recently established ESA Service for the estimation and prediction of Earth Rotation Parameters (ERPs). By so doing, the Service will rely exclusively on ESA geodetic solutions ensuring the highest possible consistency in the combination.
The operational setup for the VLBI analysis is currently being finalised and the first contributions to the IVS are foreseen for the next months. On a longer term, NAPEOS will be further developed to also support the analysis of VGOS sessions.
This presentation will explain ESA's VLBI processing setup and report on its status. The up-to-date analysis results will be presented. In order to give a flavour of the achievable accuracy, these will be compared to the results generated by other ACs, and to the combined IVS solution.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Automatic processing INT sessions with nuSolve software.

S. Bolotin, K. Baver, M. Berube, J. Gipson

Abstract VLBI INT sessions are conducted to determine the change in Earth rotations, which is measured as a correction to Universal Time, or dUT1. This correction varies stochastically with time. Since dUT1 is used in precise navigation, particularly GNS, rapid turnaround is very important. The decrease of time elapsed from observations to obtained results can be shortened with the automatic data processing of a new INT session at the analysis stage. To develop an application for this analysis we used a script mode of the VLBI data processing software nuSolve. In this script mode, nuSolve reads commands from a script file and executes them. The script engine is implemented by Qt library and supports the ECMAScript (standardized Java script) programming language. A user in the script mode has access to the same functionality of nuSolve as it is implemented in GUI mode. In this poster/presentation we discuss the application of the script for the automatic processing of INT sessions. We conducted the comparison of results from the script execution and manual data analysis for all INT S/X and VGOS sessions performed during the last five years. For 62% of the sessions the automatic script gives a solution that is identical to the one obtained by an operator. For 83% of the sessions, the difference of the dUT1 estimation between two types of solutions is less than 5 microsec. We overview the anomalies of INT sessions that cause the significant difference between automatic and operator solutions.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Estimating dUT1 from a southern hemisphere intensive baseline configuration

S. Böhm, J. Gruber, L. Kern, J. McCallum, L. McCallum, T. McCarthy, J. Quick, M. Schartner

Abstract The parameter dUT1 (UT1-UTC, difference of universal time to atomic time) is essential for the transformation between celestial and terrestrial reference systems, inherent in precise navigation and positioning applications. Geodetic Very Long Baseline Interferometry (VLBI) is the only technique to directly observe dUT1. Real-time or near-real-time navigation tasks are dependent on rapid access to Earth orientation estimates or predictions. On a rapid turnaround basis, dUT1 is provided via so-called intensive sessions, which are routinely observed daily for one hour on one or sometimes more baselines. All currently operational intensive sessions are observed using northern hemisphere stations only.
In a joint initiative of TU Wien, the University of Tasmania, the Hartebeesthoek Radio Astronomy Observatory, and later on also ETH Zurich, we set up the southern hemisphere intensive observing program (SI). The SI sessions are observed with three VLBI telescopes, all located south of the equator: HART15M (South Africa), HOBART12 (Tasmania), and YARRA12M (Western Australia). Observations including HOBART12 are observed in mixed-mode configuration, using the VGOS receiver in Hobart and the legacy systems at the two other stations. By January 2022, we have successfully observed, correlated, and analyzed more than 50 SI sessions from the years 2020 and 2021. The resulting dUT1 values from the southern intensives are compared with dUT1 from the EOP 14 C04 series and with the results of other "northern intensives". The residuals with respect to C04 of the SI are on the same level as those of the INT1 and INT3 sessions and also match the level of agreement between all the various southern and northern intensives series.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Quality assessment of UT1-UTC Estimates using VGOS

D. Mondal, P. Elosegui, C. Ruszczyk, A. Niell, J. Gipson

Abstract The next-generation VLBI system (VGOS) is currently operating a network of 9 stations to observe 24-hr sessions in every two weeks and a single baseline between Kokee Park Geophysical Observatory, Hawaii, and Wettzell Observatory, Germany, to observe 1-hr sessions (otherwise known as an intensive sessions) five days a week. The legacy S/X systems are used in a network of 15+ stations to observe 24-hr sessions twice a week, and a single baseline between Kokee Park Geophysical Observatory, Hawaii, and Wettzell Observatory, Germany, is used every day to observe a 1-hour intensive session with results expected the same day. While the goal of the 1-hr intensive sessions is to obtain UT1-UTC in a timely manner, the 24- sessions allow broader scientific analysis but require a longer time to be correlated. High precision UT1-UTC is critical for many applications, such as satellite orbit determination, spacecraft navigation, astronomical observations, and various other geophysical studies. In this presentation, we will examine UT1-UTC estimates from VGOS and compare to simultaneous S/X results for both 24-hr and 1-hr sessions using VieVS (Vienna VLBI and Satellite Software) analysis package.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Evaluation of the KOKEE12M-WETTZ13S VGOS Intensives with Calc/Solve

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Abstract The K2-WS intensives were first scheduled on an experimental basis roughly every other week in early 2020. In late 2020 these sessions began observing on a regular basis which continues. By the end of 2021 there were 126 K2-WS VGOS intensives. We use the calc /solve to analyze these sessions. We compare the UT1 estimates from the VGOS intensives with several other UT1 series: 1.) The simultaneous INT01 S/X intensives. 2.) The simultaneous R1 and R4 series; 3.) External EOP series. With respect to the either the R1and R4 series or external EOP series the scatter of both the VGOS and INT01 series is about the same. Stated another way, the VGOS intensives perform as well as the S/X intensives, but not significantly better. If we take the average of the UT1 estimates from the VGOS and S/X intensives the scatter is reduced, indicating that the two intensive series provide some independent information. Lastly, comparing the scatter between the different series with the formal errors of the UT1 estimates indicates that there is significant unmodeled error.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Comparison of simultaneous VGOS and legacy VLBI sessions

M. Glomsda, M. Seitz, D. Angermann

Abstract The VLBI Global Observing System (VGOS) represents the next-generation VLBI system, which consists of a growing network of small and fast-slewing radio antennas performing broadband observations. It has been developed to increase the accuracy and precision of VLBI measurements and the geodetic parameters that can be obtained from analysing the latter. Ultimately, VGOS is expected to approach the goals of the Global Geodetic Observing System (GGOS), which are an accuracy of 1 mm for a terrestrial reference frame (TRF) and 1 mm/decade for its long-term stability. Next to the enlarged bandwidth, these goals shall be achieved by the greater number of observations per unit time with VGOS, and the resulting improved resolution for the tropospheric modelling. After first experimental VGOS observations in 2014 and initial global measurement efforts during the Continuous VLBI Campaign in 2017 (CONT17), an operational series of bi-weekly VGOS sessions (denoted by 'VG') has become available in the meantime. Starting in early 2019, this series now has a length of about three years, and the current number of sessions is about twice as large as the number of sessions used for the ITRS 2020 realization. Furthermore, the 'VG' sessions have been scheduled to accompany the legacy VLBI rapid turnaround sessions. Hence, these data provide the opportunity to oppose the results of the new VGOS broadband to the legacy S/X-band observations, even though the VGOS antenna networks are rather small and still suffer from an unsatisfactory global distribution (they are all located in the Northern hemisphere). In this presentation, we will compare the parameters (i.e., station coordinates, Earth Orientation Parameters, and radio source positions) that we computed with our DGFI Orbit and Geodetic parameter estimation Software (DOGS) for all available 'VG' sessions between 2019 and 2021 to their respective counterparts in the rapid turnaround sessions. In particular, we will investigate the implied local ties between co-located VGOS and legacy antennas, as well as potential systematic offsets in radio source positions observed at the different frequencies. This might provide valuable information on how to combine the new VGOS with the legacy S/X network.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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The current and future performance of VGOS

T. Nilsson, R. Haas, E. Varenius

Abstract Since 2019, bi-weekly observing sessions hve been performed using the new network of VGOS stations. Currently, this network consists of nine stations and several other stations are likely to join in the near future. In this work, we investigate the accuracy of the results obtained from these sessions, with special emphasis on the station coordinates and the Earth Orientation Parameters (EOP). We compare the results to those obtained from simultaneous legacy S/X sessions, as well as to the results from GNSS. We also perform several simulations. Firstly, we make simulations for the current VGOS observing schedules in order to determine what precision we could be expect from these. Secondly, we make simulations of possible future VGOS sessions containing more stations and/or shorter scans. The results obtained in this work will thus give information on whether or not we are currently getting the results we could expect from VGOS, as well as what we could expect in the future.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Mitigating the effect of extended source structure in geodetic VLBI by re-weighting observations using closure delays and baseline-to-jet orientation

N. Kareinen, N. Zubko, T. Savolainen, M.H. Xu, M. Poutanen

Abstract The VLBI Global Observing System (VGOS) has been expanded by multiple radio telescopes globally in recent years and is being used in conjunction with the legacy network. Radio source structure has been identified as a major error in VGOS observations. In contrast to the ideal point-like and strong radio source most geodetic sources exhibit finite structure. We focus on sources having an elongated structure due to the alignment of their relativistic jets with respect to the observing baseline. If not accounted for these effects propagate to the observations and derived geodetic parameters. To mitigate this, we model the source structure in terms of closure delays and jet orientation relative to the observing baseline. Based on this model we have developed a simple-to-implement weighting scheme to re-weight the observations. We focus on CONT17 legacy sessions. The used closure delays are derived from the same data set. The effects of re-weighting are evaluated with respect to the session fit statistics and estimated geodetic parameters as well as comparing to some VGOS sessions.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Investigating the effects of source structure in VGOS observations based on closure images

Ming H. Xu, Tuomas Savolainen, Niko Kareinen, Nataliya Zubko, Susanne Lunz, Robert Heinkelmann, and Harald Schuh

Abstract Source structure has recently been demonstrated to be the major systematic error source in VGOS observations, which have a thermal noise level of a few picoseconds. Thus the full potential of VGOS can never be achieved without understanding and modeling the distortions caused by the frequency-dependent source structure. We have derived high-quality images from VGOS observations on a regular fashion through a technique of closure imaging that does not require antenna calibration information. To derive corrections for these effects, it is now very essential to align the four band images of a given source exactly as the real relation between the four band radio emission of the source. We have made an effort to align the images and performed tests of geodetic solutions with the corrections for source structure applied. We will report in this talk the results from our work on the source structure as well as the planned research on this topic for the near future.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral presentation

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Exploring Source Structure with the Bordeaux VLBI Image Database

A. Collioud, P. Charlot, S. Lambert

Abstract The Bordeaux VLBI Image Database (BVID) has made VLBI images of radio reference frame sources available to the international VLBI community since 2008. The database currently contains almost 7500 such images and associated data (especially those that qualify the source structure, i.e., compactness and structure index information) which are of interest for astrometric and astrophysical applications. Those images cover a period over 20 years (since 2000) and are for about 1500 different sources. In this presentation, we will focus on a new method to automatically determine the jet direction from the VLBI maps. We will then discuss the results derived when applying this method to the BVID images and the potential applications of such data. One of those is the study of the relation between the jet directions and the directions of the offset vectors revealed by comparing the Gaia EDR3 and the ICRF3 positions.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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First results of Earth rotation parameter estimation with piece-wise linear offsets

A. Nothnagel, S. Böhm, R. Dach, A. Girdiuk, M. Glomsda, H. Hellmers, A-S. Kirkvik, T. Nilsson, D. Thaller

Abstract With large-network IVS R1 and R4 sessions in place and high observation density VGOS sessions on the horizon, the analysis of VLBI sessions should be prepared for a higher time resolution of the Earth rotation parameters (ERP). As a first step, we tested continuous piece-wise linear offset parameterization (PWLO) at 6-hourly intervals, i.e., at 18, 0, 6, 12, 18h UT epochs for polar motion and UT1-UTC. Five VLBI analysis software packages (ASCoT, Calc/Solve, DOGS-RI, Where, VieVS) were employed for Level 2 data analysis of all IVS R1 sessions of 2020 and a combination was carried out by the IVS Combination Center at BKG.

Although there are known deficits in the geophysical interpretability of such results, the application of PWLO parameterization bears the advantage that it is easy to implement and that the results can be combined straightforwardly. One of the reasons for the latter is that the definition of the a priori values of the parameters are free of ambiguous setups which is the case in current procedures for the rate parameters reaching across day boundaries. Another advantage is that the 6-hourly parameterization can easily be used for constructing session-wise results at 0h UT which prevents from the necessity of interpolations for comparisons or combinations with other space-geodetic techniques, especially with GNSS.

When ERP are estimated with a higher time resolution beyond offsets and rates, correlations between the polar motion and celestial pole offset (CPO) parameters (nutation offsets) increase to an unacceptable level. For this reason, we fix the CPOs to the standard IAU2000A/2006 model plus a model of free core nutation (FCN) with a period of 430 days.

In this presentation, we will discuss the pros and cons of our approach as well as first results and insights. The assessment of the results will be carried out internally, i.e., between individual VLBI analysis centers and with the combination product, as well as externally with a special GNSS solution of the CODE Analysis Center computed with an equivalent solution setup and the same time resolution.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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VieSched++: Recent developments and lessons learned from two years of fully automated scheduling

M. Schartner, C. Plötz, H. Wolf, B. Soja

Abstract Currently, the VLBI scheduling and simulation software VieSched++ is used for the IVS observing programs AUA, AUM, CRD, CRF, INT2, INT3, OHG, T2, T2P, VGOS-R&D, and VGOS-S, as well as for some VGOS-O and mixed-mode R&D sessions. Besides, VieSched++ is used for various non-IVS observing programs such as the southern hemisphere Intensives, as well as Intensives between Wettzell, La Plata, and O'Higgins. Most of these programs are scheduled fully automatically at the IVS Operation Center DACH.
Within this contribution, we will give a high-level overview of the most recent developments and achievements. This includes improvements in satellite scheduling, the performance of selected observing programs and changes in our algorithms and reports. Furthermore, some future plans and projects will be highlighted.
We will also report on lessons learned while running the automated scheduling software, in particular regarding quality control and robustness.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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Investigating the Impact of GNSS-VLBI Tropospheric Ties in VLBI Intensive Sessions

Jungang Wang, Maorong Ge, Susanne Glaser, Kyriakos Balidakis, Robert Heinkelmann, Harald Schuh

Abstract Very Long Baseline Interferometry (VLBI) is the only space geodetic technique that provides the full set of Earth Orientation Parameters (EOP), including the difference between Universal Time (UT1) and Coordinated Universal Time (UTC), that is, UT1-UTC, which is essential for satellite navigation and space exploration. For the rapid determination of UT1-UTC, the VLBI intensive sessions (INT) are performed daily, typically with two to three VLBI radio telescopes observing for one hour. With such a limited observation geometry, a special processing strategy has to be adopted, such as ignoring the tropospheric gradient estimation, which results in limited UT1-UTC accuracy. We investigate the impact of applying tropospheric ties between co-located VLBI and GNSS stations in the intensive sessions, including the legacy S/X band INT1, INT2, and INT3 from 2001 to 2021, the Russian INT sessions (RuR), and the new VGOS sessions. The GNSS and VLBI observations are simultaneously processed on the observation level using the Positioning And Navigation Data Analyst (PANDA) software. Compared to the IERS EOP 14 C04 product, applying tropospheric ties reduces the UT1-UTC systematic error in INT1 (between Kokee and Wettzell) and INT2 (between Tsukuba and Wettzell) sessions, but not the new INT2 (between Ishioka and Wettzell) sessions. The UT1-UTC estimates in INT3 sessions (between Ny-Ålesund, Tsukuba, and Wettzell) are also significantly improved. Moreover, applying tropospheric ties improves the UT1-UTC estimates in the VGOS-B (between Ishioka and Onsala) and VGOS-2 (between Kokee and Wettzell) sessions. As for the RuR sessions (between Badary and Zelenchukskaya), the UT1-UTC estimates slightly deteriorate when applying tropospheric ties.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Oral

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The First Year of KOKEE12M-WETTZ13S VGOS Intensive Scheduling: Status and Efforts Towards Improvement

K. Baver, J. Gipson, F. Lemoine

Abstract The KOKEE12M-WETTZ13S (K2-Ws) VGOS Intensive series began on January 4, 2021. Evaluation of the first year of schedules has shown that the series is performing reasonably well, but the schedules could be improved. For example, the number of scheduled observations in a typical K2-Ws session is approximately half that of the first few MACGO12M-WETTZ13S Intensive sessions, and scheduling fewer observations negatively impacts UT1 results. Also, preliminary analysis of the K2-Ws observations' scheduled and achieved SNRs and their ratios shows examples where the achieved SNRs are either too high, indicating long observations that could have been replaced by a greater number of shorter observations, or too low, indicating a lack of robustness that could lead to observation loss. In this poster we describe key aspects of how the K2-Ws Intensives have been scheduled during 2021. Then we discuss the areas of concern and the status of efforts to make improvements in these areas.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P01]

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Digital Object Identifiers for the IVS

G. Coetzer, Y. Takagi, K. Elger

Abstract One of the goals of the International VLBI Services for geodesy and astrometry (IVS) is to provide data and products to support geodetic, geophysical and astrometric research and operational activities. The IVS is committed to supporting scientific discovery through good data management. To enhance data visibility and sharing, IVS data and products need to adhere to the FAIR (Findable, Accessible, Interoperable and Reusable) data principles. In support of FAIR data, the IVS board agreed on the use of persistent identifiers, i.e. Digital Object Identifiers (DOIs), for permanently identifying its data and products. In this presentation we will provide feedback of an exploratory study that is being conducted to establish best practices for attributing DOIs to IVS data and products. We also wish to create awareness of the Global Geodetic Observing System (GGOS) Working Group on DOIs.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P02]

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Determining favourable locations for new VGOS establishment in India

Sujata Dhar, Susanne Glaser, Robert Heinkelmann, Harald Schuh, Nagarajan Balasubramanian, Onkar Dikshit

Abstract To achieve the ambitious goals of Global Geodetic Observing System (GGOS), new VLBI Global Observing Systems (VGOS) stations are coming up all around the world. India is one of the countries in this direction of establishing a new facility. Very Long Baseline Interferometry (VLBI) simulation studies are a valuable tool to obtain the performance of the new establishment in the study network by assessing the improvement of geodetic parameters like Earth Orientation Parameters (EOP), station positions and velocities that contribute to the International Terrestrial Reference Frame (ITRF). In this study, similar simulations are conducted for determining favourable locations for new VGOS stations in India. Therefore, forty-two study locations around India are selected and these possible VLBI locations are scheduled, simulated and analysed in present and future IVS sessions to extensively study its impact on the global network. Contrary to the customary simulation studies considering only the improvement of geodetic parameters, this study aims at being as realistic as possible by incorporating the impact of environmental variables like extreme weather, RFI, tectonic stability, etc. of the study locations. In reality, the station's operation ability and the location's vulnerability have a substantial impact on the actual observations from any VLBI station. Therefore, the environmental variables are also integrated by a weighted scoring method to bring out a realistic simulation study for determining favourable locations and avoiding right VLBI station ending up at a wrong location. This study showed that the southern plateau and western regions of India are optimal locations for VGOS establishments. Keywords: VGOS, India, favourable locations, scheduling, simulations, environmental variables

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P03]

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A comparison of VieSched++ simulations with observed VLBI sessions

S. Hardin

Abstract Simulation can be a powerful tool for improving VLBI scheduling techniques. The scheduling software VieSched++ uses simulations to predict the formal errors for Earth orientation parameters (EOPs) in a variety of generated schedules as a means of selecting the best one. However, using these predictions is only effective if the simulation results reflect actual observations. To determine how closely the simulations match real VLBI observations, VieSched++ is used to simulate existing VLBI schedules and predict Earth Orientation Parameter formal errors. These predicted formal errors are then compared to the observed formal errors produced by analysis centers. This is performed for both 1-hour and 24-hour geodetic VLBI sessions.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P04]

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Assessing source-centric scheduling for VGOS

M. Schartner, M.H. Xu, P. Charlot, A. Collioud, B. Soja

Abstract The VLBI Global Observing System (VGOS) was designed to obtain highest quality geodetic parameters. Over the last years, it became evident that source structure effects have a significant contribution to the VGOS error budget. Therefore, it is assumed that imaging will increase in importance for obtaining highest quality geodetic results. Moreover, taking the imaging capability into account starting from scheduling, observations will significantly increase this capability for VGOS, leading to the potential contribution to radio astronomy in the VGOS era.
Currently, a geodetic and thus station-centric approach is used for scheduling VGOS sessions, designed to provide good sky-coverage at the stations. However, this scheduling strategy generates a strong imbalance among different sources w.r.t. the number of scans per source. Some sources can be observed in over fifty scans with over one thousand observations in a single 24-hour session, while a significant amount of sources may be observed only in a few scans with less than ten observations. Consequently, the scheduling is not optimized for providing a good uv-coverage at many sources, leading to poor imaging capabilities of geodetic observations.
In this contribution, we will present a source-centric scheduling approach designed for VGOS observations. It combines a geodetic scheduling optimization with a balanced distribution of scans over GMST per source. This leads to a good uv-coverage per source and provides the possibility to properly image almost twice the number of sources compared to the current station-centric scheduling approach. Based on large-scale Monte-Carlo simulations, it is proven that the proposed scheduling strategy does not compromise the geodetic session performance at all. Actually, it is demonstrated that the geodetic and astrometric performance can be increased in many cases with a more balanced scan distribution.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P05]

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The IAA VLBI Analysis Center

E. Skurikhina, S. Kurdubov, S. Mironova, A. Kudelkin M. Gribanova

Abstract The IAA IVS Analysis Center (IAA AC) operates in the Institute of Applied Astronomy of the Russian Academy of Sciences, St. Petersburg, Russia. The IAA AC contributes to all kind of IVS products: CRF-, TRF- and daily solutions. We use as Legasy as VGOS observations for the data treatment. For the new stations and for the VGOS stations the velosities and the station positions were preliminary evaluated from the time series analysis. Also new approaches for the VLBI planning are developing. Besides IVS VLBI data, IAA AC processes domestic observations produced by both the RT32 radio telescopes (Svetloe, Zelenchukskaya, Badary) and the new VGOS 13,2 m diameter radio telescopes located in Svetloe, Zelenchukskaya and Badary observatories.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P06]

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The application of the rapid data observations of The Quasar VLBI Network in order to improve the accuracy of the prediction Universal time.

M. Gribanova, E. Skurikhina

Abstract Local Approximation Technique shows good results for short-term for Universal time predictions, which is important for practical purposes. The work attempts to evaluate the improvement of predictions accuracy using the rapid data observations of The Quasar VLBI Networks. Observations for the UT1 determination are conducted according to 2 programs: R-I, hourly, one time per day on 32m antennas and rapid on the VGOS 13m antenna several times a day, duration 1 or 2 hours.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Poster [S3-P07]

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Global solution of VLBI intensive and 24h Sessions for EOP determination

S. Belda, J.M. Ferrándiz, M. Karbon, S. Modiri, S. Raut, R. Heinkelmann, H. Schuh

Abstract Nowadays, the analysis of individual sessions of Very Long Baseline Interferometry (VLBI) serves to the determination of the Earth Orientation Parameters (EOP) and other geodetic and geophysical parameters with a high level of accuracy. Nevertheless, the attainment of the stringent accuracy and stability goals pursued by the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) are set at the millimeter level. This corresponds to about 30 microarcseconds and 3 microarcseconds/year in terms of rotations and requires further advances in the technique performance. At present, the routine contribution of VLBI to the Earth rotation observation follows a discrete schedule. The daily VLBI Intensive sessions (1- or 2-hour duration) substantially contribute to monitoring the Earth Rotation variations, designed to determine Universal Time (UT1) with minimum latency. Besides, the International VLBI Service for Geodesy and Astrometry (IVS) is conducting 24h-VLBI measurements on average twice a week, which are two to three times more accurate than the Intensive sessions and allow for the determination of all five EOP.
In this study, we address the issue of estimating a 'global' VLBI solution by means of the joint analysis of the Intensive and 24-h VLBI sessions from 2002.0 up to 2014.0. Preliminary experiments show that the inclusion of 1h-long VLBI sessions in the adjustment is feasible and improves the EOP accuracy, simultaneously providing a significant advance in the temporal resolution. Furthermore, the accuracy gain is favored by the development of empirical models for seasonal station displacements with higher time resolution than the currently available models. A final objective is the estimation of the amplitudes of the principal terms of nutation, trying to empirically improve the conventional values derived from the precession/nutation theories adopted by the International Astronomical Union (IAU) and the IAG and provided by the International Earth Rotation and Reference System Service (IERS).

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Recorded presentation [S3-M08]

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The impact of erroneous a priori information on the estimation of UT1-UTC in VLBI Intensive sessions

L. Kern, M. Schartner, J. Böhm, S. Böhm, A. Nothnagel, B. Soja

Abstract With the help of VLBI 24-hour sessions it is possible to determine a large number of parameters, including station and source coordinates, the Earth orientation parameters and parameters modelling the atmospheric delays. Due to the limitation of observations of 1-hour single baseline sessions (*Intensives*) only a few parameters, such as clock offsets, zenith wet delays can be estimated in addition to the parameter of main interest which is the UT1-UTC parameter. Since the accuracy of any a priori information is crucial for the accuracy of UT1-UTC, great care has to be taken concerning their choice. For example, errors in the remaining Earth orientation parameters, namely polar motion and nutation, have an impact on the estimation of UT1-UTC. Furthermore, missing or incorrect modelling of the atmosphere loading effect or tropospheric gradients can compromise the station coordinates and further the measurement of UT1-UTC.
In this study, we performed Monte-Carlo simulations for a global 10x10 degree grid consisting of artificial VGOS telescopes, where errors in the a priori polar motion dx_p, dy_p and nutation dX, dY as well as in the station coordinates in either North-South, East-West or Up-Down are introduced. Through this systematic approach, we were able to investigate the impact of erroneous a priori information on the UT1-UTC estimation. In general, we examine that erroneous station coordinates have a variable effect depending on the direction of the error as well as baseline length and orientation. For example, concerning an error in the station height fewer baselines are impacted, making it less crucial compared to the effect of the same error in North-South or East-West direction. In previous studies, theoretical results concerning an error in the a priori polar motion have been obtained by the analysis of the corresponding partial derivatives suggesting perfectly East-West oriented baselines to be less impacted. In this study, we show that it is not as simple as that and therefore, more sophisticated analyses are necessary to investigate the impact of erroneous a priori information on the UT1-UTC measurement.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Recorded presentation [S3-M09]

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Analysis of VGOS sessions: Evaluation of performance with different software.

E. Azcue, V. Puente, M. Moreira, E.Martínez

Abstract VGOS (VLBI Global Observation System) is a new generation VLBI system. It has been developed since 2005 and it is based on the so-called broadband delay that uses four or more frequency bands. High data rate observations are taken by fast-slewing antennas, smaller than those used in the current legacy S/X infrastructure. These improvements in instrumentation are aimed at obtaining geodetic products more accurate.
In order to test the analysis of these new data, the historical VGOS sessions have been analyzed with different software. Difficulties in the current processing and similarities with the S/X generation processing are studied. Results in terms of the accuracy in EOP (Earth Orientation Parameters) estimation and coordinates repeatability are also discussed in this contribution.

Session-3: Data Structures, Scheduling and Analysis Strategies

Presentation type: Recorded presentation [S3-M10]

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

ITRF2020 and the IVS contribution

Z. Altamimi, P. Rebischung, X. Collilieux, L. Mvier, K. Chanard

Abstract The ITRF2020 will be provided in the form of an augmented reference frame so that in addition to station positions and velocities, parametric functions for both Post-Seismic Deformation (PSD) for stations subject to major earthquakes and periodic signals (expressed in the Center of Mass frame of Satellite Laser Ranging) will also be delivered to the users. The presentation will summarize the main results of ITRF2020 analysis, with a special focus on the IVS/VLBI contribution. In particular, the paper will discuss the level of the scale agreement of the four techniques, as well as their variations and behavior over time. We will also discuss the level of technique consistencies of nonlinear station motions at co-location sites, as well as some key performance indicators of the ITRF2020.

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

Presentation type: Invited

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Scale evaluation of the ITRF2020 Pre-solution

H. Hellmers, S. Modiri, S. Bachmann, D. Thaller, M. Bloeld, M. Seitz, J. Gipson

Abstract As the next official solution of the International Terrestrial Reference Frame, the ITRF2020 represents the successor of the currently used frame ITRF2014. This global solution is based on an inter-technique combination of all four space geodetic techniques VLBI, GNSS, SLR and DORIS, and benefits from a variety of contributions from different international institutions. In this context, the Combination Centre of the International VLBI Service for Geodesy and Astrometry (IVS) operated by the Federal Agency for Cartography and Geodesy (BKG, Germany) in close cooperation with the Deutsches Geodsches Forschungsinstitut (DGFI-TUM, Germany) generates the final VLBI contribution to ITRF2020. Thereafter, an intra-technique combination is applied using the individual contributions of multiple Analysis Centres (AC) with different software packages.
For the contribution to the ITRF2020, sessions containing 24h VLBI observations from 1979 until the end of 2020 were processed by 11 ACs and submitted to the IVS Combination Centre as session-wise SINEX files. These contained the datum-free normal equations with station coordinates, source positions and full sets of Earth Orientation Parameters (EOP). To ensure consistency, normal equation transformations to equal epochs and a priori values were carried out for every ACs normal equation system before stacking them in order to get the IVS combined solution. The resulting individual solutions, as well as the combination, are subject to further analysis concerning EOP and station coordinates as well as the scale and a VLBI-only Terrestrial Reference Frame (VTRF).
This presentation focuses on detailed investigations concerning the scale of the IVS contribution and the global solution. We compare the IVS contribution with ITRF2014 and ITRF2020. In addition, detailed statements on the accuracy of ERP estimates and station coordinates are carried out. In this context, the individual solutions of the different analysis centres are compared and investigated concerning potential AC- and/or software-dependencies.

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

Presentation type: Oral

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Changing from ITRF2014 to ITRF2020 in the routine VLBI analysis: First investigations

A. Girdiuk, G. Engelhardt, D. Thaller, D. Ullrich

Abstract The IVS Analysis Center at BKG took part in the activity to build the next generation ITRF, i.e., ITRF2020. Here we present the first results of using the preliminary release named ITRF2020P. The a priori station coordinates and velocities are updated as well as the PSD model coming along with ITRF2020P. The station positions show a considerable improvement compared to ITRF2014. These improvements are mostly recognized for the new VGOS stations, which are particular valuable for the different types of the VGOS sessions (IVS VGOS, mixed mode sessions and local ONTIE programms) observed in the last few years. The backward compatibility is also demonstrated for the entire VLBI data set.The advance of the PSD model is validated at the corresponding stations as well as in the intensive sessions, in which the previous ITRF2014 PSD model has shown the substantial fit. The rest of the reductions is applied along with to the current bkg2020a solution. While at first we focus our study on the verification of the VGOS station positions, we also look into the other geodetic parameter estimates, i.e. tropospheric estimates, source coordinates and EOP time series based on the new ITRF.

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

Presentation type: Oral

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Assessment of parameters describing the signal delay in the neutral atmosphere derived from VGOS observations

R. Haas, J. Johansson, G. Elgered, P.-K. Diamantidis, T. Nilsson

Abstract VGOS was designed with the goal to improve the accuracy and precision of the geodetic parameters by one order of magnitude compared with the so-called legacy S/X VLBI system. One aspect in this context is the ability to resolve small-scale and rapid variations in the signal propagation delay caused by the neutral atmosphere, which had been identified as one limiting factor of geodetic VLBI. VGOS addresses this topic by performing many observations per time unit that cover the local sky at the stations as uniformly as possible. Currently, at least a factor of two in the number of observations per station is achieved within the operational VGOS compared to legacy S/X, and future VGOS sessions will have an even larger number of observations. We assess the current ability of VGOS to sense small-scale, rapid variations in the signal propagation delay caused by the neutral atmosphere by comparing the VGOS-derived results to corresponding results from simultaneous observation with co-located instrumentation.

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

Presentation type: Oral

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A multi-GNSS integrated approach to observing UT1 with VGOS and Legacy S/X VLBI.

P.K. Diamantidis, R. Haas, E. Varenius, T.Nilsson

Abstract Routine UT1-UTC determination using intensive sessions allows for monitoring of the Earth rotation in a rapid and precise manner. The advent of the VLBI Global Observing System (VGOS) and multi-GNSS expands on these capabilities with the promise of more precise observations, and with increased temporal density and sky coverage, that are able to convey consistent tropospheric parameters and higher sensitivity to UT1-UTC estimation. We present a novel approach to rapid UT1-UTC determination using VLBI and multi-GNSS by means of combination on the observation level. We test this approach by analyzing routine legacy S/X intensive sessions (INT1) and the so-called VGOS-B sessions. These are 1 h long observing sessions between the VGOS stations at Ishioka in Japan and the Onsala twin telescopes in Sweden, which were performed simultaneously to INT1. We investigate the level of agreement of the UT1-UTC estimates between the two types of sessions in single-technique, inter- and intra-technique solutions. We present the effect of the inclusion of multi-GNSS with regards to the ability of estimating asymmetricities in the troposphere. We finally compare the results to the current state-of-the-art approach of UT1-UTC determination from intensive sessions.

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

Presentation type: Oral

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A New Wiggle in the Wobble: Uncovering Periodic Signals in Intensive Series Residuals

C. Dieck, M. Johnson

Abstract Comparing the values of UT1−UTC from an Intensive series to a reference series is a valuable method of assessing the quality of the Intensive series. Ideally, the differences in the series have a mean of zero, with some random noise. Applying a non-parametric Nadaraya-Watson kernel regression to the residuals of the MK-VLBA:PIETOWN VLBA Intensive series with respect to multiple reference series revealed that there is a statistically significant periodic deviation from the ideal. The same analysis applied to the KOKEE:WETTZELL IVS Intensive series suggests that the same signal may be present, just with a small amplitude. Analysis of the sensitivity of UT1−UTC to shifts in station position for both baselines explains the difference in amplitude; the value of UT1−UTC determined at KOKEE:WETTZELL is ∼4 times less sensitive to station position shifts than that measured with MK-VLBA:PIETOWN. In addition to detailing these analyses, we discuss the potential reasons for the periodic signal in the residuals and the plan for further investigation.

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

Presentation type: Oral

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Current CRF Status at X/S and K Bands

D. Gordon, A. de Witt, C. Jacobs

Abstract The third realization of the International Celestial Reference Frame, ICRF3, was finalized in June 2018 using VLBI sessions through March 2018. It was accepted by the IAU in August 2018 and became official on Jan. 1, 2019. ICRF3 contains 4536 sources in its X/S catalog and 824 sources in its K band catalog. However, since the finalization of ICRF3, dedicated astrometric campaigns to maintain, improve and expand the CRF at X/S and K bands have continued and now nearly four additional years of observations are available. In the northern hemisphere, these campaigns have used the VLBA at both X/S and K bands under the USNO's VLBA time share allocation. And in the southern hemisphere, the HARTRAO-HOBART26 network has been used at K band. These sessions have added $\sim$20% more sources to the X/S catalog and $\sim$25% more sources to the K band catalog, along with significant reductions in the scaled formal errors. We will discuss the current state of the X/S and K band CRF catalogs, including the distribution of sources and observations, improvements in the scaled formal errors and issues with a few ICRF3 defining sources.

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

Presentation type: Oral

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Three years of ICRF3 source positions

P. Cigan, M. Johnson, D. Gordon

Abstract Precise astronomical reference frames are extremely important for a wide variety of applications, including astronomical observations and navigation, to name a few. ICRF3 is the third realization of the International Celestial Reference Frame, created from the combined international efforts of nearly 40 years of VLBI radio observations of thousands of quasars. In the time since the definition of ICRF3 in August 2018, many additional astrometric and geodetic observations have been carried out, allowing for a regular cadence of global solutions which estimate updated earth orientation parameters as well as celestial reference frame source positions. In this talk we will examine the shifts in the radio positions of ICRF3 sources over the past three years, derived from VLBI global solutions.

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

Presentation type: Oral

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The X/Ka 2022a Celestial Frame

C. Jacobs, S. Horiuchi, L.G. Snedeker, D. Firre, Y. Murata, H. Takeuchi, T. Uchimura, S. Asmar

Abstract The X/Ka-band (8.4/32 GHz) Celestial Reference Frame became one component of the ICRF-3 in 2018. In the four years since, the X/Ka data set has increased by about 60% as well as adding the much needed north-south geometry from Japan to Australia. The latest solutions show that formerly large spherical harmonics distortions are greatly reduced with the Z-dipole term reduced from 314 μas to statistical insignificance and with the quadrupole 2,0 magnetic term reduced to less than 40% of its former value. The median formal precisions of 48 μas in $\alpha\cos\delta$ and 70 μas in δ are comparable to recent S/X solutions for the 568 common sources. Noting that the X/Ka frame is derived from a limited geometry of only five observing sites, we discuss the importance of using full covariance information when evaluating this frame. Finally, we discuss the prospects for future improvements.

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

Presentation type: Oral

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Observing Gaia transfer sources in IVS S/X R&D sessions

K. Le Bail, P. Charlot, A. Collioud, C. Gattano, D. Gordon

Abstract The ESA mission Gaia is a space observatory successfully observing in the optical realm hundred of thousand of quasars since 2014. Following the acceptance of a proposal submitted by the LAB team, the IVS Observing Program Committee allocates, since 2013, IVS S/X Research & Development (R&D) sessions to an observing program designed as "Gaia link to ICRF". These R&D sessions are dedicated to the observation of so-called ICRF-Gaia transfer sources: these sources are observed by both the IVS in the S- and X-band frequencies and by Gaia. Most importantly, they are suitable for aligning the radio and optical frames. The first seven years of the observing program have been successful on many levels: we increased the observation frequency of 195 key ICRF-Gaia transfer sources selected by the LAB team, improved their uncertainties to the required uncertainty level, and deepened our knowledge on these sources. Beginning November 2020 and following the achievements of Gaia, we adopted a new strategy to automatically select the set of sources and we adapted the scheduling. We present here a brief summary of the eight years of the observing program, discuss the new strategies adopted in 2020, both for source selection and scheduling, as well as the next anticipated steps.

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

Presentation type: Oral

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Comparing Images of ICRF Sources at S, X, K and Q-band

A. deWitt, D. Gordon, L. Hunt, C. Jacobs, M. Johnson

Abstract We have undertaken an exploratory Q-band (43 GHz) imaging-astrometry project targeting the K-band ICRF sources in three sessions each of 24 hours using the Very Long Baseline Array. The project's goal is to compare images and astrometry from Q, K, X and S-band in order to study the optimal frequency band for CRF observations. The sources were observed as close as possible temporally and typically within the same week, in order to avoid problems with source variability. We will show how source structure compares between all four bands, and the interplay between source structure, resolution, and astrometry. We hope to use the results from our campaign to determine if pursuit of a Q-band CRF is worthwhile.

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

Presentation type: Oral

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Insights into AGN parsec-scale emission from radio to GeV gamma rays from VLBI, Gaia EDR3, and Fermi-LAT

A. Pierron, S. Lambert, H. Sol

Abstract With the advent of the European Gaia astrometry mission and the constantly improving geodetic VLBI program which now provide both optical and radio reference frames with precisions better than 0.1 mas, challenging questions arise about identifying which mechanisms are behind the optical emission. Is it from a jet feature ? also observable in radio ? or a mix between the jet, the accretion disk, an extended halo or host galaxy? We use data from Gaia EDR3, the radio ICRF3, structure information from the MOJAVE program, and GeV fluxes from Fermi-LAT 4FGL catalog for a sample of about 350 common active galactic nuclei (AGN), dominated by blazars (BL Lac and FSRQs). We show that a majority (about 90%) of optical emissions can be associated with a radio feature downstream in the jet, either close the base (usually referred to as the 'radio core') or, in contrast, in ejected radio knots at parsec-scale distances. We investigate the general trends of such populations in terms of classification, color indices, radio polarization, and GeV emission.

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

Presentation type: Oral

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The Onsala VLBI contribution to ITRF2020

T. Nilsson, R. Haas, E. Varenius

Abstract In 2021, the IVS Analysis Center at the Onsala Space Observatory (OSO) calculated and submitted a VLBI solution for the IVS contribution to ITRF2020. For this solution, we used the ASCOT software, originally developed at the Bonn University. The software was updated to be able to use all the latest models required for ITRF2020, e.g., gravitational deformations of radio telescopes and the new model high frequency Earth rotation variations. The solution includes most of the geodetic VLBI sessions performed in the period 1979-2020. In total we analysed 6593 sessions; 6555 legacy S/X sessions and 38 VGOS sessions. In this poster presentation, we describe various characteristics of the solution. We also compare the OSO solution results to the IVS combined solution as well as to ITRF2020P.

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

Presentation type: Poster [S4-P01]

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Vienna contribution to ITRF2020

H. Krásná, D. Mayer, S. Böhm

Abstract The next realisation of the International Terrestrial Reference System, the ITRF2020 is currently under evaluation. The special analysis center of the International Very Long Baseline Interferometry (VLBI) Service for Geodesy and Astrometry (IVS) at TU Wien (VIE) provided one set of the normal equation systems which was combined together with contributions from other VLBI analysis centers to the VLBI input to ITRF2020. We give a documentation of the included sessions and stations as well as of the parametrisation. In addition to that, our own terrestrial reference frame, VIETRF2020, which is based on the Vienna input to ITRF2020, is presented and compared to previous TRF solutions as well as to preliminary release of ITRF2020, designated as ITRF2020P. As indicated by presentations of the IERS ITRS Product Center, the scale of ITRF2020P was constructed by "using inner/internal constraints" and as "average of SLR (1997.7 -– 2021.0) and VLBI (selected sessions up to 2014.0)". This seems to lead to deviations of the scale of our VLBI solution and probably also of the IVS combined data after 2014.0.

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

Presentation type: Poster [S4-P02]

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The influence of high frequency EOP models on the processing of VLBI observations

S. Mironova, S. Kurdubov

Abstract Short-period EOP variations are estimated by models based on an analysis of the available EOP series. The differences between the high frequency EOP models are the number of harmonics and the analyzed EOP series. At the moment, the IERS (2014) model and Desai (2019) model are recommended for VLBI data processing. We made a review and comparison of the high frequency EOP models. We described which harmonics of the high frequency EOP models can be estimated from VLBI data processing, and we made the global solution using the QUASAR software to estimate this harmonics. We evaluate the contribution of harmonics, which can not be estimated from VLBI data processing. Also, we evaluate the impact of the VLBI data on the formal errors of the estimated amplitudes of the harmonics. Finally, the set of VLBI series were processed with the recommended models and the improved models.

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

Presentation type: Poster [S4-P03]

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SINEX files combination for the station coordinates estimation using the SINCOM software

S. Mironova, S. Kurdubov, I. Gayazov

Abstract We made the stations' coordinate series for 2021 in two ways: by the processing of the VLBI observations and by the combination of the VLBI, GNSS and LLS SINEX files. We use the QUASAR and the SINCOM software for the processing and the combining, respectively. The VLBI stations coordinate series estimated by the combination were compared with the series obtained from the VLBI processing. The VLBI stations coordinates obtained by combining and the VLBI stations coordinates obtained by processing the VLBI observations are consistent with the coordinates from the global solution. Stations' coordinates obtained by combining are consistent with the coordinates from the ITRF2014 catalog.

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

Presentation type: Poster [S4-P04]

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On the prospects of explaining and modeling with higher accuracy the precession-nutation from VLBI solutions

J.M. Ferrándiz, S. Belda, S. Modiri, A. Escapa, R. Heinkelmann, H. Schuh

Abstract At present VLBI is the only technique capable of providing enough accurate solutions for the precession-nutation angles, mostly expressed as celestial pole offsets (CPO), i.e., deviations of the observed celestial intermediate pole with respect to the conventional a priori model formed by the nutation IAU2000 and precession IAU2006 current theories. Most of the available CPO solutions provide the values of the CPO pair dX, dY, and their formal errors derived through a session-wise approach, with a time tag about the centre of each 1-day long observation session. The variance (or weighted root mean squared, WRMS) of CPO time series thus gives a measure of the accuracy of the standard models. As an example, the WRMS of dX and dY from the IVS ivs19q4X combined solution amounts about 174 μas along the interval 1990-2020.
A simple detrending, equivalent to applying a linear correction to the precession model, allows to reduce their respective WRMS to 159 and 153 μas. Just recalling that the values of all the coefficients of the 5-degree polynomials that express the precession of the equator in the IAU2006 models did not arise from analytical formulas, but from computations and fitting the model to different kinds of observations made in a long-time interval, it is clear that CPO variability may be easily reduced by agreeing a suitable update of a few coefficients of those models he two last were made in 2000 and 2006. Moreover, the unexplained variance may be further reduced by introducing a suitable set of corrections to the current IAU2000 nutation models. This model provides an a priori for the nutations forced by the attraction of celestial bodies, Moon and Sun in the main. A complete revision of the nutation theory seems to be not feasible at the short term, given its complexity and the need of making it consistent with all the conventional standards ithout forgetting reference frames. The possibilities explored so far include partial re-fitting of the IAU2000 theory, meant as updating the MHB2000 transfer function but not second-order or oceanic effects among others, derivation of empirical corrections to the amplitudes of selected sets of astronomic periods, and also combinations of theoretical and empirical corrections.
This presentation intends to exemplify to which extent the unexplained variance of CPO observed by VLBI can be reduced at short time by the option of using some corrections to the precession and forced nutations models. WRMS may be further reduced by using suitable free core nutation models, but that matter is not analysed here.

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

Presentation type: Recorded presentation [S4-M05]

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Imaging ICRF3 sources at K band with the European VLBI Network

P. Charlot, M. E. Gomez, R. M. Campbell, M. Kettenis, A. Keimpema

Abstract We explore the capabilities of the European VLBI Network (EVN) to image radio reference frame sources at K band. The EVN includes long East-West and North-South baselines (from Europe to Asia and from Europe to South Africa) along with baselines of shorter and intermediate lengths within Europe, making it worthwhile to study its potential for snapshot imaging. To this end, we use a 20-telescope experiment carried out as part of the JUMPING JIVE project in October 2020 whose primary goal was to measure the geodetic positions of non-geodetic EVN antennas (i.e. antennas not equipped with the proper dual-frequency S/X receivers traditionally used for geodesy). The network comprised 16 EVN telescopes along with three e-MERLIN out-telescopes (in the UK), and was augmented by the Hobart 26 m antenna (in Australia), who kindly agreed to join the experiment. Scheduling was accomplished using sub-netting (ensuring a minimum of four stations per sub-net) to optimize the sky coverage at each telescope, as in standard geodesy experiments. A total of 80 ICRF3 sources were observed in the course of this experiment. Because the main scope was geodesy, all of these were chosen in the pool of ICRF3 defining sources. The resulting images may be used to further assess their compactness – and hence their astrometric suitability – at a frequency and a resolution higher than probed by the standard S/X observations that formed the basis for selecting those sources as ICRF3 defining sources.

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

Presentation type: Poster [S4-P06]

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Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Observing GPS Satellite Signals in L-Band with a realistic global VLBI Network: A Simulation Study

D. Schunck, L. McCallum

Abstract As a combined product of four space geodetic techniques, the ITRF heavily relies on the ties between the various techniques. The tie vectors, however, usually determined via classical surveying at co-location sites, differ from space geodesy solutions by up to a few centimetres. Observing satellites with the very long baseline interferometry (VLBI) technique is a topic of increasing interest for the establishment of space ties. Observing satellites of the global navigation satellite systems (GNSS) or of satellites dedicated to realise a space tie would directly link the two techniques and could strengthen the connection in the combination to the ITRF. Since there are no dedicated satellites launched to this time, the possibility of observing existing satellites is of vibrant interest. The question remains whether the current GPS constellation itself could serve as the linking satellites. A simulation study was set up, in which we schedule and simulate observations from VLBI telescopes to GPS satellites. A realistic VLBI-network was created from 27 globally distributed stations that are capable of observing signals in L-band. The observation schedules are optimised under the aspects of sky coverage, number of observations and slew time. The simulated observations are affected by realistic tropospheric delays, clock inaccuracies and white noise. We assess the suitability of this experiment setup for establishing the link between the VLBI and GNSS frame in terms of station positions as well as frame transformation parameters.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Oral

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Sources with significant astrometric offsets between the S/X and K-band celestial frames

A. de Witt, C. Jacobs, D. Gordon, L. Hunt, M. Johnson

Abstract Comparing the latest astrometric celestial reference frame (CRF) solutions produced by the United States Naval Observatory (USNO) at S/X-band (2022 Jan 12) and K-band (2021 Dec 08) shows 996 sources in common, of which 39 are outliers with at least one coordinate where the difference between S/X and K-band is $> 5\sigma$. Of the 39 outliers, there are 3 sources where the difference in the coordinates in δ are > 5 mas. We investigate possible astrophysical reasons for the large differences seen between the S/X and K-band coordinates for the 39 outlier sources. These large differences may indicate significant structural differences between S/X and K-band. In order to study the astrophysical differences, we conducted multi-epoch, quasi-simultaneous S/X and K-band astrometric-imaging observations between Aug 2020 and Jun 2021, using the Very Long Baseline Array (VLBA). These images allow us to directly compare the source structure at S/X and K-band. In addition, we compare the direction of the extended emission obtained from our imaging campaign to the astrometric offset direction obtained from the $\alpha\cos(\delta)$ and δ components. In this presentation we show preliminary results from our investigations.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Oral

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VGOS vs Crab

S. Kurdubov, D. Marshalov

Abstract We investigate the possibility of observation of giant pulses (GR) of the Crab Nebula pulsar with our VGOS 13 m wide band radio telescopes in VLBI and single modes. A special observation session was planned and carried out on 5 radio telescopes of the ¡¡Quasar¿¿ VLBI network in the L, S and X frequency bands. Two 32-m antennas with L-band receivers in Svetloe and Badary are used to justify the detection of pulses on 13-m antennas. The coherent elimination of the influence of the interstellar medium was carried out with a refinement of the parameter of its dispersion. The search for giant pulses was performed in the mode of processing records from individual radio telescopes and the subsequent joint determination of the difference between the moments of arrival of pulses at radio telescopes by the cross-correlation method. It was shown that Crab GP can be successfully observed on 13-m antenna with wide band receivers. The number of detected GP per minute are comparable with much larger radio telescopes. The high data rate make it possible to investigate the fine pulse structure with nanosecond resolution.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Preferred presentation type: Oral

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Evaluate the ICRF stability via extragalactic source position time series

N. Liu, S. B. Lambert, E. F. Arias, J.-C. Liu, Z. Zhu

Abstract The apparent positions of extragalatic sources are known to vary with time due to their intrinsic evolution. This kind of astrometric instability will cause an orientation variation to the axes of the celestial reference frame that are defined by positions of extragalactic sources, a phenomenon known as the celestial frame instability. Recent studies based on the extragalactic source positions time series measured by very long baseline interferometry (VLBI) suggest that sources that are considered stable are likely to become unstable as long as they are observed for a longer time span. As a result, it is necessary to regularly monitor the astrometric behavior of extragalactic sources and the axes stability of the VLBI celestial frame. We present our study on assessing the axes stability of the third generation of the International Celestial Reference Frame (ICRF3) in terms of linear drift and scatter based on extragalactic source position time series from analyses of archival VLBI observations. Our results show that the axes of the ICRF3 are stable at a level of 10 to 20 microsecond of arc, and it does not degrade after the adoption of the ICRF3 when observations from new networks are included.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Oral presentation

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ICRF densification and link between VLBI and Gaia frames

Zinovy Malkin

Abstract Determining a highly accurate link between the radio (ICRF) and optical (*Gaia*) celestial reference frames is a key task of modern fundamental astronomy. One of the most important factors limiting the accuracy of this link is the impact of outliers. A new method has recently been proposed to mitigate this effect. It is based on median filtering of the position differences between two catalogs by the equal-area cells on the celestial sphere. The VSH decomposition is further applied to this data foro the final computation of the orientation parameters between frames. The number of cells used in this procedure is crucial for improving the quality of the results in terms of achievable VSH order and the uncertainty of the VSH coefficients. Therefore, it is important to develop quantitative criteria for assessing the ICRF sky density and identifying less populated sky regions where supplement ICRF sources are most desirable. This presentation is dedicated to discussing the problems outlined above.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Oral

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Comparison of the stability of atomic clocks used in VLBI observations

V. Puente

Abstract VLBI (Very Long Baseline Interferometry) technique needs precise timestamping of the observed delays, for which hydrogen maser clocks are used. Normally, these atomic clocks also provide external frequency to the GNSS (Global Navigation Satellite System) antennas co-located in the sites.
In a least squares adjustment of VLBI observations, the parameters accounting for the lack of the syncronization of the atomic clocks are estimated using a model whereas in the GNSS analysis it is possible to perform a snapshot estimation of the clock bias, thanks to the redundancy of observations from the same antenna to several satellites. Additionally, GNSS antennas operate continuously, bringing a valuable mean to monitor the stability of the atomic clocks.
The purpose of this contribution is to use GNSS products to compare the behaviour of some of the clocks currently used in VLBI observations.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Poster [S5-P01]

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Adjustment of Galileo satellite orbits with VLBI observations: a simulation study

H. Wolf, J. Böhm, A. Nothnagel, U. Hugentobler, M. Schartner

Abstract Installing a VLBI transmitter on one or more Galileo satellites will enable VLBI radio telescopes to observe Earth-orbiting satellites in parallel to natural extra-galactic radio sources. The combination of observations to satellites and quasars permits extending the research of this interferometric technique and provides new possibilities, such as the determination of the absolute orientation of the satellite orbit in the International Celestial Reference Frame (ICRF). Moreover, the comparison of the satellite position determined using VLBI observations with positions obtained from other space geodetic techniques is possible which further enables the tying of different space geodetic techniques with high precision and results in an improvement of the Terrestrial Reference Frame (TRF).
In this work, satellite orbit arcs obtained from simulated VLBI observations to Galileo satellites are examined and investigated based on precision metrics. The study is carried out for various arc lengths and observation geometries using different VLBI networks. The scheduling software VieSched++ is applied to create schedules including observations to quasars and satellites and the Vienna VLBI and Satellite software (VieVS) is used to simulate the scheduled observations and to adjust the satellite orbit based on the Monte Carlo simulations. The precision of the adjusted arcs is studied and assessed in terms of repeatabilities and mean formal errors of the radial, along-track, and cross-track components of the satellite position.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Recorded presentation [S5-M02]

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ICRF3 Position and Proper Motion of Saggitarius A* from VLBA Absolute Astrometry

D. Gordon, A. de Witt, C. Jacobs

Abstract Sagittatius A* (Sgr A*) is a strong radio source believed to be a supermassive black hole at the center of the Milky Way galaxy. It has been observed in numerous VLBA K band (24 GHz) astrometric sessions designed to improve and expand the K band CRF since 2017. Interstellar scattering in the galactic plane smears it out such that it is resolved out on the longer VLBA baselines, but it is usually detected on the shorter baselines between PT-VLBA, LA-VLBA, KP-VLBA, FD-VLBA, OV-VLBA, NL-VLBA and some of the BR-VLBA and HN-VLBA baselines at K band. We leveraged our VLBA K-band observations of Sgr A* with data from two earlier K-band VLBA sessions in 2006 from the VGAPS campaign, giving a 15 year time span. We treated Sgr A* as an arc parameter in an ICRF3-compliant Solve global solution, yielding a time series of its positions. Analysis of that time series yields a position for Sgr A* in the frame of ICRF3 at a specific epoch with a precision of $\sim$0.5 mas and allows us to measure its proper motion. We find proper motion velocities of -3.17 $\pm$ .05 mas/yr in RA and -5.61 $\pm$ .09 mas/yr in Declination. Combining these yields a proper motion vector of $\sim$6.4 $\pm$ 0.1 mas/yr at a position angle of $\sim$209.4 degrees. We will present the observations, their analysis, and the implications for solar system motion in and out of the plane of the galaxy.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: Poster [S5-P03]

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Astrometric positions of gravitational lensed system 1422+231

Ming H. Xu, Tuomas Savolainen, Niu Liu, Alet de Witt, Susanne Lunz, Robert Heinkelmann, and Harald Schuh

Abstract Gravitational lensing can occur when a gravitational field of e.g., a cluster of galaxies distorts and magnifies the light from a distant, background galaxy that is almost in the same line of sight as the lensing mass. Among about 500 discovered gravitational lensed systems, the European Space Agency mission Gaia has detected at least one of the lensed images for about 300 ones and released their astrometric parameters in EDR3. According to a literature search, high accuracy VLBI observations to determine the relative positions between possible lensed images have been carried out for 25 lensed systems. The lensed images refer to the various visible components in the field of view in the direction of the lensing system. Because these multiple lensed images of a source are typically a few arcseconds or less apart on the sky, they can be imaged on one map. This allows to determine the relative positions between them with an accuracy of tens of microarcseconds. This may enhance the study of the position differences between radio and optical, given that the multiple lensed images of an individual source are detected by both VLBI and Gaia. We will report on the astrometric positions from historical VLBI observations reported in the literature, results from the latest VLA observations, and the Gaia EDR3 results. We will focus on the lensed system, 1422+231, for which high-accuracy relative positions are available from geodetic VLBI observations conducted in the 1990s. This study aims to understand the VLBI/Gaia position differences seen for 1422+231 and to potentially improve the modelling of the gravitationally lensed system, 1422+231, using more accurate astrometric positions from radio and optical.

Session-5: Extending the Use of VLBI to Frame Ties, Deep Space Exploration and other areas

Presentation type: poster [S5-P04]

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