23rd European VLBI Group for Geodesy and Astrometry Working Meeting
14-19 May 2017
Göteborg, Sweden

Information

May 11, 2017
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EVGA2017 information

Scientific Organising Committee (SOC)

- Sabine Bachmann, Bundesamt für Kartographie und Geodäsie, Germany
- Alessandra Bertarini, Reichert GmbH / Bundesamt für Kartographie und Geodäsie, c/o Max Planck Institute for Radio Astronomy, Germany
- Johannes Böhm, Technische Universität Wien, Austria
- Rüdiger Haas (Chair), Chalmers Tekniska Högskola, Sweden
- Evgeny Nosov, Institute of Applied Astronomy of the Russian Academy of Sciences, Russia
- Nataliya Zubko, Finnish Geospatial Research Institute, Finland

Local Organising Committee (LOC)

- Rüdiger Haas (Chair)
- Thomas Hobiger
- Niko Kareinen
- Grzegorz Klopotek
- Camilla Andersson (administrative services)

Series of events during the EVGA2017

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 May</td>
<td>18:00-20:00</td>
<td>Icebreaker and registration</td>
<td>foyer Palmstedssalen</td>
</tr>
<tr>
<td>15 May</td>
<td>08:45-17:45</td>
<td>Oral presentations</td>
<td>Palmstedssalen</td>
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<tr>
<td></td>
<td>17:45-20:45</td>
<td>Poster session</td>
<td>foyer Palmstedssalen</td>
</tr>
<tr>
<td>16 May</td>
<td>09:00-17:45</td>
<td>Oral presentations day-2</td>
<td>Palmstedssalen</td>
</tr>
<tr>
<td></td>
<td>19:00-23:00</td>
<td>Conference dinner</td>
<td>Wijkanders Restaurang</td>
</tr>
<tr>
<td>17 May</td>
<td>08:45-17:00</td>
<td>Various splinter meetings</td>
<td>HA4, EDIT 3364, EL42</td>
</tr>
<tr>
<td>18 May</td>
<td>10:45-15:45</td>
<td>Onsala Twin Telescopes inauguration</td>
<td>Onsala</td>
</tr>
<tr>
<td>19 May</td>
<td>09:00-18:00</td>
<td>IVS Directing Board Meeting #37</td>
<td>EDIT 3364</td>
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</table>
2017-05-14
Icebreaker and registration
Register, put up your posters, meet your friends, talk to your colleagues. Drink and snacks will be served.

2017-05-15
EVGA2017 Day-1

Welcome
Rüdiger Haas
08:45-09:00

Session-T1 (60 min) Chairperson: Evgeny Nosov

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lopez Fernandez</td>
<td>Technological Development for VGOS at Yebes Observatory</td>
</tr>
<tr>
<td>Sekido</td>
<td>Broadband VLBI System GALA-V and Its Application for Geodesy and Frequency Transfer</td>
</tr>
<tr>
<td>Flygare</td>
<td>Sensitivity and antenna noise temperature analysis of Onsala Twin Telescopes 3 - 18 GHz</td>
</tr>
<tr>
<td>Pantaleev</td>
<td>Design, implementation and tests of the signal Chain for the Twin Telescopes at Onsala Space Observatory</td>
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Coffee break (30 min) (coffee and sandwich served)
10:00-10:30

Session-T2 (60 min) Chairperson: José Antonio Lopez Fernandez

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nosov</td>
<td>Improvement of PCAL signal distribution on RT-32 radio telescopes of &quot;Quasar&quot; VLBI network</td>
</tr>
<tr>
<td>Klügel</td>
<td>VLBI - DORIS Interference Investigation at Wettzell</td>
</tr>
<tr>
<td>Nothnagel</td>
<td>Paraboloid deformation investigations of the Onsala 20 m radio telescope with terrestrial laser scanning</td>
</tr>
<tr>
<td>Eschelbach</td>
<td>Unified Model for Surface Fitting of Radio Telescope Reflectors</td>
</tr>
</tbody>
</table>

Strech your legs break (15 min)
11:30-11:45

Session-T3 (60 min) Chairperson: Axel Nothnagel

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>Plötz</td>
<td>On the way to regular, transatlantic VGOS sessions using an Elevenfeed and DBBC2’s</td>
</tr>
<tr>
<td>Neidhardt</td>
<td>The Jumping Jive Monitoring Work Package: centralized System Monitoring and Automation as key feature also for VGOS</td>
</tr>
<tr>
<td>Petrachenko</td>
<td>VGOS 1.1: A DBE Opportunity and Data Transmission Challenge</td>
</tr>
<tr>
<td>Lovell</td>
<td>A Year of Dynamic Observing</td>
</tr>
</tbody>
</table>

Lunch break (60 min) (lunch on your own)
12:45-13:45

Session-T4 (60 min) Chairperson: Bill Petrachenko

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
</tr>
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<tbody>
<tr>
<td>Bertarini</td>
<td>An IVS pilot study for distributed correlation in the VGOS era</td>
</tr>
<tr>
<td>Keimpema</td>
<td>Real-time eVLBI at JIVE using the SFXC software correlator</td>
</tr>
<tr>
<td>McCallum J</td>
<td>Correlation at UTAS</td>
</tr>
<tr>
<td>Weston</td>
<td>Towards Cloud Correlation of VLBI Data</td>
</tr>
</tbody>
</table>

Coffee break (30 min) (coffee and pastry served)
14:45-15:15

Session-T5 (30 min) Chairperson: Alessandra Bertarini

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>Zheng</td>
<td>The progress of VLBI terminal and correlator in SHAO</td>
</tr>
<tr>
<td>Li</td>
<td>Ultra-wide band receiver for SHAO VGOS station</td>
</tr>
<tr>
<td>Chen</td>
<td>Recent Progress in Cryogenic MMIC Design of SHAO</td>
</tr>
</tbody>
</table>

Session-A1 (15 min)
Soja | A celestial reference frame based on Kalman filtering |

Strech your legs break (15 min)
16:15-16:30
### Session-O1 (60 min) Chairperson: John Gipson

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Time</th>
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<tbody>
<tr>
<td>Wakasugi</td>
<td>VGOS development for Ishioka 13-m antenna</td>
<td>16:30-16:45</td>
</tr>
<tr>
<td>Ruszczyk</td>
<td>VGOS Interoperability Observing Sessions - Results, Lessons, Learned, and Guidelines</td>
<td>16:45-17:00</td>
</tr>
<tr>
<td>Alef</td>
<td>Bonn Correlator: Preparing for VGOS and EHT</td>
<td>17:00-17:15</td>
</tr>
<tr>
<td>Marti-Vidal</td>
<td>Linear polarizers in VLBI: offline conversion into a circular basis</td>
<td>17:15-17:30</td>
</tr>
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</table>

**Stretch your legs break (15 min)**

### Session-O2 (60 min) Chairperson: Johannes Böhm

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>McCullum L</td>
<td>The HOB experiments</td>
<td>17:45-18:00</td>
</tr>
<tr>
<td>Combrinck</td>
<td>Proposed establishment of a Fundamental Geodetic Station in Antarctica</td>
<td>18:00-18:15</td>
</tr>
<tr>
<td>Gipson</td>
<td>Simulation Results for KOKEE12M-WETTZ13S 'Intensives'</td>
<td>18:15-18:30</td>
</tr>
<tr>
<td>Kareinen</td>
<td>Optimal tag-along station locations for VLBI Intensive sessions</td>
<td>18:30-18:45</td>
</tr>
</tbody>
</table>

**Poster session (150 min) (drink and snack served)**

### 2017-05-16 EVGA2017 Day-2

### Session-O3 (60 min) Chairperson: Sabine Bachmann

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schartner</td>
<td>Recent developments in scheduling with VieVS</td>
<td>09:00-09:15</td>
</tr>
<tr>
<td>Haas</td>
<td>VLBI with GNSS-signals on an intercontinental baseline</td>
<td>09:15-09:30</td>
</tr>
<tr>
<td>Hobiger</td>
<td>Simulations of VLBI-only spacecraft orbit determination</td>
<td>09:30-09:45</td>
</tr>
<tr>
<td>Klopotek</td>
<td>Lunar observations and geodetic VLBI - A simulation study</td>
<td>09:45-10:00</td>
</tr>
</tbody>
</table>

**Coffee break (30 min) (coffee and sandwich served)**

### Session-A2 (60 min) Chairperson: Thomas Hobiger

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Time</th>
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<tbody>
<tr>
<td>Bachmann</td>
<td>ITRS realizations in the framework of ITRF2014: impact of different TRF parameterizations on VLBI combined products</td>
<td>10:30-10:45</td>
</tr>
<tr>
<td>Krasna</td>
<td>Determining the Galactocentric acceleration vector from VLBI and its impact on the terrestrial reference frame</td>
<td>10:45-11:00</td>
</tr>
<tr>
<td>Halsig</td>
<td>INT2b - determination of UT1 with parallel Intensive sessions</td>
<td>11:00-11:15</td>
</tr>
<tr>
<td>Himwich</td>
<td>Impact of station clocks on UT1-TAI estimates</td>
<td>11:15-11:30</td>
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**Stretch your legs break (15 min)**

### Session-A3 (60 min) Chairperson: Alet de Witt

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson</td>
<td>CONT14 Imaging and Closure Analysis of Source Structure Effects: Part 1 – Imaging Results</td>
<td>11:45-12:00</td>
</tr>
<tr>
<td>Xu</td>
<td>CONT14 Imaging and Closure Analysis of Source Structure Effects: Part 2 – Closure Analysis</td>
<td>12:00-12:15</td>
</tr>
<tr>
<td>Mayer</td>
<td>The application of ray-traced delays for the ICRF3</td>
<td>12:15-12:30</td>
</tr>
<tr>
<td>Charlot</td>
<td>Towards the third realization of the International Celestial Reference Frame</td>
<td>12:30-12:45</td>
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**Lunch break (60 min) (lunch on your own)**

### Session-A4 (60 min) Chairperson: James Anderson

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>de Witt</td>
<td>K-band Celestial Frame: can it be better than S/X ?</td>
<td>13:45-14:00</td>
</tr>
<tr>
<td>Le Bail</td>
<td>Investigating the noise floor of VLBI source positions</td>
<td>14:00-14:15</td>
</tr>
<tr>
<td>Titov</td>
<td>Structure of the radio source 0014+813 using CONT14 geodetic VLBI observations</td>
<td>14:15-14:30</td>
</tr>
<tr>
<td>Shu</td>
<td>Absolute astrometry of weak sources with the AOV</td>
<td>14:30-14:45</td>
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**Coffee break (30 min) (coffee and pastry served)**

14:45-15:15
### Session-A5 (60 min) Chairperson: Patrick Charlot

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:15</td>
<td>Jaron</td>
<td>Near-field VLBI delay models - Implementation and testing</td>
</tr>
<tr>
<td>15:30</td>
<td>Zhang</td>
<td>Initial Study of Lunar Librations by VLBI Observations of the Chang'E-3 Lunar Lander</td>
</tr>
<tr>
<td>15:45</td>
<td>Flohrer</td>
<td>Update on VLBI data analysis at ESOC</td>
</tr>
<tr>
<td>16:00</td>
<td>Kwak</td>
<td>DOGS-R1: new VLBI analysis software at DGFI-TUM</td>
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### Stretch your legs break (15 min) 16:15-16:30

### Session-A6 (75 min) Chairperson: Lucia McCullum

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>16:30</td>
<td>Scherneck</td>
<td>Ocean tide loading - where we are standing</td>
</tr>
<tr>
<td>16:45</td>
<td>Girdiuk</td>
<td>An empirical atmospheric tidal loading solution for particular VLBI stations</td>
</tr>
<tr>
<td>17:00</td>
<td>Jacobs</td>
<td>Twin Telescope Tests: Assessing Station Oriented Systematic Errors</td>
</tr>
<tr>
<td>17:15</td>
<td>Nilsson</td>
<td>Estimating common tropospheric parameters for co-located VLBI antennas</td>
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### Closing remarks Rüdiger Haas 17:30-17:45

### Conference dinner At Wijkanders Restaurant 19:00-23:00

### Posters Session-1

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>Bergstrand</td>
<td>Geometric variations of a geodetic telescope</td>
</tr>
<tr>
<td>Forkman</td>
<td>Accuracy assessment of the two WVRs, Astrid and Konrad, at the Onsala Space Observatory</td>
</tr>
<tr>
<td>Helldner</td>
<td>Time and frequency distribution for the Onsala Twin-Telescopes</td>
</tr>
<tr>
<td>Neidhardt</td>
<td>Communication, Coordination, and Automation for future Geodetic Infrastructures</td>
</tr>
<tr>
<td>Ruszczyk</td>
<td>The MIT/NASA Broadband Signal Chain - Present State, VGOS compliance, and Beyond</td>
</tr>
<tr>
<td>Tuccari</td>
<td>DBBC3: The new flexible, wide-band VLBI backend – status</td>
</tr>
<tr>
<td>Tuccari</td>
<td>BRAND: A very wide-band receiver for the EVN</td>
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### Posters Session-2

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Anderson</td>
<td>GFZ Simulations of VLBI Observations of E-GRASP/Eratosthenes</td>
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<tr>
<td>Baver</td>
<td>Reduction of the IVS-INT01 UT1 Formal Error through New Sked Algorithms</td>
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<tr>
<td>Behrend</td>
<td>Planning of the Continuous VLBI Campaign 2017 (CONT17)</td>
</tr>
<tr>
<td>Elgered</td>
<td>The Onsala Twin Telescopes project</td>
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<tr>
<td>Gruber</td>
<td>Geodetic VLBI Correlation at the Vienna Scientific Cluster</td>
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<tr>
<td>Hase</td>
<td>Argentinean-German Geodetic Observatory (AGGO)</td>
</tr>
<tr>
<td>Jaroenjittichai</td>
<td>Status of RANGD project</td>
</tr>
<tr>
<td>Lopez Fernandez</td>
<td>Status of RAEGE Network</td>
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<tr>
<td>Molera Calvés</td>
<td>Metsähovi Geodetic Fundamental Station - current status of the new VGOS site</td>
</tr>
<tr>
<td>Nickola</td>
<td>HartRAO antenna axis offset and its effect on troposphere modelling and antenna coordinates</td>
</tr>
<tr>
<td>Thorandt</td>
<td>VLBI at GARS O'Higgins - 25 years of operation and recent developments</td>
</tr>
<tr>
<td>Wang</td>
<td>The Sheshan VGOS station progress on construction</td>
</tr>
<tr>
<td>Wielgosz</td>
<td>The new potential VGOS site in Poland</td>
</tr>
<tr>
<td>Author</td>
<td>Title</td>
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<tr>
<td>Balidakis</td>
<td>Calculating integrated water vapor trends from VLBI, GNSS and NWM</td>
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<tr>
<td>Bolotin</td>
<td>Implementation of the vgosDb format at the GSFC VLBI Analysis Center</td>
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<tr>
<td>Corbin</td>
<td>Automated ambiguity resolution with clustering and analysis of Intensive Sessions</td>
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<tr>
<td>Gattano</td>
<td>Classification of VLBI radio-sources by astrometric stability using Allan Variance</td>
</tr>
<tr>
<td>Halsig</td>
<td>Current development progress in ivg::ASCOT</td>
</tr>
<tr>
<td>Hjelle</td>
<td>Where - A New Software for Geodetic Analysis</td>
</tr>
<tr>
<td>Karbon</td>
<td>The impact of the TRF on the CRF</td>
</tr>
<tr>
<td>Mammadaliyev</td>
<td>Improvements of the stochastic model of the VLBI data analysis in VieVS@GFZ</td>
</tr>
<tr>
<td>Modiri</td>
<td>Copula-based analysis of correlation structures in VLBI data analysis</td>
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<tr>
<td>Nilsson</td>
<td>The GFZ VLBI TRF solutions</td>
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<tr>
<td>Schubert</td>
<td>Stochastic estimation of ZWD parameter in VLBI data analysis using a Square-Root Information Filter</td>
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<td>Skurikhina</td>
<td>CONT14 Data Analysis</td>
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<tr>
<td>Skurikhina</td>
<td>VLBI Analysis at the IAA</td>
</tr>
<tr>
<td>Tanir</td>
<td>Comparison of least squares and KalmanFilter solutions from different IVS analysis centers</td>
</tr>
<tr>
<td>Thorandt</td>
<td>IVS Primary Data Center and Analysis Center at BKG</td>
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EVGA splinter meeting program

2017-05-17

<table>
<thead>
<tr>
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<th>Meeting</th>
<th>room</th>
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<tbody>
<tr>
<td>08:45-09:45</td>
<td>IVS WG 7 meeting (only WG members)</td>
<td>EDIT 3364</td>
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<tr>
<td>10:00-10:15</td>
<td>EVGA business meeting</td>
<td>HA4</td>
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<tr>
<td>10:15-12:00</td>
<td>IVS Analysis Workshop</td>
<td>HA4</td>
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<td>12:00-14:00</td>
<td>--- lunch break ---</td>
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<tr>
<td>14:00-16:00</td>
<td>V2C meeting</td>
<td>EL42</td>
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<tr>
<td>16:00-17:00</td>
<td>VGOS technology compatibility meeting (by invitation only)</td>
<td>EDIT 3364</td>
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OTT inauguration

2017-05-18

<table>
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<tbody>
<tr>
<td>10:45-11:30</td>
<td>bus from Chalmers library to Onsala</td>
</tr>
<tr>
<td>12:00-12:50</td>
<td>inauguration</td>
</tr>
<tr>
<td>12:50-13:40</td>
<td>lunch</td>
</tr>
<tr>
<td>13:40-15:00</td>
<td>visit of the observatory</td>
</tr>
<tr>
<td>15:00-15:45</td>
<td>bus from Onsala to Chalmers</td>
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IVS Directing Board meeting

2017-05-19

<table>
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<th>room</th>
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<tbody>
<tr>
<td>09:00-18:00</td>
<td>37th IVS DB meeting (IVS DB members only)</td>
<td>EDIT 3364</td>
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</table>
Inauguration of
Onsala Twin Telescopes
18 May 2017

Programme

12:00 Welcome: John Conway, director of Onsala Space Observatory.
12:10 Speeches: Stefan Bengtsson, president, Chalmers; Axel Nothnagel, chair, International VLBI Service for Geodesy & Astrometry; Malin and Josefin Flyckt, Swedish Astronomical Youth Association
12:25 Film clip Using Quasars to Measure the Earth (NASA). Live narration in Swedish: Maria Sundin, University of Gothenburg.
12:50 Lunch.
13:40 Guided tour of the observatory’s telescopes and other instruments (max 1½ h).

Practical information

Cellphones: Our observations are affected by mobile telephones. All cellphones and wifi devices must be switched off (flight mode acceptable) while in the observatory grounds.

Travel with special bus from Gothenburg: Buses to the inauguration depart at 10:45 am from Chalmers Library, Chalmers tvärgata, Gothenburg. Register (https://doodle.com/poll/axharet2b75dm7t) by May 11 to be sure of a place on the bus. The bus leaves after the ceremony no later than 3:00 pm, arriving in Gothenburg at 3:45 pm.

Travel by car: To reach the observatory, search for Observatorievägen 90, Onsala. Link to Google Maps: https://goo.gl/maps/L0xK3

On arrival at the observatory grounds: press the button on the left side of the barrier to open it. Drive towards the three large dish antennas and follow signs.

Other travel options: The observatory is 45-60 min by car/taxi from Gothenburg Airport, Landvetter, and 45 min from Gothenburg Central rail station. From Kungsbacka station it’s around 25 min by car. The observatory is not served by public transport. The nearest bus stop, Mariedal, 5 km away, is serviced by buses 731 and 734 from Kungsbacka station.

Contact us: Call +46 31 772 550 or send email to robert.cumming@chalmers.se.
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Session-1: Technology

- Oral Contributions -

Picture: The interior of the broad-band cryogenic receivers for the Onsala Twin Telescopes with a Quad-ridged feed horn (QRFH) 3–18 GHz (left) and the Eleven-Feed 2–14 GHz (right).
An IVS pilot study for distributed correlation in the VGOS era


Abstract The IVS directing board assigned in late 2016 the IVS Technical Development Coordinator, Gino Tuccari, to explore the feasibility of distributed correlation as a potential VGOS correlation architecture. Specific challenges are that the amount of data to be transferred to the correlator is going to increase, hence also the correlation time and the capacity of the RAIDs at the correlators to store the data will increase. This study will identify whether distributing the correlation of one experiment among more correlators will help to keep the data flow from observation to analysis within a reasonable time (now the guideline set by the IVS from observation to analysis should not be more than two weeks).

The general idea of this study is to have one main correlator that will receive the data at the beginning and the end of the experiment for clock and drift adjustment. The main correlator will prepare the vex and v2d files (required for the correlation within DiFX) and distribute them to the branch correlators that then correlate using exclusively the .vex- and .v2d-files coming from the main correlator. Three branch correlators located at Hobart (Tasmania, Australia), Warkworth (New Zealand) and Onsala (Sweden) will be involved. Each of the branch correlators will receive 1 hour of data of the 10 stations involved in R1.785, i.e. Hobart, HartRao, Ishioka, Katherine, Ny-Ålesund, Onsala, Shanghai, Warkworth, Wettzell and Yarragadee. Using the clock information provided by the main correlator, the branch correlators will correlate this one hour of data each, with as identical as possible DiFX versions and identical .v2d- and .vex-files. After the correlation the branch correlators will send the visibilities to the main correlator for further processing. In parallel, the main correlator correlates the data of all stations for the complete experiment. Then the results produced by the branch correlator processing and the main correlator can be compared and the strategy can be evaluated.

Session-1: Technology

Presentation type: Oral

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Recent Progress in Cryogenic MMIC Design of SHAO

Y. Chen, Z.-K. Li, X. Sun, B. Li

Abstract This manuscript reports our progress in designing cryogenic wideband MMIC LNAs for use in radio astronomical receivers. These include several WIN-150 nm/100 nm GaAs pHEMT LNAs and OMMIC-70 nm mHEMT LNAs. To make these LNAs eligible for low-temperature applications, a cryogenic noise measurement system using multi-point variable-temperature-load (VTL) method is constructed where the system is computer controlled, and both the noise calibration and de-embedding concerns are properly addressed. At 14 K ambient temperature, the WIN 5–10 GHz LNA has its averaged noise temperature equal to 8 K and the 8–20 GHz LNA is around 10 K. This also mentions our progress in integrating the wideband LNA and mixer in 150 nm GaAs pHEMT for K-band radio astronomical receiver. With chip area of $2.5 \times 1 \text{ mm}^2$, the overall conversion gain at room temperature is 20 dB and the noise is around 300 K.

Session-1: Technology

Presentation type: Oral
Sensitivity and antenna noise temperature analysis of the Onsala Twin Telescope 3–18 GHz system

J. Flygare, M. Pantaleev, B. Billade, M. Dahlgren, L. Helldner, R. Haas

Abstract The demand for higher precision measurements in Very Long Baseline Interferometry (VLBI) continues to grow, which drives the technical development of next generation international VLBI stations which is called the VLBI Global Observing System (VGOS) system. The VGOS design system includes the idea of twin telescopes, i.e. two identical VGOS telescopes that will be used for continuous observations to study geodynamical processes. Such a VGOS twin telescope system has been installed recently at the Onsala Space Observatory.

In this talk we present the estimated performance of one of the 13.2 m Onsala Twin Telescopes (OTT), focusing on the achievable system equivalent flux density (SEFD), sky noise modeling, and antenna noise temperature. The investigated telescope is a dual-reflector systems with a ring focal sub-reflector and a cryogenic wideband quad-ridge flared horn receiver operating over 3–18 GHz. We show a very high sensitivity with a SEFD of 1000 Jy and a constant antenna noise temperature over the band, as well as $T_{rec} = 10$ K over more than half of the band.

Session-1: Technology

Presentation type: Oral
Real-time eVLBI at JIVE using the SFXC software correlator

A. Keimpema, M. Kettenis, A. Szomoru, B. Campbell

Abstract Real-time eVLBI continues to form an integral element of the European VLBI network (EVN), accounting for about a quarter of all EVN hours and providing unique rapid-response capabilities to transient events as well as the opportunity for higher-cadence observations compared to the standard EVN sessions that fall three times per year. In addition to correlation there is also the possibility to record the raw voltage data locally at JIVE in parallel with the correlation. This feature is useful for experiments which require multiple correlator passes, such as e.g. transients. The feature was instrumental in the EVN localization of FRB121102.

For disk based EVN observations a number of stations made the transition from recording onto Mark5 diskpack units to recording onto so-called Flexbuffers. A Flexbuff is a Commercial Of The Self (COTS) linux based server which supports up to 36 hard drives giving a typical capacity of 100-200 TB. During the EVN session each station will record its data onto their local Flexbuff. After the session this data is transferred over the network to a Flexbuff at JIVE for correlation, ending the need to physically ship diskpacks. For each station which made the transition to Flexbuff there is corresponding Flexbuff space located at JIVE.

Since 2012 all disk based EVN observations as well as all e-EVN observations are correlated using the EVN software correlator at JIVE (SFXC). Compared to the hardware correlator it replaced, the MkIV Data Processor at JIVE, SFXC offers a much greater flexibility. For example it can correlate experiments containing a mixed number of bandwidths and mismatched side-bands – accelerating development in various digital back-ends has made this a routine situation. SFXC opens up new astronomical areas for correlation at JIVE via pulsar binning/gating (including coherent de-dispersion), multiple simultaneous phase centres, space VLBI (comprising both antennas in orbit such as RadioAstron, and near field targets in the solar system), and a phased-up mode.

SFXC is currently deployed on a linux-based 512 core COTS computing cluster. It can currently process real-time correlation for a 11 station array at 2 Gbps or approximately 18 stations at 1 Gbps, both including cross-polarizations.

There is a work package in the newly EC-funded Jumping JIVE program that will address producing SFXC output that can directly be imported into geodetic post-correlation packages and handling sub-netted schedules transparently during correlation.

Session-1: Technology

Presentation type: Oral
VLBI - DORIS Interference Investigation at Wettzell


Abstract  The Geodetic Observatory Wettzell is a so-called fundamental station of geodesy. This means that all important space-geodetic techniques are collocated at that site at distances smaller than approx. 200 meters. Such stations are of importance for the Global Geodetic Observing System (GGOS); Wettzell is a GGOS core site. Taking into account the advances made with respect to DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite), a beacon of that type is a very useful completion of the instrumentation at the Fundamentalstation Wettzell.

Unfortunately, integration of all four space-geodetic techniques (VLBI, SLR, GNSS and DORIS) may create problems with electromagnetic compatibility (EMC). While the VLBI system is designed to receive very weak signals from quasars, the DORIS beacon emits comparatively strong signals in the UHF frequency band at 401.25 MHz and in the S-band at 2036.25 MHz. This is slightly lower than the preferred observation window in current geodetic VLBI. During the observation of quasars with VLBI there is a high risk of coupling DORIS S band signals into the receiving chain of VLBI. This can generate spurious signals and, in the worst case, overload the receiver chain electronics including the risk of damage. As a consequence, cautious investigations of these potential problems were necessary before a continuous operation of the DORIS beacon at Wettzell could be granted.

Field tests under different setups were performed to assess the impact of the DORIS signals on the 20-m-RTW (legacy VLBI system) and the new 13-m-TWINs (VGOS telescopes). Different locations at the observatory in a vicinity of no more than 100 m were occupied by the DORIS antenna. Obstacles like buildings or earth mounds already attenuate the signal up to 20 dB. However the power received at the input of the low noise amplifiers (LNA) is still at a critical level when the radio telescope points towards the DORIS beacon. The quality of the correlated signals is not or barely affected at long baselines. At local baselines, however, the DORIS emission as a common mode signal degrades the correlation result. Different strategies to minimize the impact of the DORIS beacon are discussed.

Session-1: Technology

Presentation type: Oral

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Ultra-wide band receiver for SHAO VGOS station

B. Li, R. X. Sun, W. G, Y. Chen

Abstract  A standard VGOS station is under construction by Shanghai Astronomical Observatory (SHAO). The 13.2m fast-speed telescope will be finished in this year and located in the same yard with the Tianma 65 m telescope. An ultra-wide band cryogenic receiver is being build in SHAO’s laboratory and will join the initial antenna test. Two kinds of Quadruple-Ridged Flared Horn (QRFH) have been designed and fabricated according to the antenna optics. One feed is from Caltech with the frequency range 3-18 GHz. The other feed is from the antenna manufactory CETC-54 which covers 2.7-15.5 GHz. The Caltech feed and MMIC LNAs are now assembled in the dewar and cooled at 20 K plate of the G-M refrigerator. This talk will introduce the receiver structure and show some preliminary testing results.

Session-1: Technology

Presentation type: Oral
Technological Development for VGOS at Yebes Observatory

J. López Fernández, F. Tercero Martínez, J. Daniel Gallego, S. López Ruiz, P. García Carreño

Abstract  The activities in technical development related to geodetic VLBI at IGN Yebes Observatory will be summarized. They have been focused on different topics covering broad band receivers and their feeds, LNAs and PhaseCal sub-systems. Our first broad band receiver is based on a cryogenic front-end with dual linear polarization QRFH horn, directional couplers for calibration signal injection and two ultra-low noise hybrid amplifiers. The output signals from the dewar are sent through RF-over-fiber optic links to the back-end room, where they are distributed to four dual-channel frequency up/down converters. Each converters allow to select a frequency sub-band in both polarizations, with 1.5 GHz bandwidth, in the range 2-14 GHz, and convert it to baseband (DC-1.5 GHz). The measured receiver noise temperatures are lower than 25 K for most of the band.

Regarding new developments, the activity in 2-14 GHz wide-band cryogenic amplifiers for VGOS stations has continued. A new phasecal design based on optical comb generation is being investigated. We continue also with the development of broad band feeds based on conical and printed antennas with good simulated performance.

Session-1: Technology

Presentation type: Oral
Unified Model for Surface Fitting of Radio Telescope Reflectors

M. Lösler, C. Eschelbach, R. Haas

Abstract The main reflector of VLBI radio telescopes is affected by several disturbance forces. Temperature, wind, insolation or snow load deform the surface of the reflector and impair the receiving properties. Depending on the elevation orientation of the main reflector, the dead load of the dish w.r.t. the gravitation field of the Earth influence the surface negatively. In recent years, surface deformations and variations of the focal length have been analyzed by several groups. The common mathematical model to describe the main reflector is an ordinary rotational paraboloid. Due to the reflector design improvements, the surface of the main reflector of many of the upcoming VGOS radio telescopes cannot be parameterized by an ordinary rotational paraboloid. We present a unified mathematical model that overcomes this limitation and which is valid for the ordinary surface design as well as the new ring-focus reflector design of VGOS radio telescopes. The model is used for an independent confirmation of the specifications of the new Onsala Twin Telescopes at the Onsala Space Observatory.

Keywords Keywords Reverse Engineering, VGOS, Paraboloid, Ring-Focus, Focal-Length, Surface, Deformation

Session-1: Technology

Presentation type: Oral

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A Year of Dynamic Observing

J. Lovell, J. McCallum, L. McCallum, E. Iles, J. Böhm, D. Mayer, S. Shabala

Abstract  The current mode of IVS operations for legacy S/X observations has delivered Earth Orientation Parameters with a high degree of reliability for several decades. This is a consequence of excellent organisation and collaboration between many agencies across the globe, all coordinated through the IVS. However, the operating model for VGOS will likely put significant strains on the current mode of operation. If VGOS were to be implemented without significant change to the operations models, it would represent a significant increase in cost and labour. To address this issue, we have been developing and testing the Dynamic Observing concept, focusing on centralised scheduling and operation of a VLBI array with the ability to adapt to the changing availability of resources. We are also addressing an approach to maintain complete local control of facilities while allowing stations to participate in a centrally coordinated and optimised observing program. This work uses the 3-element AuScope VLBI array which was designed from the start to be centrally operated. Being a VLBI array operated by a single institution, many of the problems with obtaining remote access are avoided, allowing us to concentrate on developing and optimising the necessary techniques. We will report on our Dynamic Observing trials carried out in 2016, the challenges and successes and the work still to be done to fully implement the concept.

Session-1: Technology

Presentation type: Oral
Correlation at UTAS

J. McCallum, L. McCallum, J. Lovell

Abstract  Since the establishment of the AuScope array, we have been using a DiFX correlator to perform fringe tests and confirm the performance of the array. Since then, we have expanded its use to correlate a series of additional experiments including AUSTRAL, HOB and dynamic observing sessions in 2016. Additionally, we have begun using it to correlate observations of both GPS sources and the Chinese APOD satellite. We report here on recent results and developments in operating the correlator and fringe-fitting.

Session-1: Technology

Presentation type: Oral
The Jumping Jive Monitoring Work Package: centralized System Monitoring and Automation as key feature also for VGOS

A. Neidhardt, A. Szomoru, K. Kirschbauer, M. Schönberger, T. Bachem

Abstract  Twelve institutes from 8 different countries have teamed up in the JUMPING JIVE project, which was awarded nearly 3 million euro by the Horizon 2020 Framework Program of the EU for the next 4 years. The project is led by JIVE, the Joint Institute for VLBI ERIC, located in Dwingeloo (The Netherlands). The Technical University of Munich at the Geodetic Observatory Wettzell participates to this project integrating monitoring systems for global VLBI interfaces. This work might have a relevant impact to the VGOS operations, because it is the first founded implementation with a focus on centralized structures for VLBI networks. Monitoring systems and remote control abilities will be evaluated to find common inter- interoperability. It will adapt existing software for integration into a central infrastructure.

Session-1: Technology

Presentation type: Oral
Improvement of PCAL signal distribution on RT-32 radio telescopes of "Quasar" VLBI network

E. Nosov, D. Marshalov

Abstract Using multi-tone phase calibration in VLBI observations can potentially give better results than conventional single-tone technique. At the same time it increases the requirements to PCAL signal quality. Distortions of PCAL signal can eliminate all benefits of multi-tone calibration and make it unusable. To prevent this and to examine the condition of PCAL signals on "Quasar" VLBI network stations we performed a series of test measurements on RT-32 radio telescopes. The measurements included estimation of amplitudes and phases of all PCAL tones in all channels in standard S/X geo mode and their dependence on the antenna elevation. The results were used to perform troubleshooting on the stations which has already resulted in a significant improvement of PCAL signal quality which, in turn, is expected to lead to better calibration results, both single- and multi-tone. The talk describes the measurements taken and the results achieved.

Session-1: Technology

Presentation type: Oral
Paraboloid deformation investigations of the Onsala 20 m radio telescope with terrestrial laser scanning

A. Nothnagel, Ch. Holst, D. Schunk, R. Haas

Abstract Since terrestrial laser scanning has become quite common for surveying and other geometrical applications, it has also been used for surveying the main reflector of radio telescopes. In this presentation we describe a project for surveying the 20 m radio telescope of the Onsala Space Observatory, Sweden. In order to use only one position for the scanner with minimal obstruction, the instrument, a Leica Scan Station P20, was mounted “head-down” on one of the support legs close to the sub-reflector of the telescope. With this setup, the telescope was scanned at several different elevation positions between 90 and 5 degrees in highest resolution. We will present initial results of deformation analyses as well as of focal length variations which will be compared to empirical sub-reflector adjustments for gain optimization.

Session-1: Technology

Presentation type: Oral
Design, implementation and tests of the signal Chain for the Twin Telescopes at Onsala Space Observatory


Abstract  We give an overview on the design, realisation and tests of the signal chain for the Twin Telescopes at Onsala Space Observatory. The choice of feed and frequency band was dictated by the requirement for keeping compatibility with the S-band system and existing reference frame established from the observations performed for decades with the OSO 20 m and in the same time creating system that will be flexible for adding new frequency bands above 14 GHz. We describe the design details and test results for the two developed systems: a cryogenic front-end with 3–18 GHz Quad-Ridged Feed Horn (QRFH), installed on the Northern telescope and a cryogenic front-end with Eleven Feed for the 2–14 GHz range, installed on the Southern Telescope. We present the criteria and the selection process related to evaluation of key system components as for example feed, LNA and RFOF link. We give also details on the design of the signal chain, including RF signal distribution to the back-end, noise and phase calibration and the system for monitoring and control of the RF chain.

Session-1: Technology

Presentation type: Oral
VGOS 1.1: A DBE Opportunity and Data Transmission Challenge

B. Petrachenko

Abstract  The basic technical specifications for VGOS have not changed for a decade; they were presented in detail in 2012 at the VLBI2010 Workshop on Technical Specifications at Bad Kötzting, Germany. In the interim, circumstances have changed sufficiently in two areas to warrant a review and possible upgrade of the specifications. First, advances in DBE capabilities make it possible to envision a frequency scheme whereby any output channel can be selected from anywhere in the VGOS 2-14 GHz input range, as opposed to being restricted to four 1 GHz bands. This is desirable to mitigate some of the negative impacts of RFI and source structure, the two dominant risk factors for VGOS. Second, there is a strong desire on the part of many stations to transmit data to the correlate via the internet as opposed to via physical transport of removable media. This poses a challenge at existing correlators where anticipated input data rate capabilities do not match data production rates at the stations. New, more distributed, correlator models are being considered.

Session-1: Technology

Presentation type: Oral

Bill Petrachenko
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On the way to regular, transatlantic VGOS sessions using an Elevenfeed and DBBC2s

Ch. Plötz, G. Kronschnabl, A. Neidhardt, W. Schwarz, T. Schüler

Abstract The first transatlantic VGOS-sessions were successfully operated. Special is that different receiving hardware is used at the sites. The Geodetic Observatory Wettzell is the first site using the new broadband Elevenfeed, two DBBC-2s in combination with two FILA10G, and a Mark6, controlled by the NASA Field System. First experiences show that it was and is a continuous process of learning, testing and implementing. This talk explains the currently used systems and setups. Results from additional investigations in antenna performance and mechanical deformation are shown. Finally made implementations to get the system running are demonstrated. Finally, we show made progress but also current issues.

Session-1: Technology

Presentation type: Oral
Broadband VLBI System GALA-V and Its Application for Geodesy and Frequency Transfer


Abstract We have developed a broadband VLBI system named GALA-V, which follows the VGOS (VLBI Global Observing System) specification. The development contains broadband receiver system, data acquisition system, and up to data processing software for precision delay determination. This system demonstrated sub-pico second precision VLBI delay measurement by one second of observation between Japanese domestic broadband VLBI stations: Ishioka 13 m and Kashima 34 m. We conducted a series of broadband VLBI experiments between two small telescopes installed at NICT(Tokyo) and NMIJ(Tsukuba) for measurement of clock difference between UTC(NICT) and UTC(NMIJ). Analysis results of these experiments proved that broadband VLBI system enables pico-second precision observation even with small diameter radio telescopes. The experiment results suggest that delay precision reaches to a sufficient level by broadband system, and the error of geodetic/clock analysis is dominated by atmospheric delay uncertainty.

Session-1: Technology

Presentation type: Oral
Towards Cloud Correlation of VLBI Data

S. Weston, S. Gulyaev, B. Kim, A. Litchfield, D. Hall, J. Curtis, A. Ruthven, G. Davies, B. Lagos, D. Christie

Abstract Reducing time interval between geodetic VLBI observations and an end-product is critical in many applications — for example, generation of the dUT1 parameter for correction of GNSS orbits with high accuracy and within 12 days after observations is of great importance for GNSS-based navigation. Currently IVS data is correlated in several international Correlators (Correlation Centres); they receive data from individual radio telescope stations either in hard drives via regular mail service or via fibre using e-transfer mode. The former is not always reliable, the latter is often limited by connectivity of existing correlation centres, which can dramatically slow down the turnover of the data. We report on our initial steps towards development of a cloud correlation infrastructure for geodetic VLBI data. We started with a blade server at the AUT campus to emulate a cloud server using Virtual Machines (VMWare). The New Zealand Data Head node is connected to the high speed (100 Gbps) network ring circuit courtesy of the Research and Education Advanced Network New Zealand (REANNZ), with the additional nodes at remote physical sites connected via 10 Gbps fibre. We use real Australian Long Baseline Array (LBA) observational data from 6 radio telescopes in Australia, South Africa and New Zealand (15 baselines) of 1.5 hours in duration making 8 TB to emulate data transfer from remote locations and to provide a meaningful benchmark dataset for correlation. Data was successfully transferred using bespoke UDT network transfer tools and correlated with the speed-up factor of 0.8 using DiFX software correlator. In partnership with the New Zealand office of Catalyst IT Ltd we have moved this project into their Cloud and report on the first correlation of a VLBI dataset in a true commercial cloud environment. Using a new paradigm of multiple head nodes we reached the speed-up factor greater than one, therefore, in principle, allowing real-time cloud correlation.

Session-1: Technology

Presentation type: Oral

Stuart Weston1, Sergei Gulyaev1, Bumjun Kim1, Alan Litchfield1, Dylan Hall2, Jamie Curtis2, Andrew Ruthven3, Glyn Davies3, Bruno Lagos3, Don Christie3

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The progress of VLBI terminal and correlator in SHAO


Abstract To meet the VGOS station and the deep-space mission requirement, Shanghai Astronomical Observatory (SHAO) has carried out development works on VLBI terminal and correlator. There are two VLBI terminals under development. The VGOS terminal is for wideband observation and the maximum data speed is up to 16 Gbps with VDIF data format. The deep-space one has narrow band observation ability with 1-16 bit quantization.

A general purpose software VLBI correlator for space probe tracking, geodesy and astrophysics is developed. It has been applied to CE-3 lander phase referenced VLBI position. Besides, it will be used in Chang’E-5 mission dual objects tracking and IVS data processing.

We also tried the prototype terminal by Roach board, a GPU + CPU software correlator and a VLBI data simulator. Some progress has been made.

Session-1: Technology

Presentation type: Oral

Weimin Zheng\textsuperscript{1,2}, Renjie Zhu\textsuperscript{1,2}, Juan Zhang\textsuperscript{1,2}, Li Tong\textsuperscript{1,2}, Lei Liu\textsuperscript{1,2}, Ji Yunli\textsuperscript{1,2}, Shaoguang Guo\textsuperscript{1,2}, Fengxian Tong\textsuperscript{1,2}, Fengchun Shu\textsuperscript{1,2}

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Session-1: Technology

- Poster Contributions -

Picture: VGOS-receiver with QRFH installed in the northern OTT telescope.
Geometric variations of a geodetic telescope

S. Bergstrand, P. Jarlemark, M. Herbertsson, J. Spetz, C.-G. Svantesson

Abstract In order to become a reliable tool for sea level variation as a climate change indicator, the requirements on the ITRF produced by the International Earth Rotation and Reference Systems Service (IERS) are an order of magnitude tighter than current standards. The uncertainty components of the contributing techniques therefore have to be scrutinized and reevaluated. We employed a set of industrial geometrical instruments (electronic distance meters, laser tracker and laser scanner) to the Onsala 20 m telescope in order to quantify the different deformations that affect the results of geodetic VLBI in a spatial realm. Our conclusion is that structural monitoring of telescopes is a necessary requirement to detect and quantify the systematic errors that prohibit analytical results that meet the requirements of 1 mm accuracy in 3D and 0.1 mm/year stability on decadal time scales.

Session-1: Technology

Presentation type: Poster
Accuracy assessment of the two WVRs, Astrid and Konrad, at the Onsala Space Observatory

P. Forkman, G. Elgered

Abstract  Two Water Vapour Radiometers (WVRs), Astrid and Konrad, are operating at the Onsala Space Observatory since many years. Astrid was first used during the geodetic VLBI campaigns MERIT 1 and MERIT 2 in the autumn of 1980. Konrad was built in the late nineties and was used as a transportable instrument during the first few years of the new millennium. Thereafter it is also permanently mounted at the observatory. The WVRs measure the sky brightness temperatures around 21 and 31 GHz and are fully steerable in azimuth and elevation angle. For the space geodetic application the main output parameter is the equivalent zenith wet delays which are calculated from the brightness temperatures.

At the observatory we also operate a 22 GHz radiometer used for spectrometric observations of middle atmospheric water vapour. The data analysis of the two WVRs can also provide equivalent zenith sky brightness temperatures at the two frequencies, 21 and 31 GHz. These are used to validate the calibrations carried out for this independent mesospheric observations around the 22 GHz line.

We are now considering a new two-channel WVR and we see a need for a careful comparison of the accuracy, reproducibility, and repeatability. A first step in this direction is a comparison of the results from the existing WVRs using data from the recent years.

We will give an overview of results obtained so far. Unfortunately, there are several data gaps due to different types of instrument failures — both WVRs are becoming old. In spite of that, there are often data available from at least one of the WVRs and approximately the two are operating simultaneously for about 50 % of the time during the recent years.

Session-1: Technology

Presentation type: Poster
Time and frequency distribution for the Onsala Twin-Telescopes

L. Helldner, K.-Å. Johansson, L. Pettersson, T. Hobiger

Abstract  In order to realize the full potential of twin-telescopes it is crucial to operate a time- and frequency (T&F) distribution system which ensures that the signal chain in both systems is connected to a single frequency standard, e.g. a H-maser. For the Onsala Twin-Telescopes (OTT) time- and frequency will be obtained from the same frequency standard which is already in operation for the 20 m antenna. However, given the long distance between the H-maser and the OTT site and considering the increased precision requirements from VGOS, T&F needs to be sent via optical fiber. In this paper we are going to discuss the system design under the aspect of internal and external requirements. We present results from link stability measurements on inter- and intra scan averaging times for a non-moving antenna as well as for an antenna slewing with maximum azimuth and elevation rates. In addition, first results from tests with the Calibration and Cable Delay Measurement System (CDMS) will be shown in order to demonstrate that both telescopes can be referred to a single frequency standard (“clock”) within the VGOS technical requirements.

Session-1: Technology

Presentation type: Poster
Communication, Coordination, and Automation for future Geodetic Infrastructures

A. Neidhardt

Abstract  This poster shows ideas, implementations, and results from seven years of technical research in computer science for realizations of future geodetic infrastructures. It explains the four pillars found: stable and safe scientific software, an extended common software toolbox, autonomous production cells, and remote access and monitoring. This is combined to coordinated multi-agent systems offering solutions for operational aspects of the Global Geodetic Observing System (GGOS) with regard to "Industry 4.0".

Session-1: Technology

Presentation type: Poster

Alexander Neidhardt
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The MIT/NASA Broadband Signal Chain - Present State, VGOS compliance, and Beyond

C. Ruszczyk, G. Rajagopalan, R. McWhirter, C. Eckert, P. Elosegui

Abstract The VGOS implementation of the MIT/NASA broadband signal chain incorporates a number of technology novelties such as the Calibration Delay Measurement System (CDMS) and the ROACH2-based digital backend (R2DBE). The former is a key component for accurate estimation of instrumental delays in the signal chain, while the latter supports full 1-GHz bandwidth sampling capability.

The CDMS adds active picosecond-level cable delay measurement capabilities to the MIT/Haystack designed calibrator to correct for cable delays, signal phase, and amplitude across the full VGOS band. This is achieved by injecting broadband calibration tones spaced every 5-MHz and a switched-noise signal for post-processing corrections. There currently exist two versions of the CDMS, one that uses the same coaxial cable (LMR400) and a second with separate fiber optic cables used to transmit and receive the calibration signal. The delay stability of these systems has been designed to exceed the following standards (Allan standard deviations): 1.8e-14 at 30 s; 5.5e-15 at 100 s; 9.0e-16 at 600 s; and 1.0e-16 at 50 min. The R2DBE is an upgrade of the existing digital backend to full 1-GHz bandwidth, thus becoming fully VGOS compliant. The first R2DBE prototype is currently under thorough testing, with upcoming plans for its deployment at the Westford station for further field testing. In this presentation, we will describe the CDMS and R2DBE systems and present results from controlled environment testing as well as well from field deployments.

Session-1: Technology

Presentation type: Poster
DBBC3: The new flexible, wide-band VLBI backend – status


Abstract  The successor of the DBBC2, the most widely adapted digital VLBI backend, is the DBBC3. It has been developed with financial support by RadioNet3 (FP7-Grant Agreement no. 283393) and can sample up to 4 GHz wide bands. In its largest configuration it can output up to 128 Gbps from 84 GHz. The first DBBC3s have been delivered to astronomical and geodetic customers. Progress since the last EVGA meeting and future plans will be shown.

Session-1: Technology

Presentation type: Poster

Gino Tuccari1,2, Walter Alef2, Michael Wunderlich2, Helge Rottmann2, Alan Roy2, Sven Dornbusch2, Armin Felke2
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BRAND: A very wide-band receiver for the EVN

G. Tuccari, W. Alef, J. Flygare, J.A. López Fernández, G. Schoonderbeek, V. Bezrukov

Abstract  BRAND stands for BRoad bAND EVN, a project to build a prototype primary focus receiver with the very wide frequency range from 1.5 GHz to 15.5 GHz, to investigate secondary focus solutions, and to make a survey of the EVN telescopes in order to set the stage for equipping all EVN stations with such a receiver as soon as possible. The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730562 and is a Joint Research Activity in the RadioNet programme. We present the motivation, aims, scope and status of the project which was started on January 1st, 2017.

Session-1: Technology

Presentation type: Poster
Session-2: Observations

- Oral Contributions -

Picture: The Onsala Twin Telescopes (left foreground), and the Onsala 25 m telescope (right background).
Bonn Correlator: Preparing for VGOS and EHT

W. Alef, A. Bertarini, S. Bernhart, L. La Porta, A. Müskens, H. Rottmann, T. Schüler

Abstract In the first part we give a short overview of the geodesy-related activities of the last two years, followed by a report of the technical developments. After about seven years of operation the HPC cluster of the Bonn correlator centre was renewed to accommodate future vastly increasing data-rates of VGOS and EHT observations; its capacity should be sufficient for the next five to seven years. We will give an overview of the cluster and the correlator performance, the first EHT correlations with playback from Mark 6 recorders, and DBBC tests of the VGOS configuration. In addition a second 1 Gb line to the Internet has been made available and organisational structures had to be adapted. Due to rapidly falling costs for Gb-Internet connections we will soon be able to improve the correlator connectivity, if need arises.

Session-2: Observations

Presentation type: Oral
Proposed establishment of a Fundamental Geodetic Station in Antarctica

L. Combrinck, A. de Witt, P. E. Opsøth, A. Færøvig, L. M. Tangen, R. Haas

Abstract The Global Geodetic Observing System (GGOS) requires a globally distributed network utilizing next generation Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI) technology to meet the objectives of GGOS. It is expected that about 30 core sites will be established globally to ensure adequate network density and geometry. The proposal presented here is by an international consortium, which will consider several sites for the establishment of a new core fundamental station, operated and funded by the consortium. We have done UV simulations for several sites, and propose that Antarctica be considered. We propose the establishment of a core GGOS site at either the Norwegian (Troll) or South African Antarctica (SANAE IV) bases. Troll is located 235 km from the coast in Dronning Maud Land at 72º 01' S, 2º 32’ E, at a height of 1270 m above sea level on the Jutulsessen nunatak. SANAE IV is located 170 km from the coast at a height of 800 m on the Vesleskarvet nunatak in Queen Maud Land at 72º 40’ S, 2º 50’ W. Unlike most other Antarctica research bases, both these stations are located on exposed bedrock, not on ice, making them suitable for geodetic installations. We propose the establishment of a GGOS core station at either of these two sites, pending on detailed site surveys. We further propose the relocation of the 20-m geodetic VLBI antenna currently located at Ny-Ålesund at 79º N, Svalbard to 72º S. This will create the longest possible North-South baseline (at this stage). Simulations have shown that adding such a station in Antarctica has a very positive improvement on U-V coverage. We present an overview of the envisioned GGOS station, details and modalities of such a project and expected scientific and other benefits.

Session 2: Observations

Presentation type: Oral
Simulation Results for KOKEE12M-WETTZ13S 'Intensives'

J. M. Gipson, K. D. Baver

Abstract  Using the VLBI scheduling software sked, we have generated a series of schedules at two-week intervals spanning a year for the KOKEE12M–WETTZ13S baseline VGOS broadband observing and the standard KOKEE-WETTZELL baseline using standard operational (S/X) KOKEE-WETTZELL baseline. This memo describes the simulations and reports the results. The initial simulations indicate that the use of KOKEE12M and WETTZ13S should improve five metrics. The best VGOS INT configuration tested increases the number of scheduled sources from 16.08 to 20.53 sources, increases the number of scheduled observations from 19.18 to 56.29 observations, reduces the UT1 formal error from simulations from 7.68 $\mu$s to 3.38 $\mu$s, reduces sensitivity to atmospheric turbulence from 16.69 $\mu$s to 14.01 $\mu$s, and reduces sensitivity to source loss from 12.66 $\mu$s to 9.22 $\mu$s. But further testing is recommended.

Session-2: Observations

Presentation type: Oral
VLBI with GNSS-signals on an intercontinental baseline

R. Haas, T. Hobiger, G. Klopotek, N. Kareinen, L. Combrinck, A. de Witt, M. Nickola

Abstract We present VLBI observations of GNSS-signals performed on an intercontinental baseline between Onsala (Europe) and HartRAO (Africa). The observations are part of a ESA pilot project within Alcantara programme of the European Space Agency (ESA) and aim at achieving synergies between VLBI and GNSS. First test observations to GNSS-satellites were performed in January 2017 and the data were successfully correlated. We describe these sessions, their planning and operation, and first results.

Session-2: Observations

Presentation type: Oral

Rüdiger Haas¹, Thomas Hobiger¹, Grzegorz Klopotek¹, Niko Kareinen², Ludwig Combrinck², Alet de Witt², Marisa Nickola²

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Simulations of VLBI-only spacecraft orbit determination

T. Hobiger, G. Klopotek, T. Otsubo, R. Haas

Abstract Recently several groups have started track satellite signals in geodetic VLBI mode for test purposes. This raises the question how one can take benefit from this new observation concept and determine parameters which have been out of the scope of classical geodetic VLBI so far.

Based on the CONT14 network, we carry out extensive Monte Carlo simulations, which include either LEO or MEO satellites, allowing us to access the accuracy and precision of VLBI-only satellite orbit determination. It is also studied how traditional parameters, e.g. EOPs or station coordinates, are affected by adding satellite observations to VLBI observing schedules. An outlook on the potential and limitations of VLBI spacecraft tracking concludes the paper.

Session-2: Observations

Presentation type: Oral

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Optimal tag-along station locations for VLBI Intensive sessions

N. Kareinen, G. Klopotek, T. Hobiger, R. Haas

Abstract  IVS Intensive sessions (INT1 and INT2) are normally observed on single baselines. We investigate the potential for improving the accuracy of the obtained UT1-UTC by including a third station in a tag-along mode alongside the standard observing network. The impact of the additional station is studied with Monte Carlo simulations using the c5++ analysis software. The location of the third station is picked from a latitude-longitude grid, where adding the station leads to an increased number of observations. We express this increased number of observations as the Tag-Along Factor (TAF). Based on real Intensive session schedules from the year 2014, a set of simulate observations are generated for the two original stations and each grid point. Only locations where the grid point provides an increase of at least 40 %, 60 %, or 80 % in the number of observations for the full year of 2014 are included. These simulated data are used to estimate UT1-UTC from the INT1 (Kokee-Wettzell) and INT2 (Tsukuba-Wettzell) with including the third tag-along station. The UT1-UTC estimates are compared to a reference solution, which is simulated using only the original observing networks. We find that the WRMS of the UT1-UTC estimates with the tag-along stations are as low as 67 % w.r.t. the reference solution. Furthermore, there are several existing VLBI stations in the areas where the tag-along stations could be located. With little effort such stations could be included in a tag-along mode to the currently scheduled Intensive sessions, thus providing the possibility to improving the UT1-UTC estimates.

Session-2: Observations

Presentation type: Oral
Lunar observations and geodetic VLBI – A simulation study

G. Klopotek, T. Hobiger, R. Haas

Abstract  Recent OCEL sessions (Observing the Chang’E Lander with VLBI) allowed the IVS community to broaden the knowledge and gain new experience concerning observations of an artificial radio source on the surface of the Moon in geodetic mode. However, the performance of current and future VLBI systems, in terms of positioning accuracy of the lander on the Moon, is still rather unclear. In order to address this and subsequent questions, we carried out Monte Carlo simulations using the c5++ analysis software in order to evaluate the accuracy with which the position of an artificial radio source on the surface of the Moon can be determined if these observations would be included in regular geodetic VLBI sessions. We present the outcomes of our study and discuss the limiting factors of this concept. Our simulation results can provide valuable insights concerning global observations of lunar radio transmitters on a timely basis and may also stimulate new observing ideas for space geodesy.

Session-2: Observations

Presentation type: Oral
Linear polarizers in VLBI: offline conversion into a circular basis

I. Martí-Vidal

Abstract  Linear polarizers are being increasingly used in Very-Long-Baseline-Interferometry (VLBI) observations, partly due to their better performance and lower polarization leakage, when used in receivers with very wide fractional bandwidths. However, observing in a circular polarization basis has some strategical advances for VLBI, especially regarding the parallactic-angle correction. We have developed a software able to convert VLBI visibilities obtained with linear polarizers into a circular basis. The conversion is performed after the correlation, which has some advantages compared to an on-line conversion (i.e., at either the recording and/or correlation stage). This software was developed as part of the ALMA Phasing Project for VLBI. In this talk, we will discuss about the main advantages of our algorithm and will show its performance on real VLBI observations (in particular, eVLBI fringes with the EVN, where Effelsberg was observing with linear polarizers).

Session-2: Observations

Presentation type: Oral

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The HOB experiments

L. McCallum, J. McCallum, J. Lovell

Abstract The transition to VGOS using new telescopes raises the question of whether the long time series of the legacy antenna can be smoothly transferred to the VGOS antenna. Shall there be common observations, and if so, for how long? At Hobart, we have been operating the 26 m Ho telescope alongside the AuScope 12 m Hb telescope since 2010. Studying the results from a series of R1/R4 experiments with both telescopes participating revealed a variation in the local baseline of 2 cm. Curiously, this was not seen during Cont14. To investigate this, we ran a 14-week long observing program in 2016, with weekly 24-h sessions including both telescopes. While in one week a special session with only Hb and Ho at X-band (HOB) was run, the next week Ho was added into an AUSTRAL S/X experiment, including the whole AuScope network (+Yg and Ke). Here we report on the results of these experiments. Primarily concentrating on the measured local baseline, aspects of various analysis options of the X-band only observations or a phase solution will also be part of this contribution.

Session-2: Observations

Presentation type: Oral

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VGOS Interoperability Observing Sessions - Results, Lessons Learned, and Guidelines

C. Ruszczyk, M. Titus, A. Burns, J. Barrett, A. Niell, P. Elosegui

Abstract The VGOS network has expanded over the last two years from a single baseline of two prototype systems at Westford, Massachusetts, and at the Goddard Geophysical and Astronomical Observatory (GGAO), Maryland, to a thriving network of up to six stations, and growing. The two prototype systems share many of the broadband attributes that characterize a VGOS system, in particular the implementation of the signal chain. Using similar technology implementation at the two ends of a relatively short baseline (about 600 km) was a desirable feature since it greatly simplified the challenge of understanding the novel VGOS data, hence also helping us improve those systems. Recently, new systems have started to come online, including the 12-m antenna at the Kokee Park Geophysical Observatory (KPGO), Hawaii, and 13-m antennas at Yebe, Spain, Wettzell, Germany, and Ishioka, Japan. Among those, the KPGO system is an improved version of the Westford and GGAO systems, while the signal chain technology of the other three systems, on the other hand, differs quite substantially from the predecessors. The expansion of the VGOS network will continue to involve embracing heterogeneity while maintaining compatibility, which is a challenge. We will present our ongoing observational efforts, a series of carefully designed and executed trial sessions aimed at the seamless integration into the VGOS network of new stations as they come online. These are necessary efforts for the successful expansion of VGOS to a truly global network.

Session-2: Observations

Presentation type: Oral
Recent developments in scheduling with VieVS

M. Schartner, D. Mayer, A. Hellerschmied, L. Plank, J. Böhm

Abstract  The Vienna VLBI and Satellite Software (VieVS) offers a possibility to create VLBI schedules and is frequently used for the AUSTRAL network and for the observation of satellites. Over the last months, several new features were developed to generate schedules for special purposes. In particular, new individual weight factors are introduced to ease the optimization process for different networks. Finding a good set of optimization parameters is not an easy task. Therefore, a tool that creates multiple schedules with varying parameters was created. Additionally, automatic simulation and analysis of these schedules with other modules of VieVS is implemented. It is now also possible to apply certain conditions to the schedules. For example, you can specify a minimum number of scans/observations per source. For very special purposes a new manual scheduling tool, supporting a graphical user interface, can be used which allows to manually select sources and adjust multiple parameters like scan length or considered baselines. Some examples using these new tools are shown.

Session-2: Observations

Presentation type: Oral

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VGOS development for Ishioka 13-m antenna

T. Wakasugi, M. Umei, T. Toyada, M. Ishimoto, R. Kawabata, B. Miyahara

Abstract The Geospatial Information Authority of Japan (GSI) constructed a new VGOS antenna in Ishioka in March 2014. Since February 2015, the Ishioka 13-m antenna observed legacy S/X sessions with Tsukuba 32-m to obtain accurate positions of the new site. Then, Ishioka has started the international observations dedicated for Earth rotation measurement taking over the role of Tsukuba 32-m from the beginning of 2017. In parallel with these legacy observations, we have carried out several broadband observations compatible with VGOS frequency setup. From August to September 2016, we installed a new signal chain including QRFH (Quadruple-ridged flared horn), up-down converters, and high speed digital samplers at Ishioka in order to participate in VGOS Trial sessions which were broadband observations coordinated by IVS. Several experimental broadband observations with Kashima 34-m of NICT and Hobart 12-m of AuScope were also performed, and the compatibility of equipment between Ishioka and other overseas stations was confirmed. We report on the recent development of VGOS equipment and results of the legacy and broadband sessions for Ishioka.

Session-2: Observations

Presentation type: Oral
Session-2: Observations

- Poster Contributions -

Picture: The Onsala Twin Telescopes (foreground), and the Onsala 25 m telescope (center background).
GFZ Simulations of VLBI Observations of E-GRASP/Eratosthenes


Abstract  E-GRASP/Eratosthenes (European Geodetic Reference Antenna in Space / European Reference Antenna of Space Geodetic Techniques Enhancing Earth Science) is a proposed ESA mission that would combine all four space geodetic techniques for the first time on a single spacecraft. Precise knowledge of the terrestrial reference frame is essential in order to meet numerous existing and future science requirements for the study of the effects of, for example, tectonic motions or climate change and sea-level rise. With the aim of improving space and time references on Earth, and the realization of a terrestrial reference frame accurate to 1 mm and a long-term stability of 0.1 mm/yr, the mission provides for co-location in space that can be accessed 365 days per year. The inclusion of the VLBI technique to E-GRASP/Eratosthenes is fundamentally important to the proposed mission, and the planned apogee altitude of above 7000 km for the elliptical orbit has been driven by the goal of providing good observability by VLBI stations on intercontinental baselines. Our VLBI group at the GFZ-Potsdam has performed numerical simulations of observations of the satellite to investigate how well the VLBI frame can be linked to the satellite frame under various observation scenarios. In addition to a simulation of standard VLBI observables, we also investigate the contribution to the solution of precise point positioning (PPP) information transmitted by the satellite VLBI frequency transmitters and received by the VLBI stations. Our simulations show that VLBI observations of E-GRASP/Eratosthenes can meet the 1 mm and 0.1 mm/yr frame requirements as long as the observing VLBI network contains a reasonably large number of stations and includes a significant number of short (by geodetic VLBI standards) baselines.

Session-2: Observations

Presentation type: Poster

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Reduction of the IVS-INT01 UT1 Formal Error through New Sked Algorithms

K. D. Baver, J. M. Gipson

Abstract  Our past work has yielded information about spatio-temporal criteria for scheduling IVS-INT01 sessions’ observations to improve the sessions’ UT1 formal errors. We have added new algorithms to the Sked scheduling program on a trial basis to use what we have learned to try to reduce the UT1 formal errors of test INT01 schedules. Here we report the results from using the new algorithms.

Session-2: Observations

Presentation type: Poster
Planning of the Continuous VLBI Campaign 2017 (CONT17)

D. Behrend, C. Thomas, J. M. Gipson, E. Himwich

Abstract  Preparations are currently underway to organize the Continuous VLBI Campaign 2017 (CONT17). The observational period has been fixed to run from 0 UT on November 28 to 24UT on December 12 of 2017, that is fifteen consecutive UT days with three days in November and twelve days in December. Unlike most of the CONT campaigns, CONT17 will be set up using three different networks. It is planned to have two networks of legacy S/X stations where one legacy network will include the ten stations of the VLBA. A third network will consist of VGOS broadband stations. The legacy networks will have around 13 stations each with as much a global distribution as feasible. The VGOS network will be significantly smaller with perhaps six stations. The different networks will allow to probe the accuracy of the VLBI estimates of the EOP and investigate possible network biases. The next steps in the preparation of CONT17 include an optimal assignment of stations to the three networks based on EOP simulations with suitable observing modes, estimation of media and e-transfer requirements, assignment of correlator resources, and coordination with the LBO on VLBA constraints.

Session-2: Observations

Presentation type: Poster
The Onsala Twin Telescopes project


Abstract The Onsala Space Observatory is the European site in the International VLBI Service for Geodesy and Astrometry (IVS) that has the longest history in VLBI. First geodetic VLBI measurements were performed already in 1968 with the 25 m radio telescope. Since 1979 the 20 m radio telescope is used, which makes Onsala today the site with the longest time series in the IVS database. The observatory is one of the unique fundamental space geodetic sites that have a direct access to the sea level and co-locate VLBI, GNSS, gravimetry, and sea level monitoring. Onsala is thus an important co-location site for the Global Geodetic Observing System (GGOS).

Being well aware of the VGOS standard it was clear that Onsala was in need for a telescope with significantly faster slew rates than the existing radome-enclosed 20 m telescope. A proposal for funding of twin telescopes was submitted by the president of Chalmers in August 2011 and an approval was received in April 2012. The building permit was obtained in February 2014. Thereafter the preparation of the grounds including the construction of roads started. The procurement process was started by an invitation in June 2014 which a after an evaluation process resulted in an order for the two telescopes from MT Mechatronics in December 2014. The procurement of the foundations was handled separately by Chalmersfastigheter and an order was placed with the main contractor Hansson & Sner in August 2015. The foundations were ready for the telescopes at the end of 2015. The containers with the telescope parts arrived in June 2016 and the installation occurred immediately thereafter. The Site Acceptance Test took place in December 2016. A broad-band VGOS receiver with QRFH feed was installed in January 2017 in the north telescope, while the broad-band VGOS receiver with an Eleven feed was installed in the south telescope in February 2017. The digital backend units, two DBBC3, were installed and commissioned in March.

We give an overview of the Onsala twin telescopes project from the initial proposal work up to today when the telescopes are just starting to enter the commissioning and testing phase.

Session-2: Observations

Presentation type: Poster
Geodetic VLBI Correlation at the Vienna Scientific Cluster

J. Gruber, J. Böhm, J. McCallum

Abstract  Geodetic VLBI correlation is a new challenge in the current activities at the research area Advanced Geodesy at Technische Universität Wien (TU Wien). We have implemented the Distributed FX (DiFX) software correlator and Haystack Observatory Postprocessing System (HOPS) on the Vienna Scientific Cluster 3 (VSC-3), which is a supercomputer located at TU Wien to correlate VLBI data. In this poster we will provide information about VLBI correlation-related activities in Vienna and we will present the VSC-3 by showing some technical aspects of this high performance computer system.

Session-2: Observations

Presentation type: Poster

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Argentinean-German Geodetic Observatory (AGGO)

H. Hase, C. Brunini, A. Cassino, M. Hähner, F. Salguero, J. Vera, A. Pasquare, F. Toledo

Abstract The Argentinean-German Geodetic Observatory (AGGO) constitutes a new fundamental station for geodesy in Argentina. It is composed by the instruments which had been used previously in the TIGO-project in Chile. AGGO is a project to develop space geodesy issues in Argentina on the observational as well as on the analysis level. While the cooperation for the operation of AGGO resp. the data production is bilateral between German Federal Office for Cartography and Geodesy (BKG) and the Argentinean National Scientific and Technical Research Council (CONICET), the scientific community of Argentina will participate in the analysis of data. After two years of preparation the infrastructure the assembling of the instruments is converging towards the full operation during this year.

Session-2: Observations

Presentation type: Poster

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Status of RANGD project

P. Jaroenjittichai

Abstract Since the first light of the 2.4-m Thai National Telescope in 2013, Thailand foresees another great leap forward in astronomy. A project known, as "Radio Astronomy Network and Geodesy for Development" (RANGD) by the National Astronomical Research Institute of Thailand (NARIT) has been approved for year 2017-2021, under the Ministry of Science and Technology’s call for STEM-education proposal. Together with a 40-m radio telescope, which will operate up to 3-mm observation with prime-focus capability for low frequency and phased array feed, a 13-m VGOS telescope has been planned to be the first geodetic VLBI station in the SEA region. The 40-m radio telescopes first light is expected in late 2019 with a cryogenics K-band, and subsequently L-band receivers, while the 13-m VGOS antenna will be installed in 2019 and undergone commissioning in 2020. RFI and geophysical environment at the site has been investigated.

Session-2: Observations

Presentation type: Poster
Status of RAEGE Network

J. A. López Fernández, J. Gómez González, L. Santos, P. de Vicente Abad, S. García Espada, R. Bolaño

Abstract The RAEGE radio telescope at Yebes Observatory (Spain) is currently equipped with a VGOS-compliant broad-band receiver. The broad-band receiver, which was developed and tested in the laboratory during 2015, was installed on February 24th, 2016. The first fringe detection with the broad-band receiver in the Yebes VGOS radio telescope was confirmed on April 28th 2016. Some more tests were performed during May and June. After this, it participated in several VGOS sessions. The integration in the antenna control system and the data acquisition in single dish mode was also developed and tested. The aperture efficiency of the system was measured in different bands between 3.5 and 14 GHz and it ranges between 60 % at lower frequencies to 40 % at the higher end. The SEFD also ranges between 2000-5000 Jy along the frequency band. The first observation using four sub-bands and four RDBE’s was performed on December 19th, 2016.

Regarding RAEGE station at Santa María island (Azores, Portugal), it is currently equipped with a tri-band receiver (S/X/Ka). The tri-band receiver was installed on November 7th, 2016, and it was developed along 2015 and 2016. Onsite works continued during 2015 and 2016, and the first light was delayed to the first half of 2017.

With respect to the next RAEGE radio telescope in Canary islands, its mechanical parts arrived to Gran Canaria island in 2016, where RFI tests are being performed to find a suitable location. Once the site is identified, civil works and assembly could start.

Finally, it has to be mentioned that the invariant points of both Yebes 40-m and 13.2-m telescopes were measured.

Session-2: Observations

Presentation type: Poster
Metsähovi Geodetic Fundamental Station - current status of the new VGOS site


Abstract The Metsähovi Geodetic Fundamental Station is a key infrastructure of the Finnish Geospatial Research Institute (FGI). It is a Global Geodetic Observing System (GGOS) core site, i.e., member of the global network of geodetic stations that are used to maintain global terrestrial and celestial reference frames, compute precise orbits of satellites and geophysical studies. Metsähovi is one of the geodetic stations that has all major geodetic observing instrumentations co-located: very long baseline interferometry (VLBI), satellite laser ranging (SLR), global navigation satellite system (GNSS), superconducting and absolute gravimeters, and the DORIS beacon. In the autumn 2015 FGI obtained financial support to build new VGOS compatible radio telescope. This project is funded by Finnish Ministry of Agriculture and Forestry and the National Land Survey. The site chosen for a new telescope is within 100 m from other facilities of the Metsähovi geodetic station. The selection of the antenna manufacturer was finalised at the ends of 2016. Mechatronics MT is responsible for the assembly and installation of the new 13-metre dish by Summer 2018.

Session-2: Observations

Presentation type: Poster
HartRAO antenna axis offset and its effect on troposphere modelling and antenna coordinates

M. Nickola, A. de Witt, H. Krásná, C. Jacobs, W.L. Combrinck, J. Böhm

Abstract Data from geodetic VLBI sessions observed with the Hartebeesthoek Radio Astronomy Observatory (HartRAO) 26-m equatorially mounted Cassegrain and 15-m azimuth-elevation radio telescopes were analysed with the Vienna VLBI Software (VieVS) to investigate the correlations between antenna coordinates and antenna axis offset (AO). The VieVS estimated AO values are compared with values obtained during a local site tie performed in 2014. The simulation tool in VieVS is used to study the effect of the AO altitude troposphere correction on the AO estimate in order to examine the 1 mm accuracy in the baseline length required by the VLBI Global Observing System (VGOS).

Session-2: Observations

Presentation type: Poster

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VLBI at GARS O’Higgins - 25 years of operation and recent developments


Abstract  The German Antarctic Receiving Station (GARS) OHiggins at the northern tip of the Antarctic Peninsula is a dual purpose facility for Earth observation since more than 25 years. It serves as a satellite ground station, operated by the German Aerospace Center (DLR), as well as a geodetic observatory for global reference frames and global change. Over the last 3 years technical upgrades and improvements comprising the modernization of the cryogenic receiver, the replacement of the Mark-4 data acquisition system by digital backends and a new hydrogen maser improved the operational availability of the VLBI system considerably. As a consequence a remote operation is now possible. 23 years of VLBI campaign data are available at GARS O’Higgins. This long time series allows a reliable determination of VLBI station velocities independently of other methods like continuous GNSS measurements. This poster presents the achieved time series which are a contribution to understand global changes and help for the realization of global geodetic reference frames. Recent developments emphasize the will to improve the data yield and to support this unique network station in the future.

Session-2: Observations

Presentation type: Poster

Volkmar Thorandt, Gerald Engelhardt, Reiner Wojdziak, Thomas Klügel, Alexander Neidhardt, Christian Plötz, Daniela Thaller, Hayo Hase, Johann-Theodor Bachem, Dieter Ullrich

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The Sheshan VGOS station progress on construction

G. Wang, Q. Fan, X. Zhang, Z. Qian, B. Li, R. Zhu, R. Zhao, L. Wang, Z. Sun, C. Huang, W. Zhen

Abstract  The Sheshan VGOS station is now building its foundation (Mar 8, 2017), it is located at the yard of Shanghai Tianma 65 m radio telescope. Here we will introduce its system configuration, main equipment performances, and the construction arrangement before the end of this year.

Session-2: Observations

Presentation type: Poster
Session-3: Analysis

- Oral Contributions -

Picture: IVS station velocities.
CONT14 Imaging and Closure Analysis of Source Structure Effects: Part 1 — Imaging Results

J. M. Anderson, M. Xu

Abstract  Source structure effects are traditionally ignored in the geodetic analysis of VLBI observations by assuming that quasars are point-like, hence treating source structure effects as unmodeled error sources. This approach has generally been justified by the difficulty of regularly imaging or otherwise determining source structure from geodetic VLBI observations, and justified by prior imaging analyses suggesting that the magnitude of source structure effects is relatively small. We use imaging results and closure analysis of the 15 days of observations of the CONT14 continuous VLBI campaign to investigate not only the theoretical contribution of source structure to geodetic observations, but also to study the real impact of source structure on the entire measurement and analysis system of geodetic VLBI. We find that the actual effects of source structure have been greatly underestimated. In this part of our report, we present initial results of our imaging analysis of the CONT14 data. We have developed Python-based software using ParselTongue and AIPS to automatically flag, calibrate, and image geodetic VLBI data with little human intervention. Our uniformly-weighted images have median dynamic ranges of about 200 for individual 24 hour sessions, and about 500 for the combined 15 days of observations, with naturally-weighted images having dynamic ranges approximately a few times higher. The imaging quality is more than sufficient to determine reasonable source structure parameters for the 67 out of 73 sources that have a reasonable number of scans with three or more stations. Although numerous difficulties remain, we show that even geodetic sessions without the VLBA can be imaged to determine source structure for a significant fraction of sources.

Session-3: Analysis

Presentation type: Oral
ITRS realizations in the framework of ITRF2014: impact of different TRF parameterizations on VLBI combined products

S. Bachmann, L. Messerschmitt, D. Thaller

Abstract  In the framework of the realization of the latest International Terrestrial Reference System, different solutions using different parameterizations for station coordinates have been published. Namely, the DTRF2014, published by the German Geodetic Research Institute (DGFI-TUM), the ITRF2014, the official ITRF, published by IGN, and the JTRF2014, published by Jet Propulsion Laboratory (JPL). These different ITRS realizations are used as a priori station coordinate information for the IVS combination process. The combination on the normal equation level comprising EOP and station coordinates is well established within the IVS and in cooperation with other space geodetic techniques (e.g. inter-technique combined TRF). The availability of accurate a priori values for station coordinates plays an important role for the estimation of combined Earth Orientation Parameters (EOP). We study the impact of using the three different TRF solutions as a priori station coordinates on the routinely combined VLBI products. The results of this study and the comparisons of the different solutions will be presented.

Session-3: Analysis

Presentation type: Oral
Towards the third realization of the International Celestial Reference Frame

P. Charlot – on behalf of the ICRF3 Working Group

Abstract  The presentation will review the progress towards the generation of the third realization of the International Celestial Reference Frame. The work for ICRF3 is carried out by a Working Group of the IAU with the aim of completing ICRF3 by 2018 for adoption at the IAU General Assembly in Vienna. ICRF3 will be based on state-of-the-art astronomical and geophysical modeling and will benefit from the wealth of VLBI data acquired since ICRF2 was built in 2009 (an additional 60 % of data). Areas of work include selecting the datasets, defining the analysis configuration, identifying the stable sources, identifying the ICRF2 to ICRF3 transfer sources, and selecting defining sources for ICRF3. The latter takes advantage of the many VLBI images available to derive source structure indices which provide a mean to assess the astrometric quality of the sources. Specific attention will be paid to the treatment of Galactic aberration which affects VLBI data at a significant level due to the > 30 yr time-baseline. Besides the standard S/X band observations (2.3/8.4 GHz), data at K band (24 GHz) and X/Ka band (8.4/32 GHz) are being considered, while the recent Gaia Data Release (DR1) provides a unique check against optical positions. Finally, an additional stage which combines rigorously individual solutions into a consolidated VLBI catalog is also investigated.

Session-3: Analysis

Presentation type: Oral

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K-band Celestial Frame: can it be better than S/X?


Abstract  K-band (22 GHz) VLBI observations are very rapidly realizing their potential to form the basis for the most accurate celestial reference frame (CRF) ever constructed. Relative to the standard S/X (2.3/8.4 GHz) observing bands, AGN at K-band have more compact source morphology and smaller core-shifts. This reduction in astrophysical systematics allows a more stable CRF at K-band. The only previous K-band CRF had 274 sources. With the 16-fold increase in data rate to 2 Gbps in our recently completed VLBA observations (project BJ083), we achieved a four-fold increase in sensitivity relative to previous observations. This allowed us to quickly double the number of sources to 551 while simultaneously improving the precision. In early 2017 we were awarded eight additional 24-hour VLBA sessions (project UD001) to continue the improvement of the K-band frame precision to be significantly better than the ICRF-2. With the inclusion of archival K-band Galactic Plane observations and recent dedicated observations in the Southern Hemisphere, we now have almost 800 sources in our K-band CRF.

Our K-band CRF now has comparable precision in Right Ascension to the international standard ICRF-2. Our accuracy is currently limited by ~ 100 microarcsecond level zonal errors that we are plan to address through increased southern observations using HartRAO-Hobart and HartRAO-Robledo single-baselines. Our analysis of BJ083 shows source position precision improving as the number of delay measurements to the -0.7 power. This near linear improvement with number of observations shows that our additional observations will make rapid astrometric progress. We are optimistic that these observations will become the core of a K-band contribution to the ICRF-3.

Session 3: Analysis

Presentation type: Oral

Aletha de Witt1, Christopher S. Jacobs2, Alessandra Bertarini3, David Gordon4, Jamie McCallum5, Jonathan Quick1, Jim Lovell5, Axel Nothnagel6, Cristina García Miró7, K. Belov2
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Update on VLBI data analysis at ESOC


Abstract  ESOCs Navigation Support Office is providing the geodetic reference for ESA missions mainly based on the processing of the satellite-geodetic techniques GNSS, SLR and DORIS. Since last year the Navigation Support Office is enhancing its expertise to VLBI processing and analysis. This will extend ESOCs capabilities to determine the absolute orientation of the Earth and therewith enables the Navigation Support Office to provide a fully independent set of Earth orientation parameters for ESA missions. Our software package NAPEOS will become capable of combining all four geodetic techniques on the observation level and thus supporting GGOS, the Global geodetic Observing System. We finished the implementation of the VLBI delay model following the IERS standards and are currently working on the parameter estimation part. We will give an update of the current status of our VLBI implementation efforts in NAPEOS and address future plans and upcoming challenges.

Session-3: Analysis

Presentation type: Oral
An empirical atmospheric tidal loading solution for particular VLBI stations

A. Girdiuk, J. Böhm, M. Schindelegger

Abstract  Tidal atmospheric loading causes small but periodic reference point displacements that are conventionally treated as reductions in space geodetic analyses. On the one hand, numerical model estimates of these displacement signals are provided, e.g., by TU Wien, Goddard Space Flight Center (GSFC) or the Global Geophysical Fluid Center (GGFC). On the other hand, with the large data base of Very Long Baseline Interferometry (VLBI) observations and the high precision of other reduction models, small effects such as tidal atmospheric loading variations can be determined directly in the analysis. In the approach presented here, using the Vienna VLBI and Satellite Software (VieVS), we solve for hourly station coordinates and show particular consideration for the obvious correlations with tropospheric parameters. Specifically, hourly intervals of zenith wet delay estimates are replaced by six-hourly intervals similar to the estimation interval of tropospheric gradients. Retrieved time series (06/2011–02/2016) of positions for station Katherine, Australia, reveal amplitudes of the diurnal atmospheric signal at the level of $-0.2$ mm and $1.7$ mm (cosine and sine of radial component) with a confidence interval of $1.5$ mm (threefold formal error). These amplitudes are admittedly large, yet they exhibit fair agreement with estimates from the utilized loading models: TU Wien ($-0.6$ mm; $0.7$ mm), GSFC ($-0.4$ mm; $0.5$ mm) and GGFC ($-0.8$ mm; $1.0$ mm).

Session-3: Analysis

Presentation type: Oral
**INT2b - determination of UT1 with parallel Intensive sessions**


**Abstract**  So far, short duration VLBI Intensive sessions (INTs) for daily UT1 determinations can hardly be assessed externally for their accuracy. Although this has been tried in special R&D sessions, so far no parallel Intensive sessions on baselines with comparable properties had been observed. For this reason, we organized a second observing series in parallel to the Wettzell (Germany) and Kokee Park (Hawaii, USA) Int1 series. Between September and November 2015 30 sessions, called Int2b, were scheduled on the baseline Tsukuba 32 m (Ts) to Wettzell Twin North (Wn) with the same frequency setup as defined for the standard Int2s on the Tsukuba Wettzell 20 m (Wz) baseline. Since technical problems occurred, 23 sessions were observed successfully on the Wn – Ts baseline in total. In this presentation, the observation setup is described and the simultaneous UT1 estimates of both baselines are compared to each other providing some upper bounds for the accuracy of the UT1 results from Intensive sessions.

**Session-3: Analysis**

**Presentation type: Oral**

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Sebastian Halsig\(^1\), Simone Bernhardt\(^1\), Alessandra Bertarini\(^1\), Andreas Iddink\(^1\), Masayoshi Ishimoto\(^4\), Frédéric Jaron\(^1\), Ryoji Kawabata\(^4\), Laura La Porta\(^1\), Alexander Neidhardt\(^2\), Axel Nothnagel\(^1\), Shota Mizuno\(^4\), Arno Müskens\(^1\), Christian Plötz\(^3\), Torben Schüler\(^1,5\)

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Impact of station clocks on UT1-TAI estimates

E. Himwich, A. Bertarini, B. Corey

Abstract The determination of the station clock offsets from UTC have a direct impact on VLBI estimation of UT1-TAI. An error in the station clocks relative to UTC causes an error of the same size in the UT1-TAI. With current UT1-TAI accuracy goals approaching 1 microsecond this is a significant effect. This presentation will discuss the size of the effect, how the measurements are made, how they are applied at the correlators, and the accuracy of the results. Currently only the relative change in UT1-TAI between experiments can be reported. The historical reference value for the UT1-TAI values will be described. Possibilities for absolute determination of UT1-TAI at the current level of the relative accuracy will be discussed.

Session-3: Analysis

Presentation type: Oral

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Twin Telescope Tests: Assessing Station Oriented Systematic Errors

C. S. Jacobs, C. García-Miró, S. Horiuchi, L.G. Snedeker

Abstract Each of NASA’s three Deep Space Network sites has multiple large antennas capable of acquiring VLBI data. The long range plan is to have four 34-meter antennas at each site. At present Goldstone has three; Canberra has three, and Madrid has two with two more under construction. These antennas offer the opportunity to do connected element interferometry (CEI) over the few hundred meter baselines within each complex.

Given that all antennas within a site are of nominally the same structural design, are run off the same clock, observe through almost the same atmosphere, and are subject to almost the same geophysics, doing CEI experiments is an excellent way to probe the limits of VLBI accuracy and expose station specific systematic errors.

This paper will report the results of just such tests which achieved about 0.2 mm baseline precision per pass. Some stations exhibit more than 1 mm systematics. Based on this data we will discuss the implications for whether the IAGs goal of 1 mm station stability in VLBI geodesy is possible for large antennas.

Session-3: Analysis

Presentation type: Oral
Near-field VLBI delay models - Implementation and testing

F. Jaron, S. Halsig, S. Han, A. Iddink, L. La Porta, A. Nothnagel, Z. Zhang, L. McCallum

Abstract  VLBI observations of Earth satellites are of interest for geodetic application in order to improve the tie between ITRF and ICRF. The analysis chain for geodetic near-field VLBI observations, however, is still under construction, one important part being the modelling the VLBI delay. Near-field targets require special delay models, because the conventional models assume the source to be at infinite distance. I will present the theoretical background of near-field delay models and their implementation into the VLBI analysis software ivg::ASCOT, and compare results to observational data.

Session-3: Analysis

Presentation type: Oral
Determining the Galactocentric acceleration vector from VLBI and its impact on the terrestrial reference frame

H. Krásná, O. Titov

Abstract The acceleration of the Solar System directed towards the centre of the Galaxy raises through the relative motion of the Solar System barycentre around the Galactic centre. So far, this effect has been omitted in the a priori modelling of the Very Long Baseline Interferometry (VLBI) observable, which results in a systematic dipole proper motion (Secular Aberration Drift, SAD) of extragalactic radio sources building the celestial reference frame with a theoretical maximum magnitude of 5-7 microarcsec/year. In this work, we present our estimation of the SAD vector obtained within global solutions of the VLBI measurements using the software VieVS. We focus on the influence of the observed radio sources with the maximum SAD effect on the terrestrial reference frame. We show that the scale factor from the VLBI measurements estimated for each source individually discloses a clear systematic aligned with the direction to the Galactic centre-anticentre. Therefore, the radio sources located near the Galactic anticentre may cause a strong systematic effect, especially, in early VLBI years. For instance, radio source 0552+398 causes a difference up to 1 mm in the estimated intercontinental baseline length, which is clearly above the modelling requirements of the VLBI Global Observing System (VGOS). Furthermore, we discuss the scale factor estimated for each radio source after removal of the SAD systematic.

Session-3: Analysis

Presentation type: Oral
DOGS-RI: new VLBI analysis software at DGFI-TUM

Y. Kwak, M. Gerstl, M. Blossfeld, D. Angermann, R. Schmid

Abstract OCCAM has served as the main VLBI software at DGFI-TUM for more than 20 years. For more flexibility and compatibility, DGFI-TUM started to develop its own VLBI software called DOGS-RI. DOGS-RI is a software library of the DGFI Orbit and Geodetic Parameter Estimation Software (DOGS) package which also includes the software libraries for SLR analysis and intra-/inter-technique combinations. That will give a possibility to keep consistency between software libraries sharing common modules. To validate DOGS-RI, we conducted internal comparisons with OCCAM solutions and external comparisons with the IVS combined solution.

In this presentation, we introduce the structure and features of DOGS-RI and some validation results. We also discuss future plans for the software and for the VLBI analysis at DGFI-TUM.

Session-3: Analysis

Presentation type: Oral

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Investigating the noise floor of VLBI source positions

K. Le Bail, D. Gordon, J. M. Gipson

Abstract  The noise floor of ICRF2 was evaluated at the level of 40 μas. Eight years of various improvements later (technique, measurements, models,...), we expect this level to have decreased significantly. The objective of this paper is to determine the noise floor of each source of the current VLBI solution with the Allan variance. The Allan variance quantifies the variance of time series at different sample periods, but it also gives access to time series statistical characteristics as the type of noise. When time series exhibit a flicker noise, it can be interpreted as any additional data will not add any more information and the noise floor is reached. For each source of the latest GSFC solution, we estimate the type of noise of the time series as a combination of white noise and flicker noise using least-squares on the Allan variance log-log curves. Each source is then quantified by their levels of white noise and flicker noise. We are interested in sources with a flicker noise level larger than a white noise level, which would suggest the noise floor is reached for these sources.

Session-3: Analysis

Presentation type: Oral
The application of ray-traced delays for the ICRF3

D. Mayer, J. Böhm, H. Krásná

Abstract  The current realisation of the International Celestial Reference System (ICRS), the ICRF2, uses VLBI data from 1979 until March 2009. Since then the data set has grown and the distribution of stations around the globe has changed (more southern stations, e.g. the Austral network). The new data reveals a systematic bias in declination between the old ICRF2 solution and the new ICRF3 prototype solutions. We investigate the influence of different troposphere modelling approaches on this bias with the Vienna VLBI and Satellite Software (VieVS). In particular, we examine the effect of using a priori ray-traced delays, which have been derived from re-analysis and operational data of the European Centre for Medium-range Weather Forecasts (ECMWF) with a spatial resolution of one degree and a temporal resolution of six hours. For example, we find a systematic effect in declination at the 100 μas level when using ray-traced delays instead of the standard approach with the estimation of gradients. Furthermore, we discuss other modelling approaches and their effects on the ICRF3, such as downweighting low elevation observations, a priori gradients from the DAO and GRAD (gradients calculated from the ECMWF data with temporal resolution of six hours) model and the applications of constraints on these gradients.

Session-3: Analysis

Presentation type: Oral

David Mayer, Johannes Böhm, Hana Krásná
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Estimating common tropospheric parameters for co-located VLBI antennas

T. Nilsson, K. Balidakis, S. Glaser, M. Karbon, R. Heinkelmann, H. Schuh

Abstract  In recent years, several new VGOS telescopes have been constructed. Many of these have been routinely participating in the regular IVS sessions, often together with a co-located legacy VLBI antenna. Such observations are interesting for determining the local ties between the legacy and VGOS telescopes, thus validating the local ties estimated in local surveys. Since the two co-located antennas will be subject to approximately the same atmospheric effects, it is possible to estimate common atmospheric parameters for them in the VLBI data analysis. This could improve the precision of the estimated parameters, in particular the baseline vector between the co-located telescopes.

In this work we investigate the impact of estimating common zenith wet delays and gradients for co-located VLBI telescopes. We show that the repeatability of the height difference between the telescopes is improved by about 50% when common zenith wet delays are estimated, while estimating common gradients improves the length of the baseline vector. Furthermore, we also investigate if there are any benefits of estimating common or correlated tropospheric parameters for the case when two telescopes are not co-located but located several kilometers apart, for example the Tsukuba and Ishioka telescopes in Japan.

Session-3: Analysis

Presentation type: Oral
Ocean tide loading - where we are standing

H.-G. Scherneck, M. S. Bos, R. M. S. Fernandes

Abstract  The actual state of affairs in ocean tide loading is reviewed, including the Free Ocean Tide Loading Service. As of current, the service computes loading parameters from a range of ocean tide models, eleven harmonic species in time and gridded in space at resolutions as given in the 27 data sources, adding local improvement with a high-resolution coastline model. In the context of this conference, we concentrate on vertical and horizontal displacement. The advent of tide models with 1/16 × 1/16 degree resolution strained the computation on the machine at Onsala Space Observatory beyond practicability. One of our measures was to relay the computation to a dedicated computer at SEGAL UBI/IDL. Another was to retain the 1/16 degree resolution only near coasts, making use of the quad-tree algorithm already engaged in the coastline process. The presentation shows the attainable gain in precision by comparing parameters based on (a) lower-resolution models, (b) on 1/16 degree resolution throughout, (c) on the mixed resolution representation, and (d) on a mapping approach that, by inherent limitation, skips the coastline resolution altogether. The latter method will be detailed; we will present the options it offers to prospective users. The options include fast retrieval of displacements at random locations from a disseminated set of grid files, which could be attractive primarily in the context of fast evolving space geodetic networks.

Session-3: Analysis

Presentation type: Oral
Absolute astrometry of weak sources with the AOV

F. Shu, S. Gao, F. Tong, W. Jiang, T. Jiang

Abstract  In recent years, more and more compact radio sources have been detected in various VLBI observing campaigns. Most of those detected sources have unresolved flux densities below 0.2 Jy and large position uncertainties above 2 mas. In order to improve their position estimates, it is required to conduct high sensitivity astrometry at S/X dual band. In the past two years, we carried out a few AOV observing sessions at the highest possible data rate within the framework of the IVS, aimed to observe a set of weak sources along the ecliptic plane and in the southern hemisphere, and achieve the regular geodesy goal. So far more than 100 weak sources have been observed. We will present scheduling strategy and some preliminary results.

Session-3: Analysis

Presentation type: Oral
A celestial reference frame based on Kalman filtering


Abstract  In this study, we investigate a novel approach to the determination of celestial reference frames (CRF). Instead of a constant model for radio sources positions, we adopt a time series representation, which allows temporal variations of radio source coordinates to be taken into account. In particular, the added flexibility is beneficial for radio sources from the "special handling" category. We compute our time series-based CRF solutions by Kalman filtering and smoothing radio source positions, which are initially obtained from single-session VLBI analysis. The temporal resolution of the estimated CRF coordinates is identical to that of the input data, i.e. usually 1-4 days. The magnitude of the coordinate variations is controlled by the amount of process noise applied in the filter, which is in turn derived from analyzing the Allan standard deviation of the corresponding radio source coordinate time series. We investigate the quality and characteristics of the Kalman filter CRF, inter alia by comparison to a traditional solution based on a global least squares adjustment using the same input data.

Session-3: Analysis

Presentation type: Oral
Structure of the radio source 0014+813 using CONT14 geodetic VLBI observations

O. Titov, Y. Lopez, L. McCallum

Abstract We have developed new approach to facilitate the structure delay for extended radio sources using the post-fit residuals calculated after adjustment of geodetic Very Long Baseline Interferometry (VLBI) observations by standard way. No imaging of a radio source is required for that method. The simplest model of a radio source including two point-like components could be presented with four parameters (angular separation, orientation, flux ratio and difference of spectral indexes) at multi-baseline VLBI network for each baseline separately. We demonstrate effectiveness of this approach on example of radio source 0014+813 intensively observed during two-week CONT14 campaign under auspices of International VLBI Service (IVS) in May 2014. Some large systematic differences in post-fit residuals for baselines of 5000 km and longer were detected. We estimated all four parameters for each baseline and determined average characteristics of the 0014+813 radio structure at the frequency 8.4 GHz. The radio source is confirmed to consist of two components separated by 0.5 mas and aligned with "north-south" direction. Implementation of the structure model to analysis of the CONT14 data set results in displacement of the 0014+813 declination on 0.070 mas north with respect to its reference position.

Session-3: Analysis

Presentation type: Oral
CONT14 Imaging and Closure Analysis of Source Structure Effects: Part 2 — Closure Analysis

M. Xu, J. M. Anderson

Abstract  Source structure effects are traditionally ignored in the geodetic analysis of VLBI observations by assuming that quasars are point-like, hence treating source structure effects as unmodeled error sources. This approach has generally been justified by the difficulty of regularly imaging or otherwise determining source structure from geodetic VLBI observations, and justified by prior imaging analyses suggesting that the magnitude of source structure effects is relatively small. We use imaging results and closure analysis of the 15 days of observations of the CONT14 continuous VLBI campaign to investigate not only the theoretical contribution of source structure to geodetic observations, but also to study the real impact of source structure on the entire measurement and analysis system of geodetic VLBI. We find that the actual effects of source structure have been greatly underestimated. In this part of our report, we present the results of closure analysis of the CONT14 continuous VLBI campaign, using the actual geodetic observables provided in the standard geodetic datasets to study the complete source structure effects on the measurements and analysis of the geodetic VLBI data. Closure quantities eliminate the effects of, and errors in the modeling of, source directions, atmospheric and ionospheric delays, clock offsets, station position offsets, Earth orientation parameters, and so on, effectively leaving only the contributions of source structure and measurement errors. Using the source structure identified in our imaging analysis of the same CONT14 observations, we show that although our image-based source structure models accurately describe the general trends of the closure quantities, there remains a significant amount of scatter, with the amount of scatter that depends on the strength of the source structure. Through a variety of statistical analyses, we show that the real size of the source structure effects and their effect on the measurement noise is far greater than previously estimated, and these effects have a significant role in the overall error budget for geodetic VLBI. Finally, we consider our results in the context of future geodetic VLBI observations including VGOS.

Session-3: Analysis

Presentation type: Oral
Initial Study of Lunar Librations by VLBI Observations of the ChangE-3 Lunar Lander

Z. Zhang, S. Han, A. Nothnagel

Abstract  Currently, lunar libration information is mainly obtained from the Lunar Laser Ranging observations. The Chang’E-3 lunar lander as an artificial radio source on the Moon provides the opportunity to observe the Moon with VLBI. Since VLBI has a high sensitivity in the transverse direction, VLBI group delays allow estimating the position(s) of the lander and/or the librations of the Moon. The librations are normally described by three Euler angles which represent the total movements caused by forced and free components. Separation of the free libration parameters may be possible from a series of observing sessions. For all possible solutions, the partial derivatives of the observed group delays w.r.t. the position of the Chang’E-3 lunar lander, the three Euler angles, and six model parameters for the free libration were derived. For validation, a few initial group delays from Chang’E-3 lunar lander VLBI observations are analyzed on the basis of these derivatives. Additionally, simulations for estimating the lunar librations from Chang’E-3 VLBI observations were performed.

Session-3: Analysis

Presentation type: Oral
Session-3: Analysis

- Poster Contributions -

![Graph showing the distance between Onsala and Westford over years with a linear trend and a rate of 16.34 ± 0.05 (mm/yr).]

Picture: Baseline length Onsala – Westford.
Calculating integrated water vapor trends from VLBI, GNSS and NWM


Abstract  Water vapor is the most efficient greenhouse gas component as it enforces global warming and reduces the absorption of solar energy. Variations in the water vapor content at its different states drive weather and climate change. The integrated water vapor (IWV) can be deduced from space geodetic techniques observing at microwave frequencies, such as very long baseline interferometry (VLBI) and global navigation satellite systems (GNSS). The explicit purpose of this study is twofold. First, we present the optimal way to extract integrated water vapor from any numerical weather model (NWM). Second, we investigate the impact of alternating the modeling and parametrization of the propagation delay in the electrically neutral atmosphere on IWV trends from VLBI data analysis. In particular we alternate the a priori zenith hydrostatic delays as well as the constraints imposed on zenith non-hydrostatic delays and horizontal gradients. To this end we have analyzed all geodetic VLBI sessions (except for the so-called intensive sessions) using the least-squares module of VieVS@GFZ. Rigorously accounting for troposphere ties, we compare IWV trends estimated from our VLBI solutions with those estimated from consistent GNSS data processing at co-location sites, as well as those from the ERA Interim NWM.

Session-3: Analysis

Presentation type: Poster
Implementation of the vgosDb format at the GSFC VLBI Analysis Center


Abstract The IVS Working Group 4 developed the new format to store and exchange data obtained from geodetic VLBI observations. The new data format, vgosDb, will replace existing Mk4 databases this year. At the GSFC NASA we developed software that implements vgosDb format and will be used routinely to convert correlator output to the new data storage format. On this poster we present the vgosDb capable utilities that will replace the legacy software and our plans for switching to vgosDb format in the routine VLBI data analysis.

Session-3: Analysis

Presentation type: Poster
Automated ambiguity resolution with clustering and analysis of Intensive Sessions

A. Corbin, S. Halsig, A. Iddink, F. Jaron, A. Nothnagel

Abstract  The first steps for analysing VLBI sessions include ambiguity resolution and ionospheric correction as well as extracting cable calibration and applying meteorological data. An automated procedure for these steps has been developed within the software package ivg::ASCOT. Resolving the ambiguities is a crucial step because unsolved ones will propagate into the subsequent solution. In a first step, an adjustment is performed using ambiguity free single band delays with down-weighted multi-band delays and estimating only for the clock parameters. The delay residuals are computed with these parameters and the ambiguities of the multi-band delays are then resolved by clustering the multi-band residuals with agglomerative hierarchical clustering. This distance-based clustering technique computes a dendrogram and creates clusters with the known ambiguity spacing. So far, the procedure works for Intensive Sessions involving two stations reliably. The validity of the approach is tested by carrying out the full session adjustment incorporating zenith wet delays and UT1-UTC. The resulting UT1-UTC time series is compared with results from other analysis centers to evaluate the performance of the automated procedure. Based on experiences with these sessions, the functionality is currently being expanded to networks of stations.

Session-3: Analysis

Presentation type: Poster
Classification of VLBI radio-sources by astrometric stability using Allan Variance

C. Gattano, S. Lambert, Ch. Bizouard

Abstract  Improve the stability of the official celestial reference frame is essential for several scientific topics (e.g. astrometry and geodesy are two of the most important fields impacted). The way in which we realize the Celestial Reference System [CRS] have changed during the 90s for a better stability. Extragalactic radio-sources observed by Very Long Baseline Interferometry [VLBI] are now been selected to represent the frame, replacing the stars in this purpose. Today, we benefit from more than 35 years of VLBI observations with an accuracy lesser than the milli-arcsecond, and at such a precision, some of the sources manifest an evident apparent motion of their radio-centre on the sky. Astronomers select a subset of the most astrometrically stable sources, i.e. the less mobile, in order to realize the International Celestial Reference System [ICRS]. But the choices of the subset vary from the epoch and from the method. In 2018, a new subset will be chosen for ICRF3. In our works, we rigorously establish the astrometric stability of all the sources observed by VLBI for which the observations are available on the International VLBI Service [IVS] database to help in this task.

Coordinates time series of each sources are precisely determined and the stability of the series are computed using the Allan Variance. It leads us to a new classification of the sources with respect to this stability regarding the level and the color of the noise dominated at each time scale appreciable from the observation history of VLBI. Our works are progressing to automation.

This study fall within the era of Gaia. Because the satellite will deliver an equivalent astrometric precision in optic in the next years, it will be possible to study radio-optical links of extragalactic radio-sources (some achievements as already be done in this direction, see Mignard et. al. 2016, Petrov and Kovalev 2016, Kovalev et al. 2016). Furthermore, Gaia is estimating positions at different epochs, each time a source is crossing its focal plane, and that during the five nominal years of the space mission. This optical position variability is not accessible yet but when it will be, we will be able to compare with our data products and improve our knowledge of the physic behind differential astrometric positions and displacements.

Session-3: Analysis

Presentation type: Poster
Current development progress in ivg::ASCOT

S. Halsig, Th. Artz, A. Corbin, A. Iddink, F. Jaron, T. Schubert, A. Nothnagel

Abstract In December 2015, the VLBI group of the Institute of Geodesy and Geoinformation at the University of Bonn (IGG VLBI group, ivg) started the implementation of a new analysis toolbox named Analysis, Scheduling and Combination Toolbox (ivg::ASCOT). The software package is implemented in C++ and should finally be able to perform schedules of VLBI sessions, simulations of VLBI observations, and geodetic data analysis based on the IERS2010 conventions and intra-technique combination in a flexible environment. In this poster, the current development progress is presented. In this context, special consideration is given to the scheduling module based on singular value decomposition and impact factors as well as an automated ambiguity resolution and different possibilities to perform least squares adjustments (classical least squares adjustment, least squares collocation method and filter techniques).

Session-3: Analysis

Presentation type: Poster

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Where - A New Software for Geodetic Analysis

G. A. Hjelle, A.-S. Kirkvik, M. Dähnn, I. Fausk, E. Mysen

Abstract The Norwegian Mapping Authority (Kartverket) is an associated analysis center within the IVS. We are currently developing Where, a new software for geodetic analysis. Where is built on our experiences with the Geosat software, and will be able to analyse and combine data from VLBI, SLR, GNSS and DORIS. The software is mainly written in Python which has proved very fruitful. The code is quick to write and the architecture is easily extendable and maintainable, while at the same time taking advantage of well-tested code like the SOFA and IERS libraries.

This presentation will show some of the current capabilities of Where, including benchmarks against other software packages, and outline our plans for further progress.

Session-3: Analysis

Presentation type: Poster

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The impact of the TRF on the CRF

M. Karbon, T. Nilsson, R. Heinkelmann, H. Schuh

Abstract  Currently three Terrestrial Reference Frames (TRF) are available, the ITRF2014 from IGN, the DTRF2014 from TUM-DGFI, and JTRF2014 from JPL. All use time series of space-geodetic station positions and Earth orientation parameters, but the concept of combining these data is fundamentally different. The IGN approach is based on the combination of time series, while the DGFI is combining the normal equation systems. Both yield in reference epoch coordinates and velocities for a global set of stations. JPL uses a Kalman filter approach, realizing a TRF through weekly time series of geocentric coordinates. Further, discontinuities present in the TRFs due to f.ex. Earth quakes are not necessarily set at the same epoch in the different solutions, or present in all of them. As the determination of the CRF is not independent of the TRF and vice versa, the choice of the TRF might impact on the CRF. Within this work we assess this effect by comparing different CRF determined by VLBI, using different TRF realizations. We detect significant shifts in declination as well as rotations around the axes of the celestial frame.

Session-3: Analysis

Presentation type: Poster
Improvements of the stochastic model of the VLBI data analysis in VieVS@GFZ

N. Mammadaliyev, R. Heinkelmann, T. Nilsson, H. Schuh

Abstract  In geodetic VLBI, usually the least-squares adjustment method is applied for the estimation of the unknown parameters. The complete model of the least-squares adjustment contains the full variance-covariance matrix of the observables. However, the current stochastic model of the VLBI analysis software VieVS@GFZ includes only diagonal elements in the weight matrix of the observations that depend e.g. on the uncertainties provided by the VLBI correlation process. The observations are assumed to be independent. A number of studies had shown that modelling the stochastic model as a diagonal matrix affects the accuracy of the estimated parameters and the parameters themselves. The aim of this study is the improvement of the variances by incorporating all error sources affecting the observed minus computed delays, and the modeling of additional covariances in order to obtain a more realistic stochastic model in terms of a fully populated variance-covariance matrix. In order to evaluate possible improvements, the extended stochastic model will be applied to the analysis of the continuous VLBI campaign 2014 (CONT14) data using the VieVS@GFZ VLBI analysis software. The results demonstrate that an extended, fully populated variance-covariance matrix provides different adjusted parameters with more realistic formal errors.

Session-3: Analysis

Presentation type: Poster

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Copula-based analysis of correlation structures in VLBI data analysis

S. Modiri, R. Heinkelmann, K. Balidakis, H. Schuh

Abstract In this study, we develop a novel method to analyze and to exploit the dependency structure between parameters which have a stochastic nature. There is a well-introduced method called Copula and we apply it for VLBI data analysis. The Copula method exploits both linear and non-linear dependency between variables and it is a very powerful and efficient tool for dealing with multi-dimensional data and for modeling the relation between parameters. Then, we explore the potential of Copula-based methods to describe the relationship between station coordinates estimated from VLBI data analysis and displacement models for tidal and geophysical loading effects. First, we analyze the solid Earth tides, hydrology as well as non-tidal atmospheric pressure loading over short and long time spans using three different Archimedean Copula (Clayton, Frank, and Gumbel). The results show that Copula is able to capture and to model mentioned tidal and geophysical loading effects on VLBI station coordinates. Thus, we show that the proposed method is able to evaluate and analyze different types of tides and loading models for the displacement of the VLBI station coordinates.

Session-3: Analysis

Presentation type: Poster
The GFZ VLBI TRF solutions

T. Nilsson, S. Glaser, M. Karbon, B. Soja, R. Heinkelmann, H. Schuh

Abstract Recently, we have implemented a Kalman filter module in the VieVS@GFZ software. We have used this module to analyze all geometrically stable geodetic VLBI sessions. Based on the output from this analysis, we then calculated a global solution in order to obtain a VLBI terrestrial reference frame (TRF). In this work we present the properties of this TRF solution and compare it to a similar VLBI TRF from another global solution based on the same VLBI sessions but analyzed with the classical least squares module in VieVS@GFZ, as well as to the ITRF2014, the DTRF2014, and the JTRF2014. Furthermore, we test the impact of including different types of VLBI sessions in the global solution.

Session-3: Analysis

Presentation type: Poster
Stochastic estimation of ZWD parameter in VLBI data analysis using a Square-Root Information Filter

T. Schubert, S. Halsig, A. Iddink, F. Jaron, A. Nothnagel

Abstract  Many parameters of VLBI data analysis such as the zenith wet delay (ZWD) underlie stochastic processes and require a stochastic rather than a deterministic modeling. In contrast to least squares approaches filtering offers a way of sequential processing of parameter estimation. We perform filtering with a Kalman Filter and extend this to a Square-Root Information Filter which optimizes numerical stability. For validating the results, numerical weather models (MERRA and ECMWF) and a least squares approach (CPWLF) are applied. We find that the results highly depend on the stochastic modeling (filter tuning), i.e., the correct assessment of process noise variances, which is intended to be derived from post-fit residuals, and external meteorological data.

Session-3: Analysis

Presentation type: Poster
CONT14 Data Analysis

E. Skurikhina, A. Ipatov, S. Smolentsev, A. Diakov, V. Oli trophies, S. Kurdubov

Abstract Results of data processing of CONT14 15 day campaign of continuous VLBI sessions with a network of 17 globally distributed stations in May 2014 with participation of two stations of Russian QUASAR network stations Badary and Zelenchukskaya are presented. Analysis results on EOP precision, baseline length precision are discussed. The observed intraday variations EOP are compared with a tidal model and with results of previous CONT campaigns. Troposphere parameters are compared with ones obtained with GPS technique.

Session-3: Analysis

Presentation type: Poster
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, such as daily SINEX files, TRF- and CRF-solutions, rapid and long-term series of EOP and tropospheric parameters, which are obtained from the IVS observational sessions. The IAA AC also generates and submits to IVS NGS files transformed from Mk3/DBH files. Besides IVS VLBI data, IAA AC processes domestic observations produced by both the RT32 radio telescopes (Svetlo, Zelenchukskaya, Badary) and the new RT13 radio telescopes of new generation located in Zelenchukskaya and Badary observatories.

Session-3: Analysis

Presentation type: Poster

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Comparison of least squares and Kalman Filter solutions from different IVS analysis centers

E. Tanır Kayıkcı, Ö. Karaaslan

Abstract  IVS Analysis Centers apply various statistical methods, namely Least-Squares (LSQ) method, the Kalman Filter (KF) method, the Square-Root Information Filter (SRIF) and the Least-Squares Collocation (LSQC) method and consider the behaviour of stochastic parameters in different approaches. The majority of geodetic VLBI analysis softwares uses LSQ, e.g., CALC/SOLVE software, Vienna VLBI Software (VieVS) and OCCAM. QUASAR and OCCAM use LSQC. Kalman filters or square-root information filters are applied in OCCAM and SteelBreeze. Eventhough Kalman Filter is not one of the commonly used techniques in VLBI analysis software, it has some advantages to determine short-term random variations in the estimation of tropospheric delays and clocks which might affect accuracy of estimated parameters accuracies. In Least-Squares (LSQ), parameters are described as constant through different measurement epochs. LSQ estimation supposes that the parameters that we want to estimate are constant for all observation equations in the problem. Nevertheless we can have the case that certain parameters in the same problem might have variations based on the time, atmosphere or any other causes. However, in Kalman Filter estimation procedure, parameters can have variations at each epoch and their behaviours can be described statistically so this procedure allows the estimation of instantaneous changes. Additonally, with the Least-Squares estimation method; each observation requires the computation of a multidimensional matrix inverse. Computations with the Kalman Filter method are simpler and faster, so the method is very convenient when a number of parameter changes must be quickly analyzed.

In this study, we first consider comparison of KF and LSQ solutions from different IVS analysis centers to some ideas about the procedures which can be implemented in Kalman Filter output to make it combinable with LSQ results are given for VLBI intra-technique combination.

Session-3: Analysis

Presentation type: Poster
I VS Primary Data Center and Analysis Center at BKG

V. Thorandt, G. Engelhardt, D. Ullrich, R. Wojdziak

Abstract The BKG (Federal Agency for Cartography and Geodesy) Data Center is one of the three IVS Primary Data Centers. It archives all VLBI related data of IVS components and provides public access for the community. The VLBI Analysis Group of BKG is part of the jointly operated IVS Analysis Center of BKG and the Institute for Geodesy and Geoinformation of the University of Bonn. The BKG is responsible for the computation of time series of earth orientation parameters and tropospheric parameters, the generation of SINEX files for 24 hours VLBI sessions and Intensive sessions, and quarterly updated global solutions for terrestrial reference frame and celestial reference frame realizations.

Session-3: Analysis

Presentation type: Poster
The new potential VGOS site in Poland

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Abstract  We consider the possibility of an adoption of the Polish radiotelescope RT-3 in Piwnice near Torun to the VGOS standard. This telescope is a one of two existing in Torun Centre for Astronomy. Meanwhile the 32-meter telescope is used for astrophysical purposes, the smaller one, RT-3 15-m radio telescope, could be possibly included into VLBI network after some necessary modernization. It is assumed to be available for geodesy 6 days per week. This radio antenna was built in 1989, it has an equatorial mount and it is placed in well-established observatory site with all facilities needed, such as hydrogen maser, geodetic network around the site, meteorological station, etc. The RT-3 telescope need an renovation to fulfill the VGOS requirements. Here we present the antenna and the scope of work to be done as well as the theoretic analysis of the impact of including RT-3 into the routine observations on geodetic parameters such as EOP or station coordinates.

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