EUROPEAN SCIENCE FOUNDATION

32 CRAF News

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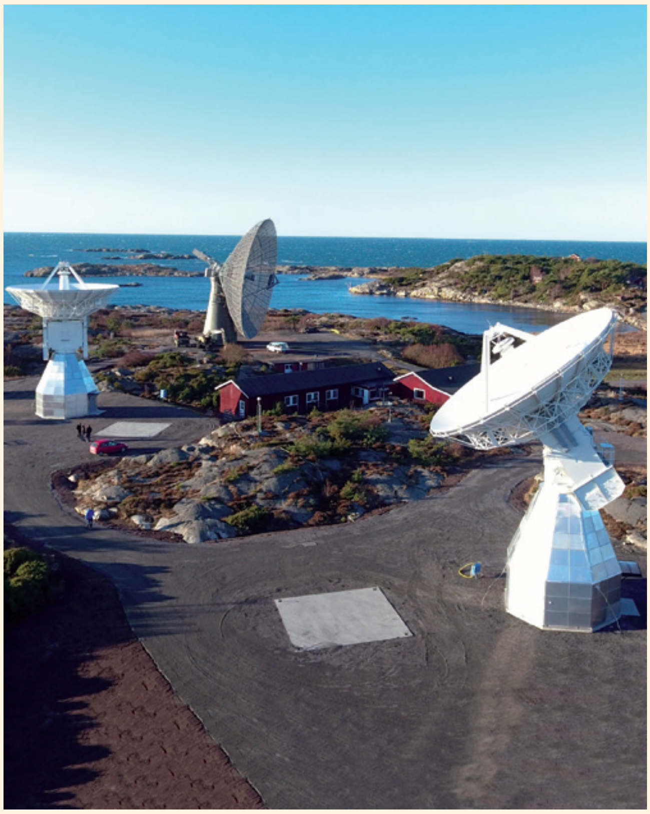
Editorial

I had been made aware of the interference to radio observations from home electrical equipment, motor vehicles etc. as long ago as the early 1960s, when I first became interested in radio astronomy. In order to avoid the considerable radio interference generated by the trolley bus system, lorries, cars and other household and industrial, electrical equipment, Sir Bernard Lovell had already moved out from the city-based University of Manchester to the Cheshire countryside (Jodrell Bank), where the University Botany Department owned some land for their research, As a young Ph.D student, I soon realised that random noise signals from industrial and domestic sources (EMI) were not the only form of interference that could occur. Following the advice of my supervisor, I had built my first receiver to operate at 7.8 GHz and installed it on the MK II telescope. To my deep disappointment, it turned out to be saturated by a radio communications link. Embarrassingly this turned out to be a link belonging to our own observatory, carrying the data back to Jodrell Bank from our only outstation telescope at the time. Since then, the numbers of radio links have increased considerably, and even with the introduction of optical fibres, they continue to be used by commercial companies, as they find them to be much cheaper than optical fibres for comparatively low data rates.

There have been a number of occasions over the years when we have had to search for sources of interference, clearly of a communications nature, in the protected bands allocated for radio astronomy. After much time and effort, the source of the interference – often malfunctioning equipment – has been identified and turned off by its owners until it could be repaired. Nowadays, not only are there fixed links, which are solely ground-based, but there are many Earth to Space, Space to Earth and even a number of Space to Space communications links, which are possible sources of interference to radio telescopes, especially if there are equipment failures.

Perhaps now of greater concern are the tens of thousands of small satellites (picosatellites, cubeSats, one Web and Space X internet broadband satellites etc.) projected to be launched within the next few years. As an example, with an ultimately planned total number of over 7 500 Space X satellites and a projected size of ~2 000 km for the diameter of the patch of the Earth that could be illuminated by a single one of them, the probability that many are visible to a radio telescope at any one time would appear to be very high. Add to this the several tens of thousands of small satellites expected to be launched by other companies, the failure of only a very small fraction of them could be very damaging for radio astronomy observations on the Earth. Without a facility to switch off the transmissions of a failed satellite, and a failure could mean that transmissions into a radio astronomy protected band cannot be stopped, radio astronomers might have data very badly affected by interference, or even have to stop making observations and wait until a failed satellite falls back to the Earth, as it is very unlikely to be economic to pay a visit to a failed small satellite for a quick repair. This could be very costly for radio astronomy.

Peter Thomasson



Cover
The Onsala Twin Telescopes, built between 2015 & 2017, to be used in a VLBI Global Observing System (VGOS). The diameters of the two telescopes are 13,2 m. Also shown in the photograph is the 25.6-m polar-mount telescope, a general-purpose, radio telecope built in 1963.
Credit: Roger Hammargren, Onsala Space Observatory, Sweden.

Report from the 61st CRAF Meeting

The 61st CRAF Meeting was organised by Lóránd Eötvös University (ELTE) and took place from the 13th to 15th June 2018 inclusive in Budapest and Bercel village, Hungary, the latter being approximately 50 km NNE of Budapest and close to a possible site for a new radio observatory. The meeting on the third day was held in Bercel Castle,

The meeting was opened in ELTE by a welcome from Prof. Dr. Imre Jánosi, the Vice-Dean of the Faculty of Science, to which Peter Thomasson, the CRAF acting chairman responded, thanking ELTE for its hospitality. There were 20 participants at the meeting, one of whom, Antonis Polatidis, was the proposed new CRAF member to represent the Netherlands. (The CRAF members agreed with the proposal for Antonis Polatidis to represent the Netherlands and invited him to be present at the whole meeting.) There were also 2 observers, G.H. Tan from ESO and F. Di Vruno, representing the SKAO.

Following a review of the 'Action Items' not only from the CRAF 60 meeting, but also from a CRAF Web meeting in October 2017, the minutes of the CRAF Web meeting were reviewed and approved.

The CRAF Budget

There was a careful review of the CRAF budgets from 2017 to 2019 inclusive, which showed a final positive balance, but only because of a 'carryover' from previous years. As appears to be the case with many budgets nowadays, there was a realisation that increased funding for CRAF would be required in the near future to ensure its viability, and above all to fund the work that it undertakes in trying to preserve spectrum for radio astronomy at a time when spectrum is perceived to have very considerable financial and societal value.

RadioNet H2020

RadioNet has been an invaluable contributor to the operations of CRAF, in particular Work Package (WP) 4.2, entitled Spectrum Management, which provides funds for representation of European and South African radio observatories in spectrum management at a European (CEPT) and Global (ITU) level. A report on the current status of this, prepared by Hans van der Marel, was presented by Michael Lindqvist, which showed a current satisfactory situation. In addition to his WP4 (Sustainability) role, the RadioNet Management had proposed that Hans van der Marel should take over as WP4.2 task leader, which meant that a second approver within CRAF for WP4.2, in addition to Lindqvist, had to be identified. Pietro Bolli was unanimously approved for this role by the CRAF EC.

A Workshop on the future role of spectrum management and CRAF is to be co-organised by CRAF and IUCAF, with funding from IUCAF, Stellenbosch University in South Africa and RadioNet under WP3 (training). This workshop, initially planned to take place in Stellenbosch University in 2018, has now been postponed until 2020 (initially 2019, but further delayed because of the WRC). This might now seem to be a long way into the future, but there was a reminder that time passes quickly and activity is already required from those identified to organise the workshop from the CRAF side.

CRAF Frequency Manager (FM) Report

The CRAF Frequency Manager presented her report for the previous year (i.e. 12 calendar months – May 2017 - May 2018), during which she outlined the main spectrum issues currently affecting the Radio Astronomy Service (RAS) in Europe, and provided a forward look at the work envisaged in the coming months. A major part of this future work involved attendance not only by the CRAF FM, but also individual CRAF members, at a very large number of preparatory meetings, which she listed, in preparation for the next World Radio Conference (WRC-19). Inevitably, the problem of interference from the Iridium communications satellites, in particular the current status of the assessment of the newly launched satellites, was discussed. There was also an update on the progress of the WRC-19 Agenda Items, which were relevant to radio astronomy, as a result of the outcomes from recent meetings.

The Stakeholders Forum

Eight directors from the CRAF member institutions attended the 'Stakeholders Forum' (two by remote access), which has become a part of the CRAF face-to-face meeting during the afternoon of the second day. The CRAF liaison at the ESF also attended the Stakeholders Forum remotely. As a result of the resignation for personal reasons of the CRAF Chairman, Wim van Driel, and the lack of an immediate replacement, a CRAF management group was established during this forum, with Peter Thomasson becoming its initial spokesperson. It was envisaged that this would function until the end of 2019; i.e. the end of the current World Radio Conference cycle. The main tasks of the team would be to ensure the continued functioning of CRAF, to prepare for the WRC-2019 and also to consider the introduction and establishment of 'CRAF Work Items'. At this present time when there has been a massive increase in the use and demand for spectrum, it was recognised that more CRAF members needed to give more of their time to spectrum management. The 'CRAF Work Items proposal', originating from MPIfR and described by Benjamin Winkel, is intended to increase the active participation of the CRAF members in national and international spectrum management, in particular at CEPT and ITU meetings, so that the overall workload of CRAF is more evenly shared amongst the CRAF members. The proposal, which was presented for consideration, envisaged teams of 3 or 4 CRAF members following particular spectrum management topics and attending meetings relating to them.

Observatory reports

As at every CRAF plenary meeting, each CRAF member present gave a report on new or ongoing interference problems from which their observatories were suffering.

Also of particular interest was perhaps that a workshop had been organised at MPIfR to teach CRAF participants how compatibility studies can be performed using the new Pycraf software package, introduced a year ago by MPIfR. This had eventually resulted in a publication (https://arxiv.org/abs/1805.11434) to demonstrate its application using a contemporary example (generic compatibility study for 5G at 24 GHz).

Peter Thomasson & Vincenza Tornatore

Report from the 62nd CRAF (Web) Meeting

As has become the norm, the 62nd CRAF Meeting was held in the autumn time, on 24 October 2018, and was a Web Meeting into which 14 participants dialled. In addition to a review of the Action Items resulting from the 61st CRAF Meeting, held in Budapest, Hungary, the main items of the Agenda were the approval of the minutes of the 61st CRAF Meeting, a report of meetings attended by the CRAF Frequency Manager, and an in depth discussion of the 'Work Items proposal' originating from MPIfR, which is intended to increase the active participation of the CRAF members in national and international spectrum management, and in particular at CEPT and ITU meetings.

No issues were raised arising from the Minutes of the 61st Meeting, which were therefore approved. The acting Chairman, Peter Thomasson, led the assessment of the Action Items, which resulted in 3 items being closed, but 2 new items to be added to the list. These concerned the introduction of a new 'Work Item' and associated workshop on pycraf, proposed by Benjamin Winkel, and a plan to produce a document in collaboration with the SKA, which would provide basic information on RFI & EMC matters for newly established/proposed observatories.

CRAF Frequency Manager (FM) Report

The CRAF Frequency Manager presented her report covering the period of time since the 61st CRAF Meeting, and provided a list of ITU & CEPT meetings, attendance at which over the coming months by the FM and/or individual CRAF members was very desirable. It was established that there had been, and would continue to be attendance at the ITU WP7D and SG7 meetings by CRAF members and 'observers'.

Work Items

Based upon his presentation at the 61st CRAF meeting, Benjamin Winkel gave a presentation on the motivation for the work distribution within CRAF and once again explained the idea of creating work items and associated status sheets for teams of no more than 5 people. Software was proposed for investigation as to its suitability for archiving conversations and work progress, and a list of five Work Items, considered to be currently the most important, was drawn up. It was decided that one item, 'activities in SE21/SE24/SRD', with Pietro Bolli as its co-ordinator, would 'start the ball rolling'.

Next CRAF Meeting

It was decided that the next CRAF face-to-face meeting would be held in the first half of 2019 (the earlier the better) at Jodrell Bank Observatory, UK, either at the SKAO or the Observatory itself – the exact dates still to be defined.

Peter Thomasson & Vincenza Tornatore

Low-loss Superconducting Filters for the Sardinia Radio Telescope

Radio Frequency Interference (RFI) is so detrimental to radio astronomy that several different strategies must be adopted to alleviate its impact on scientific observations. Thus CRAF represents the interests of European radio astronomers at a regulatory level. International spectrum management is fundamental to the defence of the frequency bands allocated to radio astronomy from the active services. However, other complementary strategies continue to be explored by astronomers to defend the quality of their observations. Nowadays spectrum monitoring and interference mitigation techniques are tools that are commonly in use in radio astronomy observatories. In addition, the design of front-end receivers, which are robust to RFI, is another key area that is not being neglected by radio astronomers. This is especially true when, in the presence of strong artificial radio frequency signals, a microwave filter in front of the Low Noise Amplifier (LNA) can be mandatory to prevent non-linearity in the LNA and unwanted modulation products in the mixer. Such filters are required to have extremely low-loss performance to limit any added noise to the receiver. As a result, and because of their excellent electrical conductivity, planar microwave components based on High Temperature Superconductors (HTS) have been intensively studied. Yttrium Barium Copper Oxide (YBCO) shows a huge increase in its electrical conductivity below its critical temperature of 89 K, reaching at 20 K a value several orders of magnitude higher than that of copper. While the usage of such devices has been limited to a very few applications because of the impracticality of the necessary cooling process for many telecommunication systems, radio astronomy is very amenable to this kind of technology since the receiver front-ends are already cooled to 20 K.

During the last few years a number of HTS microwave filters have been designed and fabricated for three receivers installed on the 64 m Sardinia Radio Telescope (SRT). All these filters are based on a YBCO film laid on a Magnesium Oxide (MgO) substrate with a thickness of 0.5 mm and a dielectric constant of 9.65. The front-end receivers for which they have been developed are:

a) P-band receiver (305 - 410 MHz)
b) High C-band receiver (5.7 - 7.7 GHz)
c) Low C-band receiver (4.2 - 5.6 GHz)

The microwave filters have been designed to transmit with minimal losses in the nominal frequency band of the receiver and to attenuate the out-of-band frequencies. The specific attenuation masks depend on the RFI environment and on the compression characteristics (non-linearity to high level signals) of the LNAs. The filter circuits are microstrips and spirals based on classical designs using the electromagnetic coupling between different resonators. From the filter specifications, the order of the filter is defined and the coupling coefficients between resonators are given by tables available in the literature. Using commercial electromagnetic simulations, the circuit geometry can be optimised in order to achieve the desired responses. When the filter layout is complete, the final chips are manufactured using an ion-beam milling process. The chips are then glued to the gold or silver plated titanium alloy carriers using adhesive conducting film. The titanium alloy is selected because it shows a thermal expansion coefficient quite close to that of the MgO substrate, thus avoiding stresses during cooling.

The characterisation of the devices is performed at a cryo-temperature of approximately 20 K using a Vector Network Analyser (VNA). One of the main issues of this measurement is the VNA calibration, which is carried out by placing accurate standards at the ends of the input and output cables within the cryostat. Alternative strategies are to calibrate the VNA either at room temperature, with corrections made for the lower losses of the cables when they are cooled, or to make all the measurements at cryo-temperatures. There are pros and cons for each of them.

Details of each filter series are summarised in Table 1. A photograph of a filter for each of the three, different, frequency bands is shown in Figures 1a, 1b & 1c.

Figure 2 shows the experimental scattering parameters (transmission and reflection) for one prototype of each design in their respective passbands, together with the simulated results. All the filters have been designed with a goal of -20 dB for the reflection coefficient in the simulations (red dashed curves). The measurements show that values of approximately -17 dB have been achieved (blue dashed curves), a little less than expected because of inaccuracies in the model and discontinuities in the transitions between the microstrips and the connectors. As far as the transmission coefficient is concerned, only the ripple arising from the mismatch is plotted for the simulations (red continuous curve), as the ohmic losses, which are dominated by the connectors and the conducting glue, have not been included. The measurements performed at cryogenic temperatures (blue continuous curve) include both contributions and show that ohmic losses account for 0.1 to 0,2 dB. The filter characteristics in Figure 2(c)

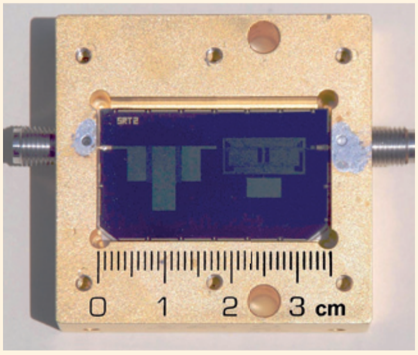


Figure 1a. HTS P-Band filter

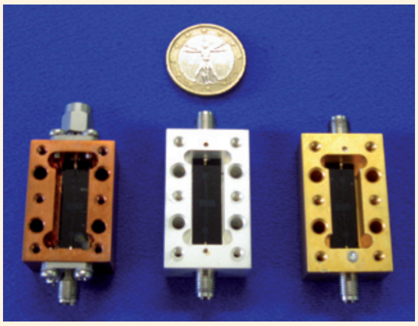


Figure 1b. HTS High C-Band filter

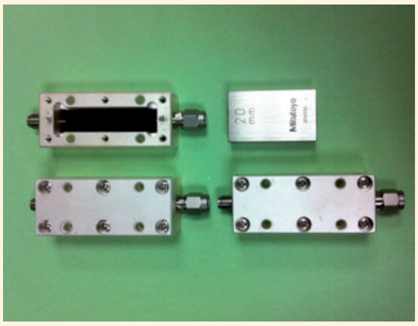
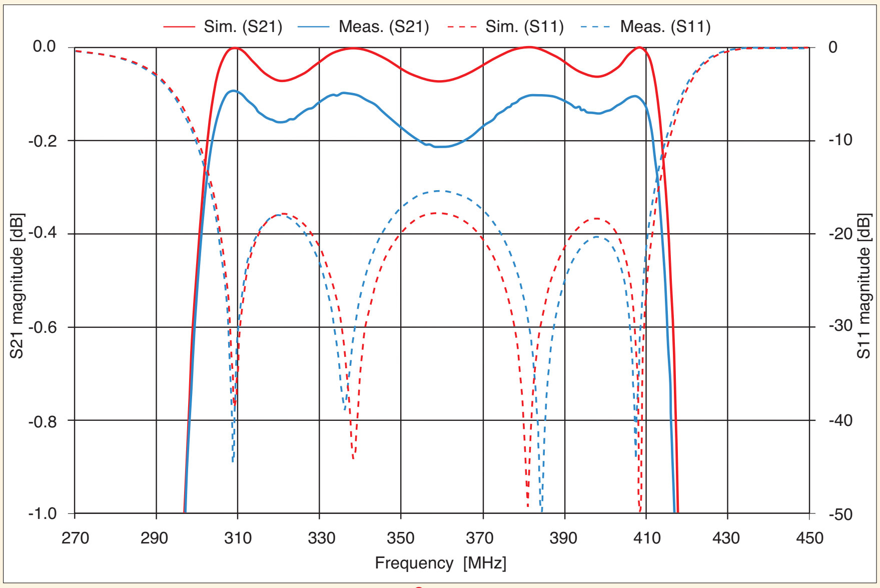
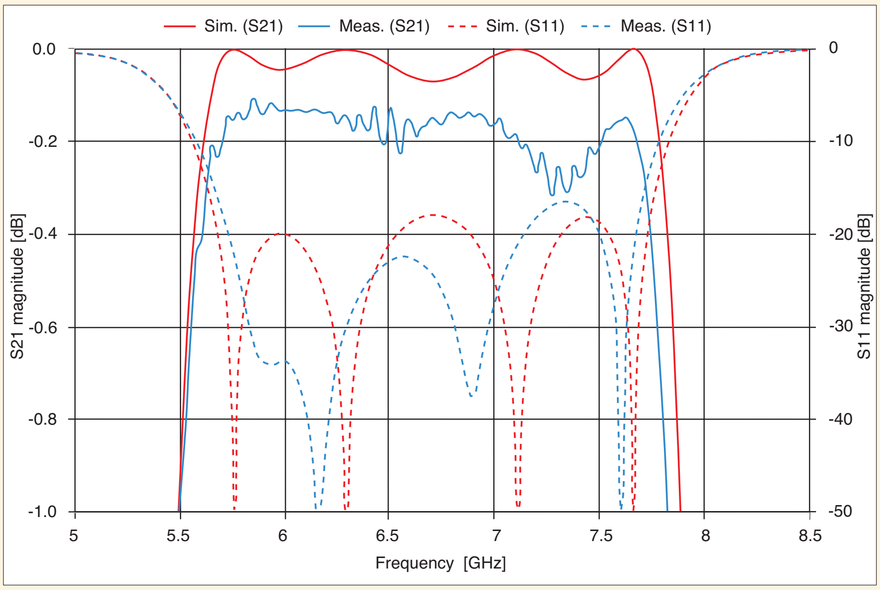


Figure 1c. HTS Low C-Band filter

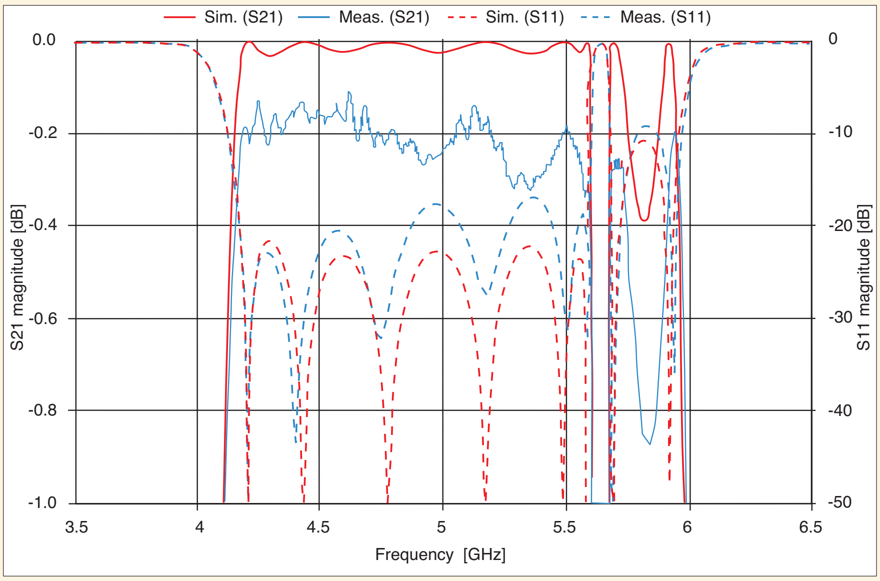
Figure 2. The experimental scattering parameters (transmission and reflection) for one prototype of each design in their respective passbands, together with the simulated results (a, b & c corresponding to Figures 1a, 1b & 1c).



2a



2b



2c

Filter	HTS P-Band	HTS high C-Band	HTS low C-Band
SRT receiver	P-band chain of the dual-frequency P/L-band receiver	High C-band receiver	Low C-band receiver
Technology	High Temperature Superconductor: Yttrium Barium Copper Oxide Substrate: Magnesium Oxide Connectors: K-sparkplug Carrier: Titanium plated with gold and/or silver		
Filter motivation	Increasing the attenuation of external signals, in particular the FM radio broadcasts and a 426 MHz carrier, by at least 30 dB.	Increasing the attenuation of external signals by at least 10 dB outside the range of frequencies 5.0 to 9.5 GHz.	Increasing the attenuation of external signals, in particular by at least 20 dB for a signal centred at 5640 MHz emitted by weather radar.
Filter layout	4^{th} order band-pass plus 5^{th} order low-pass filter to attenuate harmonics	4^{th} order band-pass	6^{th} order band-pass plus 6^{th} order narrow-notch stop-band
Receiver frequency range	305-410 MHz	5.7-7.7 GHz	4.2-5.6 GHz
Matching (S11) in the bandpass	< -17 dB	< -16 dB	< -15 dB
Losses in the bandpass	0,1 dB	0.15-0,2 dB	0.15-0,2 dB
Filter status	In operation since 2013	Filter not installed	Receiver under construction
Reference	P. Bolli, F. Huang, *Experimental Astronomy* vol. 33 (1), 2012	P. Bolli et al., *Journal of Astronomical Instrumentation* vol. 3 (1), 2014	P. Bolli et al., *Experimental Astronomy* vol. 45, 2018

Table 1. Parameters for the 3 High Temperature Superconducting Filters, installed on the Sardinia Radio telescope.

include a deliberate deep notch as described in Table 1. The characteristics to the right of the notch are not relevant to the specification and therefore have not been designed accurately. The overall agreement between measurements and numerical results is quite good, although efforts to improve the electromagnetic model and the VNA calibration strategies are continuing.

Pietro Bolli, INAF, Arcetri Astrophysical Observatory, Italy

The VLBI Global Observing System (VGOS)

Introduction

Very Long Baseline Interferometry (VLBI) is a technique, which has been developed for synthesising a very high resolution (virtual) radio telescope (i.e. one of very large size) by combining together in an appropriate manner the signals received by a number of lower angular resolution (and therefore smaller in size) telescopes spatially separated by distances ranging from a few hundred to several thousand kilometres. Knowledge of the accurate positions and detailed motions of these small telescopes on the Earth's surface are essential to correctly combine the signals together to produce a very high resolution image of an astronomical object, which might be at the extremeities of the known Universe. As the positions of a large number of these objects on the celestial sphere, in particular those which appear point-like because of their great distance from us, are known to a high accuracy after many years of measurement, it follows that geodesists can determine the smallest variations in the rotational speed of the Earth, the position of its rotational axis in space, and also the positions of the individual small telescopes on the Earth's surface. Otherwise, either the objects being observed would not appear to be in their correct positions in the sky or the data from the small telescopes could not be correctly combined together to provide a correct image of the object in the right place in the sky. Since the individual telescopes are 'sitting on' the tectonic plates that form the Earth's surface, which are moving, it follows that the motions of the tectonic plates can be determined. The accuracy with which they can be determined is dependent upon the maximum distance between a pair of telescopes, or the effective size of the synthesised telescope. The larger the synthsised telescope, the more accurately can the motions and positions be determined.

The importance of VLBI for space and satellite missions, as well as for time-keeping, made it necessary to establish a permanent observation service, which in 1999 resulted in the International VLBI Service for Geodesy and Astrometry (IVS). It is a service for both the International Association of Geodesy (IAG) and the International Astronomical Union (IAU). The requirement of the IAG from the IVS is the delivery of a time series of geodetic parameters, such as Earth orientation parameters, station positions for terrestrial reference frames, and baseline evolutions for geodynamical studies. The IAU requires the positions of the radio sources to better determine the international celestial reference frame (ICRF).

The IVS was created on a best efforts basis by an existing multilateral cooperation, which started in the 1980-ies as a part of NASA's Crustal Dynamic Project. Once founded, the IVS member institutions began to consider how geodetic VLBI should best function. Working groups were initiated, which considered technical progress of relevant VLBI components, such as computational power, electronics, and mechanical solutions. Integration of these ideas into a modern-day concept has led to what is now called the VLBI Global Observing System (VGOS). Important aspects of VGOS are:

- fast slewing radio telescopes (azimuth 12 deg/s, elevation 6 deg/s) enabling an increased number of observations per time unit than previously, and thus allowing sub-diurnal Earth rotation variations to be determined
- increased sampling rates up to 16 Gbps, which improve the signal-to-noise ratio and shorten the on-source observation time to 10 seconds
- broadband receivers covering a spectrum from 2 - 14 GHz to enable connection of the phases of four observing spectral bands, each of 1 GHz width, and thus increasing the observational precision
- a continuous 24 h/7 days operation providing uninterrupted Earth monitoring.

The VGOS concept is the VLBI part of a larger endeavour; the Global Geodetic Observing System (GGOS), which in turn is part of the most prominent global change monitoring challenge; the Global Earth Observing System of Systems (GEOSS). This is a United Nations initiative by the Group on Earth Observation (GEO) which was started at the UN Meeting in Johannesburg, South-Africa, in 2006. GGOS aims at providing a terrestrial reference frame with an error level of approximately 1 mm globally! This resolution, achievable by geodetic measurements and appropriate modelling of geodetic results, should be possible in the near future. Consideration of global change processes (e.g. the increase of sea-level) requires precise reference frames in order to make the right political decisions on investments in flood protection for harbours and dykes. Any prediction with its error margins from simulations already needs a vertical reference of the above quoted accuracy. It clearly matters whether construction projects suggest an elevation of 20 cm or 40 cm for a harbour infrastructure.

GGOS needs the new concept of VGOS for the realisation of the most precise global reference frame to be linked with the celestial reference frame. As the work for it cannot be fulfilled by one country alone, it required attention by the United Nations. On February 26, 2015, the 69th UN General Assembly adopted its resolution 266 "A global geodetic reference frame for sustainable development". Amongst other demands it:

4. "Invites Member States to commit to improving and maintaining appropriate national geodetic infrastructure as an essential means to enhance the global geodetic reference frame".
5. "Also invites Member States to engage in multilateral cooperation that addresses infrastructure gaps and duplications towards the development of a more sustainable global geodetic reference frame".

To satisfy demand "4", national geodetic infrastructure (including radio observatories for geodetic VLBI) requires improvement and protection. This is a relevant task for all national authorities, usually the mapping and the spectrum authorities.

To satisfy demand "5", it is necessary to expamd the existing geodetic reference network with new VLBI stations in order to achieve a better global coverage, and hence a more precise global reference frame. It is hoped that more member states will contribute VGOS infrastructure to the IVS in the future.

Fifteen years have passed since the first ideas of VGOS were discussed. During this time several countries have made and/or are making an effort to modernise their VLBI infrastructure by committing new VGOS radio telescopes to the IVS. The network, including new VGOS radio telescopes, currently comprises the following observatories:

- ITU-Region 1 Europe/Africa:
  - Germany: Wettzell (2);
  - Spain: Yebes, Gran Canaria (under construction);
  - Portugal: Santa Maria, Flores (planned);
  - Sweden: Onsala (2);
  - Norway: Ny Ålesund (2);
  - Finland: Metsähovi (under construction)
  - South-Africa: Hartebeesthoek (under construction);
  - Russia: Zelenchukskaya, Badary, Svetloe (under construction);
  - Italy: Matera (planned).
- ITU-Region 2: Americas:
  - USA: Greenbelt, Westford, Kokee Park, MacDonald (under construction).
- ITU-Region 3 Asia/Australia:
  - Japan: Ishioka;
  - China: Shanghai;

– Australia: Hobart, Katherine, Yarragadee;
– France (Tahiti): (planned);
– Thailand: Chiang Mai (planned).

In parallel with the development of a VLBI global observing system, the expansion of mobile phone services and access to the internet are demanding more and more electromagnetic spectrum within the radio window of the atmosphere. The massive installation of transmitters on the Earth's surface or on-board satellites calls for a prudent spectrum management. So far there is no specific spectrum allocated to geodetic VLBI. In fact, for the purely passive geodetic VLBI service the little-used spectrum of the legacy bands 2.20 - 2.35 GHz, 8.1 - 8.9 GHz have served for decades. The proposed allocations for 5G mobile telephones (3.3 - 4.2 GHz, 4.4 - 4.9 GHz, 5.9 - 7.1 GHz) and the satellite-based communication infrastructure (10.7 - 12.7 GHz) will occupy spectrum, which has also been identified for observations by the new VGOS observatories with their broadband receivers, which cover a range 2 - 14 GHz (See Figure 3).

Hayo Hase, Federal Agency for Cartography and Geodesy, Germany,
Rüdiger Haas, Chalmers University of Technology, Sweden

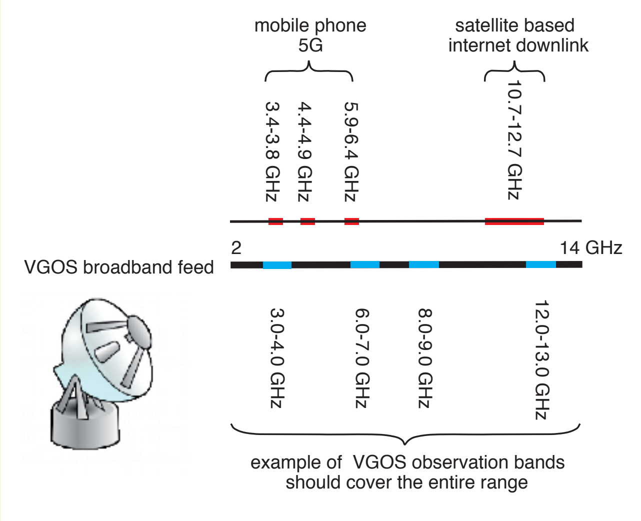


Figure 3. Future 5G base stations and satellite-based internet downlinks such as Starlink and Oneweb conflict with the monitoring of the Earth by the VGOS.

VGOS at the German Geodetic Observatory at Wettzell

The Twin Telescope Wettzell (TTW) project is the German realisation of a VGOS conforming antenna pair. It consists of two identical antenna systems with broadband receivers. After a long planning phase, finance was approved by the German Federal Parliament and the construction was undertaken from 2010 to 2012. The Twin telescopes started an operational test phase with an official inauguration with international guests on April 26th, 2013.

Whereas the two telescopes with their 13,2 m dishes have exactly the same structures and support slewing speeds of 12 degrees per second for azimuth and 6 degrees per second for elevation, their receiving systems are different. The northern antenna has an S-/X-/Ka- triband horn to be compatible with the legacy S-/X-system of the existing, established network, but also provides a Ka band feed, which opens the additional possibility for broadband tests.

The southern antenna already uses the broadband Elevenfeed system built by Omnysis, Sweden. It is capable of receiving all the frequency bands from ~1 GHz to 12 GHz with bandwidths ranging from 512 MHz to 1 GHz, which are freely selectable. Both antennas use a Digital Baseband Converter (DBBC) to digitise the sig-

Figure 4. The Twin Radio Telescopes of the Geodetic Observatory, Wettzell, Germany.

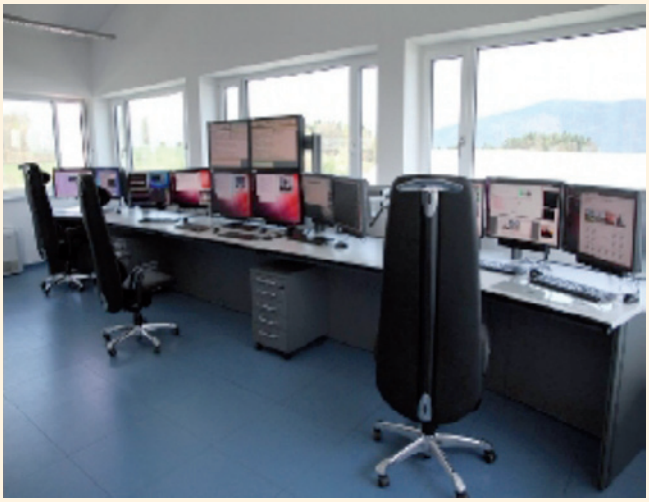


Figure 5. The Control Room of the Twin Radio Telescopes of the Geodetic Observatory, Wettzell.

nals for recording on data recorders (Mark5 and Mark6 systems).

The legacy S-/X-antenna with a 20 m dish continues to be operational, and with ~4000 operating hours per year, is still the most used geodetic antenna. All antennas can be used to support sessions of the IVS, the EVN and domestic tasks. The broadband systems are already used in regular, biweekly VGOS test sessions together with sites in the USA, Japan, and Europe. Meanwhile, all tasks for domestic needs from scheduling and observations to correlation and analysis can be undertaken locally at the observatory. Unfortunately all systems already suffer from radio interference caused by mobile phone base stations and wireless communications.

Alexander Neidhardt, Technical University Munich, Germany

Figure 6. The Onsala Twin Radio Telescopes of the Chalmers University of Technology

The Onsala Twin Telescopes (OTT)

During the period from 2015 to 2017 the Onsala Twin Telescopes (OTT) (Figure 6) were built at the Onsala Space Observatory, Sweden. The OTT are two identical VGOS-compliant radio telescopes, each having a 13,2 m diameter main reflector and 1,5 m ring-focus subreflector. The telescopes are located at a distance of 70 m from each other and are both equipped with cryogenically cooled, dual linear polarized, broadband receiving systems. One of the OTT receivers has a quad-ridge flared horn (QRFH) covering 3 - 18 GHz (Figure 7a), while the other has an Eleven-feed system covering 2.2 - 14 GHz (Figure 7b).

The receivers are interchangeable and the measured receiver noise T_{REC} is ~10 K for most of the frequency band. The front-ends on the telescopes are connected via ~1 km of optical fibres to two DBBC3 digital back-ends, each of which is connected to a FlexBuff recorder that currently has a capacity of 360 TB and a 10 Gbps connection to the 100 Gbps Swedish fibre backbone. Both telescope systems are equipped with a phase and cable measurement system (CDMS). The time and frequency distribution system uses a common H-maser. First light with both telescopes was achieved in the spring of 2017 and the first successful interferometric measurements with international partner stations were carried out in the autumn of 2017 using both telescopes. Since then, at least one of the telescopes has participated in the regular international VGOS test sessions. Currently, the commissioning phase continues with a fine-tuning of both systems. The aim is to become fully operational as part of the VGOS network in 2020. The plan is to operate the OTT as a true twin telescope system, i.e. observing with both telescopes simultaneously in a global VGOS

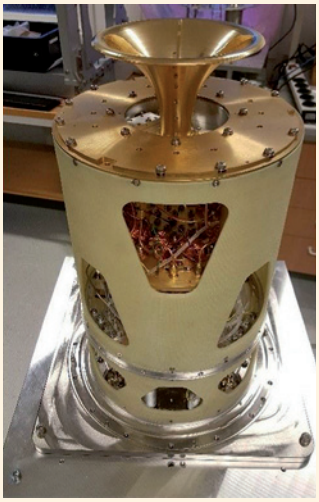


Figure 7a. The Quad-ridge flared horn

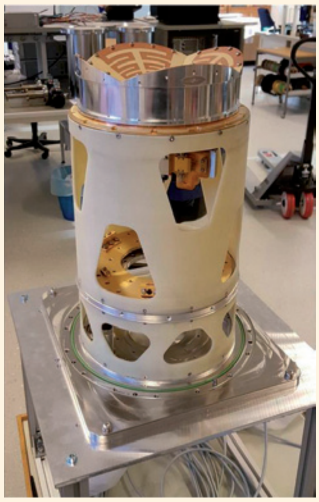


Figure 7b. The Eleven-feed system

network. This will allow the telescopes to be included in different subnets simultaneously, thus providing simultaneous observations in different azimuth and elevation directions. Using this type of observing mode, the local atmosphere can be sampled significantly better than with a single telescope, thus allowing improved modelling of atmospheric turbulence, which is the largest source of error in geodetic VLBI.

Rüdiger Haas, Chalmers University of Technology, Sweden

Spanish contribution to VGOS

The Spanish National Geographic Institute (IGN), in cooperation with the Regional Government of the Azores (GRA, Portugal), is contributing to VGOS through the so-called RAEGE project, which stands for Atlantic Network of Geodynamical and Space Stations. Four geodetic stations are to be established; one in Yebes (Spanish mainland), a second in Gran Canaria (Canary Islands) and two in the Azores islands (Santa María and Flores, Portugal). This arrangement of stations is very appropriate for measuring tectonic plate movements, in addition to other key geodetic parameters, since the Yebes station is located on the Eurasian tectonic plate, two of the sites (Gran Canaria and Santa María) are located on the African tectonic plate, and the last one (Flores) is on the North American tectonic plate (Figure 8).

Initially, each station will be equipped with a VGOS radio telescope, in addition to complementary geodetic and geophysical equipment, such as a permanent GNSS station and a superconducting gravimeter. However, the Yebes station will also be equipped with a Satellite Laser Ranging (SLR) system, which means that Yebes will become the fundamental geodetic station in Spain and one of the key stations within the Global Geodetic Observation System (GGOS).

The IGN has considerable expertise, gained over very many years, in VLBI receiver development and observations, being a member of the European VLBI Network since 1993 and one of the founding institutes of the Joint Institute for VLBI in Europe (JIVE). The IGN has been participating in geodetic VLBI campaigns with its now old 14 m radio telescope in Yebes since 1995, and a new 40 m radio telescope, inaugurated in 2007, now also regularly contributes to IVS campaigns.

In October 2013, a new VGOS radio telescope was inaugurated in Yebes and first light observations and commissioning were performed with a tri-band (S/X/Ka) receiver. More recently a VGOS broad-band receiver (2 - 14 GHz) was installed and is currently in operation. All these receivers were developed at Yebes Observatory.

First light and VLBI fringes were obtained from the 13.2 m Santa María VGOS antenna in March 2018. It was equipped with a tri-band receiver (S/X/Ka). It is expected to be equipped with its final VGOS broadband receiver after approximately one year of operation. Planning for the Gran Canaria station is well under way. The location has been identified and environmental authorisations issued. Civil works are expected to start in 2019. Finally, the Flores station is expected to be contracted by GRA in 2019.

José Antonio Lopéz Peréz, Instituto Geográfico Nacional, Spain

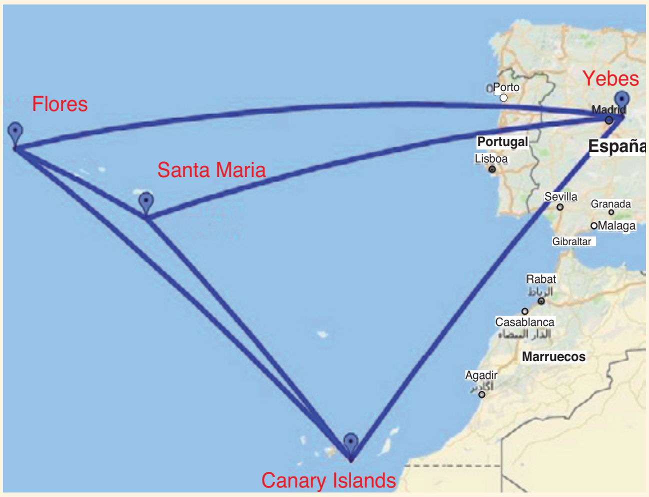


Figure 8. Locations of the Spanish / Portuguese Telescopes.

VGOS telescope at Metsähovi Geodetic Fundamental Station

The Metsähovi Geodetic Fundamental Station in Southern Finland (60.2N, 24.4E) is a key infrastructure of the Finnish Geospatial Research Institute (FGI). It is a Global Geodetic Observing System (GGOS) core site; i.e. a member of the global network of geodetic stations which is used for maintaining global terrestrial and celestial reference frames, for computing precise orbits of satellites, and for geophysical studies. Metsähovi is one of the few geodetic stations that has all the major geodetic observing instruments co-located. These include satellite laser ranging (SLR), very long baseline interferometry (VLBI), global navigation satellite systems (GNSS), superconducting and absolute gravimeters, a TerraSAR X retroreflector, and also a Doppler Orbitography and Radio positioning Integrated by Satellite (DORIS) beacon located at a distance of approximately 2 km from the Metsähovi

Figure 9. The Metsähovi VGOS telescope site during the initial construction phase.

Geodetic Station. It contributes to several global services of the International Association of Geodesy (IAG) and, because of its long existence, helps to retain sustainability in the maintenance of global reference frames.

Installation of the new VGOS radio telescope began at Metsähovi Geodetic Station during the summer of 2018, which when completed will be equipped with a broadband receiver, which has an operational frequency range from 2 to 14 GHz, and a Quadridge Flared Horn (QRFH) feed, designed to provide dual linear polarisation. The receiver noise temperature is less than 30 K across the whole of the frequency band when there is no external RFI signal. The backend of the telescope system will be a Digital Baseband Convertor – DBBC3-8L8H.

Figure 9 shows the telescope site during the initial phase of the telescope construction, completion of which is expected in 2019. Following this, installation and testing of the signal chain components will take place. It is expected that the new VGOS radio telescope will start regular observations before the end of 2019.

Nataliya Zubko, Finnish Geospatial Research Institute (FGI), Finland

The Norwegian Mapping Authority's Geodetic Earth Observatory – Ny Ålesund, Svalbard

The new geodetic Earth observatory, built by the Norwegian Mapping Authority (NMA) in Ny Ålesund, 79 degrees north, was inaugurated on June 6, 2018. It ranks as the northernmost facility of its kind and forms part of the global network. Surrounded by the Brandal lagoon, Cape Mitra and Kings Fjord, the new impressive twin telescopes will contribute significantly to the VGOS. Each antenna measures 13.2 metres in diameter and is 18 metres above the ground. This fundamental site for geodesy is complemented by a Satellite Laser Ranging facility, a time and frequency laboratory and a gravity laboratory. It is expected to be fully operational by 2022. It has an estimated cost of ~NOK 300 million.

Frode Koppang, Norwegian Mapping Authority, Norway

Report from the 10th IVS General Meeting (Svalbard / Norway)

The 10th General Meeting (GM2018) of the International VLBI Service for Geodesy and Astrometry (IVS) was hosted by the Norwegian Mapping Authority (NMA) Kartverket on the Arctic archipelago of Svalbard from Monday 4 June to Friday 8 June inclusive. The meeting, which included plenary sessions, poster sessions, an analysis workshop, several IVS splinter meetings and the IVS Directing Board meeting, took place in the city of Longyearbyen, which is the largest settlement and capital of Svalbard, located on the largest island, Spitsbergen. During this same week – on 6th June – the official opening of the NMA Kartverket's new Earth Observatory took place in Ny Ålesund. A ship transported all the participants through the beautiful Arctic scenery from Longyearbyen to Ny Ålesund, some 70 miles to the northwest of Longyearbyen.

Figure 10. The two Norwegian 13-m VGOS telescopes at Ny Ålesund.

Figure 11. Map of the Svalbard archipelago showing its location relative to Norway and also the relative locations of Ny Ålesund and Longyearbyen.

Ny Ålesund was formerly known for coal mining in the Kings Bay area, whereas nowadays it is a centre for international Arctic, scientific research and environmental monitoring, where ten different countries have permanent research stations. It is located at 78°55' N and 11°56' E on the west coast of Spitsbergen at a distance from the North Pole of 1,234 km. To preserve the site, which is one of the world's largest areas of untouched nature, Ny Ålesund is not open to the general public. A detailed topographic Map of the Svalbard islands is shown in Figure 11.

The IVS GM2018 meeting started with registration and an "Icebreaker Reception" on the Sunday evening at the Radisson Blu Polar Hotel. However, most of the meeting activities took place in the Kulturhuset in Longyearbyen, with the opening ceremony being held on the Monday morning. The participants were welcomed by Per Erik Opseth (Director Geodetic Institute) NMA and by the IVS Chairman, Axel Nothnagel. There followed a keynote speech by Zuheir Altamimi (IAG Vice-President, IGN France) entitled "The UN-GGIM Initiative on the Global Geodetic Reference Frame: Strengths and Weaknesses". He noted the achievement of the United Nations (UN) in recognising the importance of geospatial information to address global challenges by creating a UN Global Geospatial Information Management (UN-GGIM) Subcommittee on Geodesy and producing a roadmap to implement a Global Geodetic Reference Frame (GGRF) for the time period since 2015. The space-geodetic techniques; i.e. very long baseline interferometry (VLBI), satellite laser ranging (SLR), Global Navigation Satellite Systems (GNSS) and DORIS system play a major role for an accurate, accessible and sustainable GGRF to support science and society.

The theme of this 10th IVS General Meeting was the contribution of the VLBI Global Observing System (VGOS) to the Global Geodetic Observing System (GGOS) in its efforts towards sustainable development.

The GM2018 was organised into five oral plenary scientific sessions:

1. Building the VGOS network
2. VGOS techniques and observations
3. Legacy S/X and mixed legacy/VGOS operations
4. VLBI core products and their improvements
5. Extending the scope of VLBI usage

A 30 minute video, 'Quest for the Exact Position', prepared for outreach and communications by a Norwegian documentary film-maker and concerning the importance of global geodesy for the world, was shown to the meeting participants, who numbered more than 100 from 19 different countries, and who gave a total of 62 oral presentations and produced 34 posters. This gave a wide and deep overview of the current status of VGOS, its technical development and its upgrade. The first new types of observations, VGOS data correlation and analysis, both for local and global experiments, were presented, as were the main scientific results and the expected future challenges, both for VGOS and the existing VLBI legacy technique. A poster session was organised in the afternoon of the Tuesday, which led to several, productive discussions.

As is quite well-known, the VGOS project (see separate article in this issue), foresees the reception of 4 spectral bands of 1 GHz width each within the interval from 2 GHz to 14 GHz. However, there is increasing interest in this frequency range from industrial and commercial services for both Earth and satellite based communications that could degrade VGOS observations. On this matter a presentation "VGOS Wideband Reception and Emerging Competitor Occupation of VLBI Spectrum", was given to provide an alert to the danger of high data loss because of Radio Frequency Interference (RFI). Furthermore, the role and importance of the three organisations, CRAF, CORF and RAFCAP operating in ITU Regions 1, 2 and 3 respectively, representing the interests of scientists using radio frequencies for research (radio astronomers and

Figure 12. The KSAT global network – 35 antenna systems installed and operational at SvalSat. © KSAT – Yann Ziegler

Figure 13. Inauguration of the Earth Observatory in Ny Ålesund. From l. to r.: Per Erik Opseth, Lars Jacob Hiim & Anne Cathrine Frøstrup.

passive services) was underlined. So that the VGOS community and the above three 'sister' organisations operating all over the world can have closer and more meaningful collaborations, registration at the ITU of VLBI and VGOS radio telescopes was recommended. In addition, a good relationship between scientific organisations and national administrations at different levels (local, regional and global) to defend VGOS frequencies was also stressed.

Two guided visits to the Svalbard Satellite Station (SvalSat) were organised for all the meeting participants, who were divided into two groups. Group 1 visited the site in the evening of the Monday and Group 2 of the Tuesday. Each day, shuttle busses transported one group to the satellite ground station located on Platåberget near Longyearbyen. SvalSat, operated by Kongsberg Satellite Services (KSAT), and its Troll Satellite Station (TrollSat) in Antarctica are the only ground stations on the Earth that can see a low altitude polar orbiting satellite (e.g., in a sun-synchronous orbit) on every revolution as the Earth rotates. The whole facility consists of 50 antennas in total, 35 of which are installed in SvalSat alone (see Figure 12). The antennas, which are both multi-mission and customer-dedicated, are able to operate in the C, L, S, X and ka- bands, making SvalSat the largest commercial ground station in the world.

Wednesday June 6th was dedicated to the visit to Ny Ålesund and the ceremony for the inauguration of the new Twin Telescopes. A boat trip of approximately 5 hours brought all interested participants to Ny Ålesund.

The new VGOS twin telescopes and their location are shown and described in the previous article by Koppang (see Figure 10).

More than 150 guests participated in the ceremonial inauguration and listened to opening speeches by Anne Cathrine Frøstrup, Director General, NMA and Lars Jacob Hiim, State Secretary to the Norwegian Minister of Local Government and Modernisation, who outlined the importance of the twin telescopes in Ny Ålesund as part of "a basic global infrastructure for better Earth observation and for better monitoring of satellites, especially in the High North, where it is a key for the measurement of and dealing with climate change and is fundamental for our understanding of sea level change". Per Erik Opseth, head of the NMA's Geodetic Institute, emphasised that anyone who worked on this project was "respectful of the job being done, the environment and surroundings we're working in, and the fact that we're delivering something which will contribute to better monitoring of changes to the planet" (see Figure 13)

A guided tour of the facilities was provided, which demonstrated that the twin telescopes are part of a wider project at the NMA – the geodetic Earth observatory. At Ny Ålesund several geodetic measuring techniques are used; VLBI, SLR, GNSS, Doris and gravimetry. In August 2017 NASA and NMA signed an agreement to develop a state-of-the-art Satellite Laser Ranging facility with a current goal of having all systems up and running in Ny Ålesund by 2022.

At the end of the tour the attendees were invited to a Festive lunch at Kongsfjord Hall, which was accompanied by music composed and played by Fredrik Øie Jensen (saxophone) and Kjetil Rostad (guitar) especially for the inauguration, The lunch provided an opportunity to thank many people and organisations, which had made it possible to realise the challenge of building two radio telescopes in such a remote place. Amongst those warmly thanked, both with words of gratitude and personalised gifts, were Veidekke, an Arctic turnkey contractor, who had the task of preparing the station site and the new instrumentation building (a job that proved to be very demanding in the arctic conditions), Germany's MT Mechatronics and its Spanish sub-contractor, Asturfeito, who delivered the antennas, and also NASA collaborations.

Figure 14. Participants at the GM2018 meeting in front of a bust of Roald Amundsen in the centre of Ny Ålesund.

Before the return boat trip to Longyearbyen, the GM2018 guests had an hour for sightseeing at Ny Ålesund (see Figure 14). It was noted that guards were standing watch with their rifles shouldered, taking care that the perimeter around the site did not receive an uninvited visit from "polar bears". Such an event is not impossible considering that there are more bears (approximately 3 000) than people living on the archipelago.

The meeting was officially closed on the Thursday by Axel Nothnagel, who thanked the local organisers and all the participants, who had arrived from all over the world. Dirk Beherend had the honour of announcing that the next IVS General Meeting will be held in Annapolis, Maryland, USA from March 22-28, 2020, where the local host will be NVI Inc., i.e. essentially the Goddard VLBI group. In the evening the traditional conference dinner took place at which the LOC presented certificates of appreciation to the meeting attendee with the most posters; to the most seasick person and to the winner of a photographic competition, the winning photograph being a representation of the Arctic midnight sun (Figure 15).

Following the IVS GM2018 meeting, a further two days were allocated for an analysis workshop and also for a Board of Directors' Meeting. The 10th IVS General Meeting was a huge success, with presentations of outstanding research, productive splinter meetings, diverse social activities, and all of that in a very friendly atmosphere and in a unique venue wilderness amidst the beauty of the Arctic. The day of the boat excursion to/from Ny Ålesund (10 hours at sea) was a splendid sunny day, during which people could enjoy the Spitsbergen scenery of snow-capped pointed peaks and glaciers that plunge into blue waters. Special treats were a walrus colony stopover and a helicopter rescue training exercise. I am sure that all the attendees will have very fond memories of the events for a very long time, and all were very grateful to our local hosts from the Norwegian Mapping Authority for making it all happen.

Figure 15. Arctic Midnight Sun Photo Prize winner. © Yann Ziegler

Vincenza Tornatore, Politecnico di Milano, DICA, Italy

The European Science Foundation hosts five Expert Boards and Committees:

- The European Space Sciences Committee (ESSC)
- The Nuclear Physics European Collaboration Committee (NuPECC)
- The European Marine Board (EMB)
- The Committee on Radio Astronomy Frequencies (CRAF)
- The Materials Science and Engineering Expert Committee (MatSEEC)

In the statutory review of the Expert Boards and Committees conducted in 2011, the Review Panel concluded unanimously that all Boards and Committees provide multidisciplinary scientific services in the European and in some cases global framework that are indispensable for Europe's scientific landscape, and therefore confirmed the need for their continuation.

The largely autonomous Expert Boards and Committees are vitally important to provide in-depth and focused scientific expertise, targeted scientific and policy advice, and to initiate strategic developments in areas of research, infrastructure, environment and society in Europe.

Committee on Radio Astronomy Frequencies (CRAF)

CRAF is an Expert Committee of the European Science Foundation. Established in 1988, it represents all the major radio astronomical observatories in Europe. Its mission is to coordinate activities to keep the frequency bands used by radio astronomers in Europe free from interference.

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