

31 CRAF News

**The newsletter of the ESF Expert Committee
on Radio Astronomy Frequencies**

July 2017

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Editorial

The Right to Remain Silent

In the June 17 issue of *New Scientist* an article* appeared entitled “Right to silence”. In the online version, which appeared on June 14, it is called “Spectrum wars: the battle for the airwaves”. Judging from the titles one might think it concerns the arrest of criminal suspects being read their rights, or even science-fiction warfare. In fact, it is about the day-to-day activities in which CRAF is deeply involved: keeping the radio frequencies used for radio astronomical research free from interference.

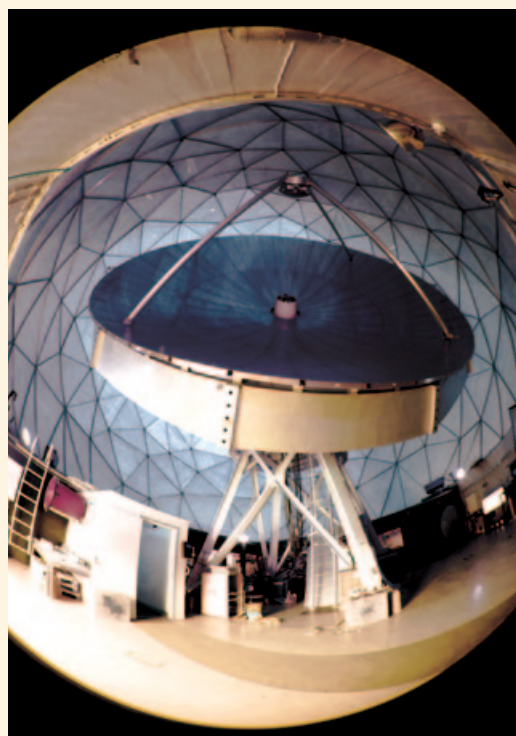
The “Right to silence” title of the printed version is catchy, and we hope that it will entice many readers to be informed about the need for CRAF’s activities. However, for those of us working at the coalface of spectrum management, we know that absolute radio quiet simply cannot be achieved amongst the crowded airwaves, which have to be shared equitably by many. The goal is rather to maintain a level of radio quietness using the regulatory tools available to ensure that radio astronomers are able to continue making their sensitive observations.

CRAF has significantly broadened its activities over the past 18 months since the last World Radiocommunication Conference (WRC) of the International Telecommunication Union, where the agenda was set for the revision of the global Radio Regulations at the next WRC in 2019. This involves a series of potential threats to our continued scientific use of the radio spectrum.

As an international organisation, CRAF has representation at meetings at a European and global level at which future threats to radio astronomy are studied and decisions on new frequency allocations are made. At a national level CRAF members interact with their Spectrum Agencies to advocate the CRAF positions, and to protect their radio telescopes. Part of CRAF’s strategy is the establishment of a core group of members to perform the increasingly complicated studies of the compatibility between radio astronomy and new radio applications that are a potential threat to radio astronomy observations.

* Stephen Battersby, Right to Silence, *New Scientist* 17 June 2017, p. 33

Wim van Driel, CRAF chairman



Cover

The Metsähovi 14-m radio telescope inside its radome. The telescope is operational at frequencies from 2 GHz to 150 GHz.

Credit: Merja Tornikoski, Aalto University, Metsähovi Observatory, Finland.

Report from the 59th CRAF meeting

The 59th CRAF meeting was organised by Aalto University in Helsinki, Finland, from 31 May to 1 June 2016. However, for the first day's meeting, the participants were transported to Metsähovi Radio Observatory, which is affiliated with Aalto University, but located ~35 kilometres to the west of the University's Otaniemi campus.

The new CRAF chairman, Wim van Driel, who had been identified as the preferred candidate for the position by the search committee, and approved in a secret ballot to replace Hans van der Marel, opened the meeting at 09.00 by welcoming the CRAF members present and also two observers, H. Smith and R. Millenaar.

A guided tour of the Metsähovi Radio Observatory and the Finnish Geospatial Research Institute facilities during the lunch break on this first day provided the participants with an interesting introduction to the work at both of these facilities. The participants were warned to beware of possible snakes whilst at the site – a very rare piece of advice when attending CRAF meetings!!

On the second day the meeting continued in Aalto University, where the participants, who all introduced themselves, were welcomed by Jyri Hämäläinen, Dean of the School of Electrical Engineering. Petteri Jokela of the Finnish Communications Regulatory Authority (FiCoRA) gave a talk about his organisation and issues that may be of concern to CRAF, and Rita Taurio, a Senior Science Adviser to the Academy of Finland, provided information about the Academy and in particular its Natural Sciences and Engineering Research Council (RCNE), through which the Finland contribution to the funding of CRAF is made.

• Communications concerning CRAF

Correspondence

A letter has been received by van der Marel (the previous CRAF Chairman) from Philip Diamond, the Director-General of the Square Kilometre Array Organisation (SKAO) in which he accepted the offer of observer status in CRAF, but informed CRAF that, since the SKAO had become a Sector Member of the ITU-R, it now had an independent voice at the ITU and its meetings. He also informed CRAF that the SKAO, being a global partnership, cannot give financial support to CRAF, a European organisation. However, he offered to host and to organise one of the future CRAF meetings at the SKAO Headquarters at Jodrell Bank in the U.K. Harry Smith had been appointed as the SKAO's Spectrum Manager.

New CRAF website

A new CRAF website has been developed and the transfer of the information from the old website is almost complete. Hezareh, the CRAF Frequency Manager (FM), will maintain the new website in the future.

CRAF member institutes and organisations

Callisto is a worldwide network of low cost radio spectrometers for solar observations (see <http://e-callisto.org/> and the article in this newsletter). There had been a suggestion that a representative of the Callisto community could perhaps become a CRAF member to the benefit of both organisations, and also perhaps to European and African countries (ITU region 1) that do not have a member of CRAF. It was decided that a CRAF sub-committee would initially consider this.

This also raised the issue of European countries with known radio astronomy activity (e.g. the Ukraine and Ireland), but no institute with a CRAF member or CRAF observer status, which might contribute to CRAF and its work. The CRAF chairman would carry out a review.

Budget

The final 2015 CRAF budget and the provisional 2016 one showed that CRAF, although solvent at the time, would require increased funding for a sustainable budget in the future. This was an item for discussion with the observatory directors within the framework of the revision of the CRAF Charter and modification of it and its Rules and Procedures.

• RadioNet

RadioNet3 Framework Programme 7

RadioNet3, which was supported by the European Commission under the 7th Framework Programme (FP7) from 01.01.2012 to 31.12.2015, had several work packages (WPs), amongst which was WP7, which was concerned with Radio Astronomy Spectrum Management. The main aim of WP7 was the financial support of CRAF committee meetings and the participation of CRAF Members at international spectrum management meetings. A final report on RadioNet3, prepared by Lindqvist, was presented at the CRAF meeting by van der Marel. The final list of all the meetings supported was presented, fully justifying the expenditure of the entire budget.

There was a unanimous vote of thanks to Michael Lindqvist for his work in managing WP7.

RadioNet4 H2020 funding application

Van der Marel presented the new RadioNet4 application, which was submitted on 30 March 2016 in response to

the EC Horizon 2020 Framework call under a heading of “Research & Innovation, Topic: Integrating Activities for Advanced Communities”. RadioNet4 has 14 Work Packages and funding has been requested to support CRAF meetings and CRAF members’ attendance at international spectrum management meetings under WP 4.2. Support has also been requested for an international spectrum management school to be held in 2018 under WP3-Training.

• European Science Foundation

Van Driel described the current status of the European Science Foundation (ESF) based on a presentation provided by Jean-Claude Worms, the Chief Executive Officer (CEO) of the ESF and the person responsible for liaison with CRAF. After 42 years of activity in European research, the ESF has undergone a major change of focus. It continues to contribute to the European Research Area (ERA), but now principally as a service-based organisation. It is building on core strengths developed in peer review, evaluation, project management services and career tracking. It continues to host five Expert Boards and Committees (EBC), including CRAF, which provide in-depth and focused scientific expertise in selected disciplines. A new brand name, “Science Connect”, was registered in November 2015, but the ESF brand will still be used in connection with the new one.

• Frequency Management Activities

The CRAF Frequency Manager (FM), Talayeh Hezareh, presented a full report of her activities and financial expenditure over the period 01 May 2015 – 30 May 2016 and provided a forward look at the work envisaged in the coming months, detailing planned meetings of the CEPT and ITU, which she deemed to be of importance to CRAF. Her main workload during this past year had been the preparation for and attendance at the ITU-R World Radiocommunication Conference 2015 (WRC-15), and afterwards involvement in the new work cycle for the next WRC in 2019.

The CRAF meeting approved the FM’s report for the period 01 May 2015 to 30 May 2016.

• Status of Iridium NEXT

The bilateral discussions between CRAF and IRIDIUM ended in early 2015, when IRIDIUM’s proposals for organising limited, pre-announced periods of reduced levels of out-of-band emission into the primary RAS band 1610.6 – 1613.8 MHz from its new generation NEXT satellites in their so-called Radio Astronomy Protection (RASP) mode, were deemed unacceptable by CRAF.

(Note that at this time, the Iridium NEXT constellation was foreseen to complete full deployment in 2017, but failure of a Space-X launch has resulted in delays.)

Report from the 60th CRAF meeting

The 60th CRAF meeting was organised by the Max Planck Institute for Radio astronomie (MPIfR) in Bonn (Germany). It took place from the 3rd to the 5th May 2017, although on 4th May the meeting was held at the Effelsberg radio observatory (operated by MPIfR), thus enabling a guided tour of the observatory to be undertaken immediately following the lunch break.

Fifteen CRAF members were physically present for the meeting plus one member, who took part via Skype. Harry Smith of the SKAO attended as an observer and there were four candidate CRAF members; Joe McCauley from Trinity College, University of Dublin, Ireland; Viktor Tóth from the Eötvös University, Budapest, Hungary; Marian Soida from the Jagiellonian University of Kraków, Poland and Serge Yerin from the Institute for Radio Astronomy of the National Academy of Sciences, Kharkiv, Ukraine.

The following directors (or their representatives) of the CRAF Member Institutions attended the meeting on 5th May: Stéphane Corbel (INSU, France), Simon Garrington (STFC and Jodrell Bank, UK), Hans Olofsson (Onsala Space Observatory, Sweden), Adrian Tiplady (SKA South Africa and Hartebeesthoek Observatory), Tiziana Venturi [through Skype] (INAF, Italy), René Vermeulen (ASTRON, Netherlands) and Anton Zensus (MPIfR, Germany).

The ESF CEO, Jean-Claude Worms, attended the morning session on 5th May, and the International VLBI Service (IVS) chairman, Axel Nothnagel, attended part of the afternoon session on the 5th May. There were also five visitors, who were invited to participate as guests on the 4th May, when the meeting was held at the Effelsberg radio observatory: Karl Gypstra and Alex Kraus, both from the Effelsberg radio observatory, Markus Dreis from EUMETSAT, Ralf Ewald from the German Space Agency (DLR) and Jürgen Nitschke from the German Federal Network Agency (BNetzA), the last four giving presentations relating to their work and spectrum management.

The CRAF chairman, Wim van Driel, opened the meeting on 3 May by welcoming the participants, and

explained that the meeting (and future ones) would be held under the provisions of the CRAF Charter as contained in the 2004 MoU between the ESF and the CRAF institutional Member Institutions, until such time that they would be replaced by new provisions.

Following adoption of the agenda, it was agreed that H. Smith and A. Jessner (former CRAF Frequency Manager and Chairman, respectively) and the four candidate CRAF members be invited to attend all meeting sessions.

Comments were invited on the draft minutes of the November 2016 CRAF web-meeting before their approval.

• **Communications concerning CRAF**

New CRAF expert members

In addition to the four candidate CRAF members present at the meeting (referred to above), there were two other candidates, Mykhaylo Panchenko from the Austrian Academy of Sciences and Padelis Papadopoulos from the Aristotle University of Thessaloniki, Greece, for whom proposals had been received by the ESF. Two out of the total of six candidates were from countries for which there was to be representation on CRAF for the first time, Mykhaylo Panchenko (Austria) and Serge Yerin (Ukraine). Two of the others were replacing previous / existing CRAF members; Viktor Tóth replacing Istvan Fejes (sadly deceased) and Padelis Papadopoulos replacing John Seiradakis (retiring). Previously there had been a Polish representative from the University of Torun, but whose membership had lapsed, and now Marian Soida from the Jagiellonian University in Kraków would be representing Poland. The sixth nomination for Ireland (Joe McCauley for the University of Dublin) was for conversion from Observer Status to Institutional Membership. The CRAF members accepted all the proposed new expert members by acclamation.

Budget

Preliminary versions of the CRAF operational budgets for the years 2016 and 2017 were presented and the final 2016 CRAF operational budget was approved by the meeting after taking into account the latest financial overview statements received from the ESF. The provisional 2017 CRAF budget was presented and, after much discussion, was approved by the meeting. However, it was clear that a long-term, sustainable, annual CRAF operational budget needs to be discussed and organised with the institutional members' directors.

Involvement of the Callisto community

The possible representation of the Callisto community

on CRAF, introduced at the last meeting, was further discussed. It was queried whether a Callisto representative could take part in CEPT meetings and noted that the formal registration of many, very small Callisto antennas would be a challenge. LOFAR staff have experience in the registration of a large number of widely spread radio telescopes, and the SKAO is having to consider the registration of SKA telescopes. The sub-committee formed at the last CRAF meeting was continuing its work.

Search for a CRAF vice-chairman

CRAF has never had a vice-chairman, but it was considered a good idea to appoint one, who would probably later become the next Chairman. Expressions of interest were requested.

Compatibility/sharing studies

Following a presentation by Winkel, it was decided that there was a great need for a CRAF 'core group' of members, who could perform complex compatibility and sharing studies to assist CRAF's work in the protection of the radio astronomy bands. It was commented that only the French administration appeared to regularly carry out such studies for the RAS. A core Studies Group was formed with the aims of carrying out such studies and also holding 'intensive' training workshops that might interest Masters / Ph.D. students. Funding was included in the 2017 budget for this.

CRAF Charter

Following an initial update on the process by the Chairman, there was considerable discussion of the CRAF Charter and the establishment of a new Stakeholder Council with the institutional directors during the morning of 5th May. The directors also met in closed session during and after lunch. Significant progress was made, but a final agreed Charter and the form that the Stakeholder Council will take requires further discussion.

• **RadioNet H2020**

Van der Marel informed the meeting of the success of the RadioNet4 H2020 application. The top-level Work Package in which CRAF is involved is WP4 (Sustainability); the budget to support CRAF activities is in WP 4.2 (Spectrum Management), which covers a 4 year period.

• **Workshop on the future role of spectrum management and CRAF**

The RadioNet4 H2020 application for the funding of a Spectrum Management School, in 2018 under WP3-

Training had been successful. It was decided that there would be more benefit if this were to be merged with the planned IUCAF summer school on Spectrum Management for Radio Astronomy. As possible venues, Paris and South Africa were proposed.

• Frequency Management Activities

In addition to the full report of her numerous activities and financial expenditure over the period 01 June 2016 – 30 April 2017, the CRAF Frequency Manager (FM), Talayeh Hezareh, provided a detailed financial report and listing of national and international meetings that she had attended during the first three years of her contract. She also pointed out that she was now maintaining the CRAF Web site.

The FM's main workload in the coming months was likely to be in connection with the preparatory work associated with WRC-19 agenda item. She was also following up the interference from Iridium MSS operations with the RAS

The CRAF meeting approved the FM's report for the period.

• Improvement of CRAF operations

In addition to all the other work undertaken by the CRAF FM, she had been considering how one might improve the CRAF operations, and had produced a document relating to this, which was introduced by the chairman and discussed by the meeting. Amongst the many suggestions was the formation of a preparatory group for the wide-ranging issues tabled in ITU-R Working Party 7D (radio astronomy), to be led by the CRAF chairman.

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The Northern Extended Millimetre Array (NOEMA)

Introduction

Millimetre wave radio astronomy, which started in 1970 with the detection of carbon monoxide (CO) by R.W. Wilson et al [1] at a wavelength of 2.6 mm, is of particular interest as it probes the thermal emission from cold material. Many molecules have spectral lines arising from rotational transitions within the millimetre range, as indicated by the large list given in the ITU Report, ITU-R RA.314-10. At the present time almost 200 molecules have been detected in the interstellar medium and in circumstellar shells. Of these approximately one third have been discovered using instruments of the Institut de Radioastronomie Millimetrique (IRAM), which has its headquarters in Grenoble, France. Currently, one of the key challenges is the search for prebiotic molecules and their seeds in the interstellar medium, which if found, should lead to an understanding of galactic star forming regions and the chemical processes that lead to the emergence of life on at least one planet (i.e. the Earth).

The millimetre range is also of paramount importance for the study of the Universe in its infancy, for an understanding of how the first stars and galaxies formed. The optical emission from the stars during this early phase of the existence of the Universe is redshifted so much by the time that it reaches the Earth because of the expansion of the Universe, that it is received within the (sub)-millimetre domain. This emphasises the need for continuous spectral coverage to enhance our ability to detect still unknown molecular species and also possible emission from very highly redshifted galaxies. In many cases, millimetre radio astronomy provides information that is unique; i.e. information that cannot be obtained at other wavelengths.

There are inherent difficulties in making observations at these frequencies; e.g. the problems of atmospheric absorption and emission, which perhaps explain the late development of millimetre radio astronomy compared with that at lower frequencies. In recent times the development and construction of very high-frequency, sensitive receivers and associated electronics has also had a major impact, as has the construction of large antennas with surface accuracies of better than one twentieth of a millimetre and pointing accuracies of better than one arcsecond.



Credit: NOEMA telescopes' image courtesy of IRAM.

IRAM

IRAM came into being in 1979, the result of a collaboration between the French National Institute for Earth Sciences and Astronomy (CNRS / INSU) and the German Max-Planck Gesellschaft (MPG). In 1990 the Spanish National Geographic Institute (IGN) joined the collaboration. IRAM operates at two telescope sites; at Pico Veleta near Granada in Spain, where there is a 30-m telescope, and also in the French Alps near Gap, where there is the NOEMA, previously known as the Plateau de Bure Interferometer (PdBI). Both observatories are located at relatively high altitude (3000 and 2600m respectively) to overcome the adverse effects of atmospheric water vapour on observations. Both stations participate in intercontinental VLBI observations at mm wavelengths as partners of the Global Millimetre VLBI Array at 3mm and the Event Horizon Telescope (whose goal is to image the black hole at the centre of the Milky Way) at 1mm. The observing oversubscription (ratio of requested time versus available observing time) is more than three for NOEMA and both IRAM observatories produce more than 200 refereed publications per year.

In addition to the headquarters of IRAM in Grenoble, there is a support centre in Granada. State of the art receivers and 'backends' are developed in-house, essentially for the IRAM telescopes, but also for other observatories. Thus IRAM acts as a centre of expertise in the millimetre domain and pursues active research throughout the radiofrequency domain using cutting-edge technologies. Approximately 120 people work for IRAM in France and Spain.

NOEMA

With the advent of the Atacama Large Millimetre Array (ALMA) in Chile (i.e. in the southern hemisphere), it was felt that there was a requirement for an ALMA-competitive array in the northern hemisphere with a sensitivity within a factor of perhaps a few of that of

ALMA. The new instrument would operate at millimetre wavelengths, be usable for large surveys and be capable of rapid and efficient technological upgrades. To achieve these goals, the IRAM founding members decided in 2011 to fund the NOEMA project, which consisted of a number of improvements to the Plateau de Bure Interferometer.

NOEMA is now an interferometer array of 15-m diameter antennas, each with a Cassegrain focal arrangement and an rms surface accuracy of 35 microns, as is required for good aperture efficiency at millimetre wavelengths. Each antenna is equipped with a cryostat containing four receiver bands covering a frequency range from 72 to 373 GHz. The antennas can be moved along two tracks and thus rearranged to provide different array configurations for low and high angular resolution observations. There are also water vapour radiometers on each antenna operating at 22 GHz monitoring the amount of water vapour in the line of sight of each antenna. The data from the radiometers enable corrections to be made to the interferometer data for the variable path lengths to each telescope caused by atmospheric (tropospheric) turbulence. These radiometers are key elements for successful observations.

Compared with the original Plateau de Bure interferometer, the main improvements have been:

- i) extension of the maximum baseline from 0.8 to 1.6 km.
- ii) a doubling of the number of 15-m antennas from 6 to 12.
- iii) installation of new sideband-separating receivers on all 12 antennas to cover 2 sidebands, each of width 8 GHz and providing 2 linear polarisations (i.e. a total of 32 GHz per antenna).
- iv) construction of a new correlator, which can be configured to provide full bandwidth coverage at low spectral resolution or a number of lower bandwidth spectral windows at high-resolution. (Since this original design, the project has been further extended to include dual-band observations, i.e. to enable observations to be made in two frequency bands simultaneously by the addition of a second correlator).

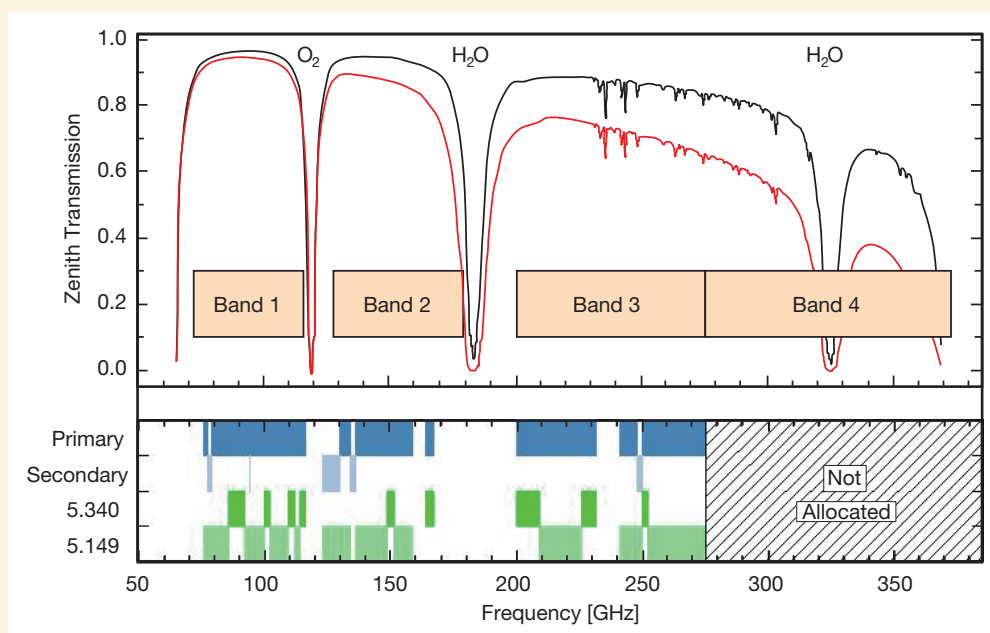


Figure 1. Zenith transmission in the bands used by NOEMA. Also indicated are the radio astronomy bands listed in Footnotes 5.340 (all emissions prohibited) and 5.149 (all practicable steps to be taken to protect radio astronomy) to the Radio Regulations.

The project has been split into 2 Phases:

Phase I includes the construction and equipping of 4 new antennas, 10 new receivers and the correlator.

Phase II completes the project with the construction of the last 2 new antennas, the baseline extension and the provision of dual-band observing.

Phase I, which is scheduled for completion by the end of 2017, has a budget of €33M. As of January 2017, eight antennas are available and all are equipped with new receivers. The new correlator is planned to arrive in May 2017. Antenna 9 is scheduled for commissioning mid-March 2017 and antenna 10 in November 2017. The total NOEMA budget, not including manpower, is €55M.

Spectrum use

NOEMA has 4 receiver bands: the '3mm band' covers 72-116 GHz, the '2mm band' 127-179 GHz, the '1mm band' 200-276 GHz and the '0.8mm band' 275-373 GHz. The first three of these bands have either primary or secondary allocations to the Radio Astronomy Service (RAS) and also have either 5.340 (all emissions are prohibited) or 5.149 (administrations are urged to take all practicable steps to protect the RAS from harmful interference) footnotes. The fourth band covers a spectrum range that as yet has not officially been allocated by the ITU.

Being on a high-altitude plateau (the Plateau de Bure) and not in a direct line of sight to any large human concentration means that there is some shielding from possible interfering signals. However, the terrain does not protect the facility from satellite emissions (e.g. Cloudsat

at 94.05 GHz) and other airborne devices. Although the observatory is within a protection zone for some frequencies (e.g. 22 GHz), the move to higher frequencies for many commercial applications is of considerable concern. Among these one can cite the development of radiolocation radars in cars and helicopters in the 76-81 GHz range, the possible use of the 81-86 GHz band for 5G mobile phones, as is being discussed under WRC-15's resolution 238 (WRC-19 agenda item 1.13) and the identification of frequency bands for the fixed and mobile service application above 275 GHz (WRC-19 agenda item 1.15). It is to be noted that the receiver chain has a very reduced dynamic range (less than 10 dB) compared with receivers at lower frequencies because millimetre receiver developments are at the frontiers of technology. Consequently, observatories operating at millimetre wavelengths are much more prone to inter-modulation products in the presence of a strong interference signal.

[1] Wilson, R.W., Jefferts, K.B and Penzias, A.A.; 1970, ApJ., 161, L43.

Vincent Piétu

Coexisting with Radio Frequency Interference (RFI) – Workshop Report

In October 2016 a workshop on Radio Frequency Interference was organised and held at the USA National Radio Astronomy Observatory's (NRAO's) Socorro site in New Mexico. It was co-organized by URSI, GRSS, IUCAF, CSIRO, ASTRON and EURASIP*, and was attended by approximately 100 delegates, mostly radio astronomers and Earth Exploration Satellite Service (EESS) specialists. Well-known experts participating in the International Telecommunications Union Radiocommunications (ITU-R) Study Group 7, and in particular Working Parties (WPs) 7C and 7D, attended this workshop. The considerable development of commercial radio communications, and the related increase in radio frequency interference, are very critical issues for observational radio sciences, such as radio astronomy, microwave remote sensing of the Earth, and solar and ionospheric studies, for which highly sensitive measurements are required.

During the discussions, in particular concerning questions of regulation, it was noted and appreciated by the participants that the author was the only representative of a national regulatory authority, and was thus able to give somewhat more insight into the ITU-R regulatory work. The presence of at least one USA Federal Communications Commission (FCC) official would have been very interesting when, for example, there were discussions on RFI by Iridium.

Numerous presentations described the difficulties encountered and the degradation of the quality of the observations in recent years. This is because of the explosion in the number and types of active spectrum users, the capability of RF devices to operate at ever higher frequencies, that until recently were only used for radio astronomy and space research, and the proliferation of unlicensed, low-cost devices. In addition to the expected and well-known RFI from satellites, aircraft, mobile devices and media broadcasting etc., unexpected ground-based RFI is now appearing, arising from other developments, such as wind turbines / farms. Examples were presented of radio astronomy sites that have long been protected from RFI by a wise choice of their geographical location (terrain protection), but which are now receiving strong interference as a result of reflections/scattering by wind turbines from distant non-line-of-sight, ground-based, RFI sources. With further planned development of wind farms, this type of "new" interference will certainly have a growing

impact, and not only on science services.

Several presentations were made on the recent progress of standard mitigation techniques such as adaptive filtering, adaptive noise cancellation, anti-coincidence with array systems, temporal/frequency excision and blanking, and finally flagging and excising by data analysis. Interesting contributions were presented on the development of databases to store RFI data for use in the analysis of measurements using complex mathematical algorithms for the elimination of RFI from the wanted signals before or after processing. Unexpected experts in RFI, at least as far as this author was concerned, were scientists working for the SETI (Search for Extraterrestrial Intelligence) Institute, whose knowledge of RFI mitigation and removal techniques was very impressive.

It was interesting to note that the scientists developing and improving mitigation techniques are not too keen to have too much publicity, since this could encourage regulators to allocate new radio communication services close to their fundamental observatory frequency bands. However, it was noted that all mitigation of RFI nevertheless leads to data loss and is extremely time consuming (>90% of the research time). Prevention of interference is far better than mitigation and coordination, and regulation should be increased. For example, it was argued that the ITU standards for spurious and out-of-band emissions are not sufficient for the protection of passive services. The French and European Space Agencies (CNES & ESA) highlighted their experience with the Soil, Moisture & Ocean Salinity satellite (SMOS) during the last 6 years, when numerous RFI signals in the purely passive band, 1400-1427 MHz, supposedly protected by Footnote N° 5.340 to the Radio Regulations (all emissions prohibited) were detected. Clearly, there is also a need for improvement in reporting to the administrations involved the presence of RFI to space sensors. ITU-R SG 7 is currently developing a standardised form for reporting RFI events to passive space sensors to the ITU BR* and to the appropriate administrations involved. A similar form is also being planned for active sensors.

Finally, one of the highlights of this workshop was certainly a visit to NRAO's Very Large Array (VLA) site, approximately 80 km west of Socorro on the plains of San Agustin at approximately 2000 m altitude. It should be noted that when the VLA was built in the 1970s, the radio astronomers asked for the establishment of a radio quiet zone around it. This was refused by the US military because of the location of the White Sands Missile Range and the site of Trinity, the code name for the first atom bomb test, which occurred during WW II, only ~100 km away.

*** Abbreviations in this article:**

NRAO	National Radio Astronomy Observatory
URSI	International Union of Radio Science
GRSS	Geoscience and Remote Sensing Society
IUCAF	Scientific Committee on frequency allocations for radio astronomy and space science
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ASTRON	The Netherlands Institute for Radio Astronomy
EURASIP	The European Association for Signal Processing
ITU	International Telecommunications Union
BR	Radio-communications' Bureau

Damien Philippe Scherrer, Bundesamt für Kommunikation, Switzerland

Callisto as a Worldwide RFI-Monitor

The Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) of ETH Zürich has been distributed worldwide in the frameworks of the International Heliophysical Year 2007 (IHY2007) and the International Space Weather Initiative (ISWI) as a contribution to universities and colleges, especially in developing countries. The instrument is a dedicated tool for observations of the Sun at metre radio wavelengths with its primary aim being the identification and study of solar radio bursts, which are an indication of accelerated

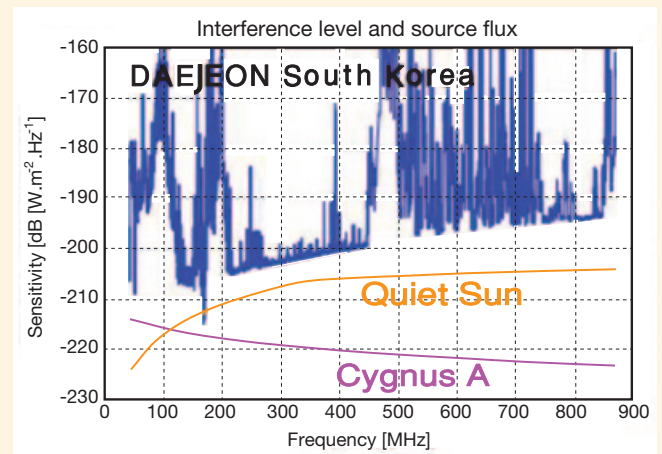


Figure 2. RFI measurement performed in 2012 in South Korea, showing a more or less clean frequency range between 230 and 450 MHz. Between 240 and 260 MHz we can identify geostationary satellite downlinks. An antenna with a gain of >7 dB would enable detection of the quiet Sun at 300 MHz.

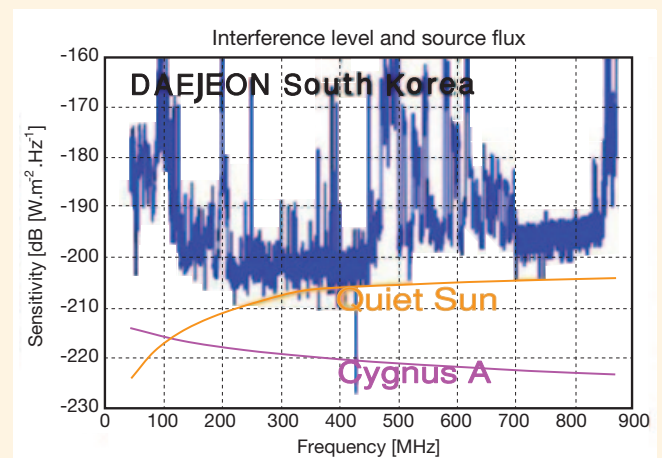


Figure 3. RFI measurement performed in 2016 at the same location with the same instrument. There are no longer any clean frequency ranges. In the 240 to 260 MHz range the geostationary satellite downlinks are hardly visible. To detect the quiet Sun requires an antenna with a gain of at least 10 dB.

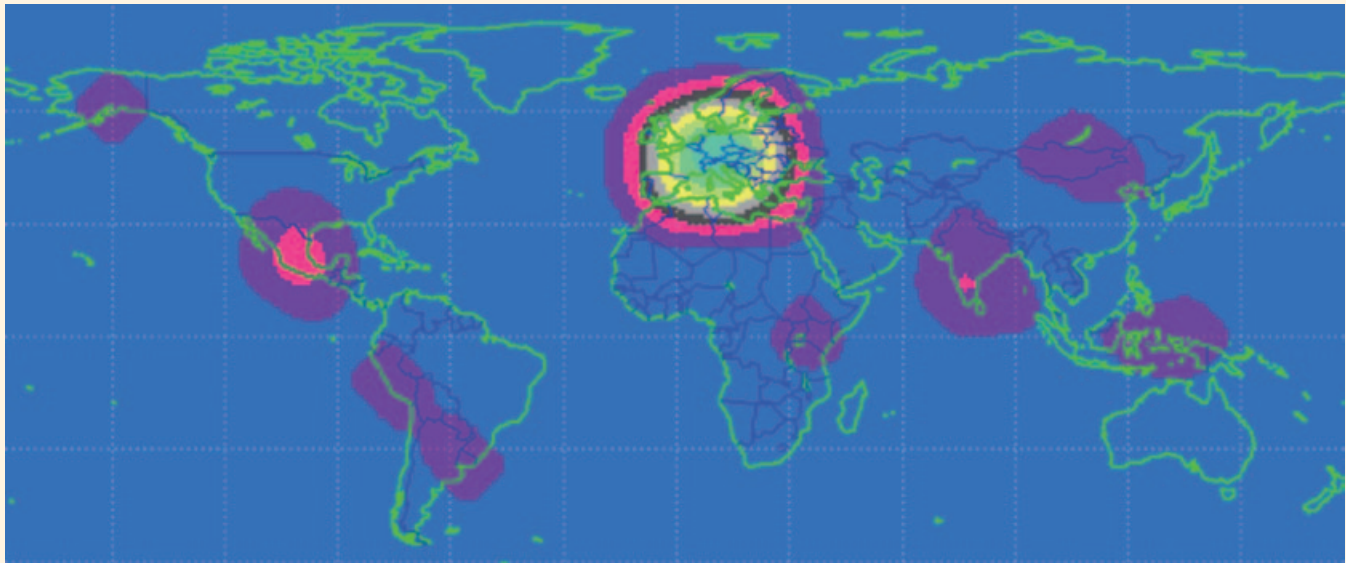


Figure 4. Highest levels of RFI were found in the European region followed by Mexico City in Mexico and Pune in India.

particles in complex solar magnetic field structures. To date more than 120 instruments have been commissioned at more than 67 locations from South Africa to Siberia as well as from Alaska (eastwards) to Australia. Besides the regular burst observations a special function in Callisto software named 'Save spectral overview' allows observers to capture a full spectrum in the frequency range of Callisto from 45 MHz to 870 MHz with 13,200 channels separated by 62.5 KHz. Between 2007 and 2016 dozens of spectral overviews have been collected, calibrated and plotted.

A catalogue with all the plots from all over the world, which are a part of the instrument array quality control, can be found on the instrument website. For cases of very strong and wideband RFI, there is a dedicated communications channel to the instrument's principal investigator (PI), currently at ETH in Zürich, so that potential mitigation procedures can be discussed. Repeatedly observed spectral overviews also enable the detection of trends in RFI-level and frequency occupation. An example of this is shown in figures 2 and 3 from the Korean Astronomical Institute (KASI) in Daejeon, South Korea. Within a 4 year period the situation changed dramatically, mainly because of an increase of broadband noise arising from poorly designed and badly shielded local digital electronic equipment.

Since there is little funding and very limited manpower in developing countries, any calibration process must be cheap and simple. It is therefore essential that all spectrometers have an identical response of 25.4 mV/dB, very similar low noise amplifiers (LNAs) with a noise figure (NF) ~ 1 dB and, in most cases, a logarithmic periodic dipole array (LPDA) with a gain in the range 10 to

12 dBi, as claimed by the antenna manufacturer. Two measurements are required for calibration: first, a 50 ohm termination resistor is connected to the LNA input and a measurement made as a reference of approximately

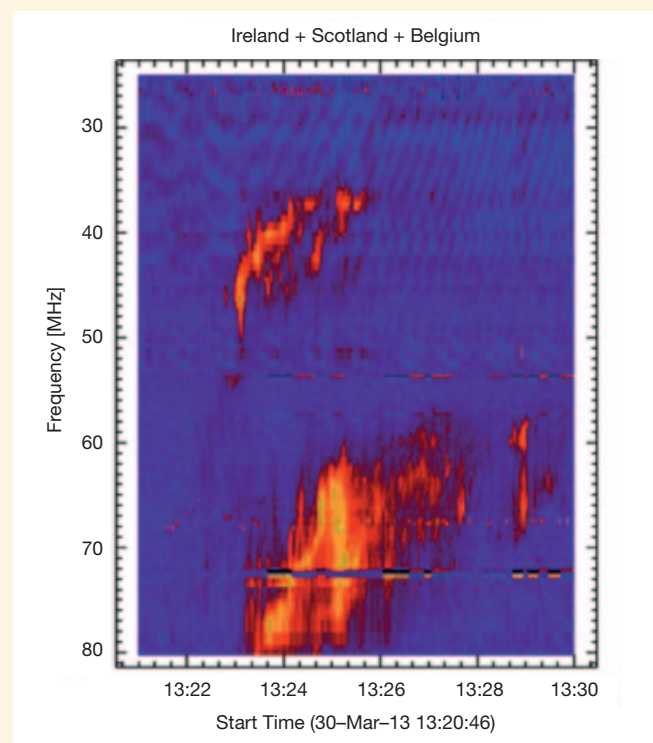


Figure 5. Example of a combined image depicting a type II solar radio burst with fundamental and first harmonic. The image is a combination of observations from Birr/Ireland, Glasgow/UK and Humain/Belgium. All the local RFI from 'self-generated' sources and transmitters does not correlate and vanishes when the burst is correlated and therefore results in an increased signal-to-noise ratio. The horizontal structures at 54 MHz and 73 MHz are the result of very strong transmitters in Glasgow which are so strong that they are still visible in the spectra. The drift rate of this type II burst allows solar scientists to determine the radial velocity of the preceding coronal mass ejection (CME).

–120 dBm power. Then, a second measurement is made with the antenna attached to the LNA input.

By making a number of assumptions, simple calculations can be made to determine the receiver noise temperature, T_{rx} . It is determined by assuming a 1 dB noise figure at an ambient temperature of 300 K and a radiometric bandwidth of 300 KHz leading to $T_{rx} \approx 378$ K. The level of RFI is then expressed as a factor Y with respect to the 50 ohm reference. Taking into account the effective antenna area of an isotropic radiator, the RFI-flux can be determined and compared with that of the quiet flux of the Sun. The result is a number expressed in dB that indicates how much gain the antenna should have to give a discernible result while pointing the main beam to the celestial position of the Sun. The stronger the RFI, the higher the antenna gain has to be to detect the quiet Sun.

Solar scientists are usually interested in broadband information rather than single frequency observations. Therefore, averages over the frequency range of the particular Callisto receivers can be determined. These numbers are shown as coloured areas overlaid on the world map in figure 4. The most quiet spectra between 45 MHz and 870 MHz were found in Peralejos in Spain, Kangarlussuaq in Greenland and Tian Shan mountains (near Almaty) in Kazakhstan. It is to be noted that even deep in the Gotthard tunnel in Switzerland the RFI-level is much higher than in the above locations. Another radio quiet location was found in Glendalough National Park in Ireland. Unfortunately, we were thrown out of the park because it is forbidden to carry out spectrum measurements without permission, although taking photos with cameras was acceptable. The worst locations in terms of strong RFI ($S > -160$ dB [$W/m^2/Hz$]) are Mexico City in Mexico, Lima in Peru, Los Molinos in Montevideo, Uruguay and Hurbanovo in Slovakia.

Observations at these locations are very challenging, given standard LPDA antennas with a 10 dB gain pointing at the Sun. However, there are still parts of the spectrum in which solar burst observations can be made with antennas having a gain of the order of >12 dB at these bad locations. Many locations with strong interference saturate the LNA and/or the receiver, producing harmonics and cross-products. It was also found that quite a lot of RFI is self-produced, mainly caused by badly designed power supplies, LED lights and poorly shielded cables in the nearby observatory or laboratories.

It is essential that solar radio burst observations are broadband to obtain information about the burst structure. Solar scientists cannot rely solely on single frequencies that are reserved for the passive services like

radio astronomy. Consequently, several mitigation procedures, such as insertion of filters in the RF-path between the antenna and the LNA must be applied. Thus low-pass filters, high-pass filters, band-pass filters and notch or band-reject filters in various combinations may be needed.

In order to determine the full frequency/time-structure of solar radio bursts it is essential to use the redundancy that is provided by instruments at different longitudes and latitudes. RFI at separate locations is usually not correlated. Therefore, it is possible to reconstruct solar radio burst images by combining results from different locations as demonstrated in figure 5. Of course, a clean spectrum is much more preferable. However, this is becoming more and more difficult to obtain because of the increasing number of transmitters below 1 GHz and the increasing ‘self-generated’ RFI.

Abbreviations in this article:

IHY:	International Heliophysical Year
ISWI:	International Space Weather Initiative
LED:	Light Emitting Diode
LNA:	Low Noise Amplifier
LPDA:	Log Periodic Dipole Array
NF:	Noise Figure
PI:	Principal Investigator
RFI:	Radio Frequency Interference

References:

- The Callisto instrument was described in more detail in CRAF newsletter Nr. 21, July 2010 here: <http://craf.eu/wp-content/uploads/2015/03/nwsl21.pdf>
Link to spectral overviews: <http://www.e-callisto.org/OVS/Spectral%20Overview.html>

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Ukrainian radio astronomy: brief history and prospects

In the late 1950s Ukrainian researchers recognised the possibilities of low-frequency, radio astronomy, and a team of scientists and engineers, led by S. Braude (1911–2003), a member of the Ukrainian National Academy of Sciences (NAS), started development of new equipment for the exploration of cosmic radio emission and the development of new methods of observations. They were based at the Institute for Radio Physics and Electronics in Kharkiv and their efforts were supported by the NAS of Ukraine, which resulted in the development and construction of UTR-2 (the Ukrainian T-shape radio telescope, model 2); the world-largest decametre-wave radio telescope at that time (Figure 6). UTR-2 started operations at the beginning of the 1970s, since when it has remained one of the most sensitive telescopes in the world in its frequency range because its receiving and amplifying equipment has been constantly upgraded. After gaining much experience from the development and operation of UTR-2, a team of its creators founded a new Institute of Radio Astronomy of the NAS of Ukraine (IRA NASU), which now oper-



Figure 6. North arm (720 wideband dipoles) of UTR-2 radio telescope.

ates the telescope. In the 1970s–80s they also developed a supplementary decametre VLBI system, spread across the Ukraine – the Ukrainian Radio interferometer of the National Academy of Sciences (URAN), which operates in the same frequency range as UTR-2 from 8 to 32 MHz (Figure 7). Nowadays UTR-2 and 4 URAN stations have modern amplifying systems and baseband receivers with fast 16-bit ADCs and real-time calculation of spectra, developed at IRA NASU (Zakharenko, V. et al., 2016).

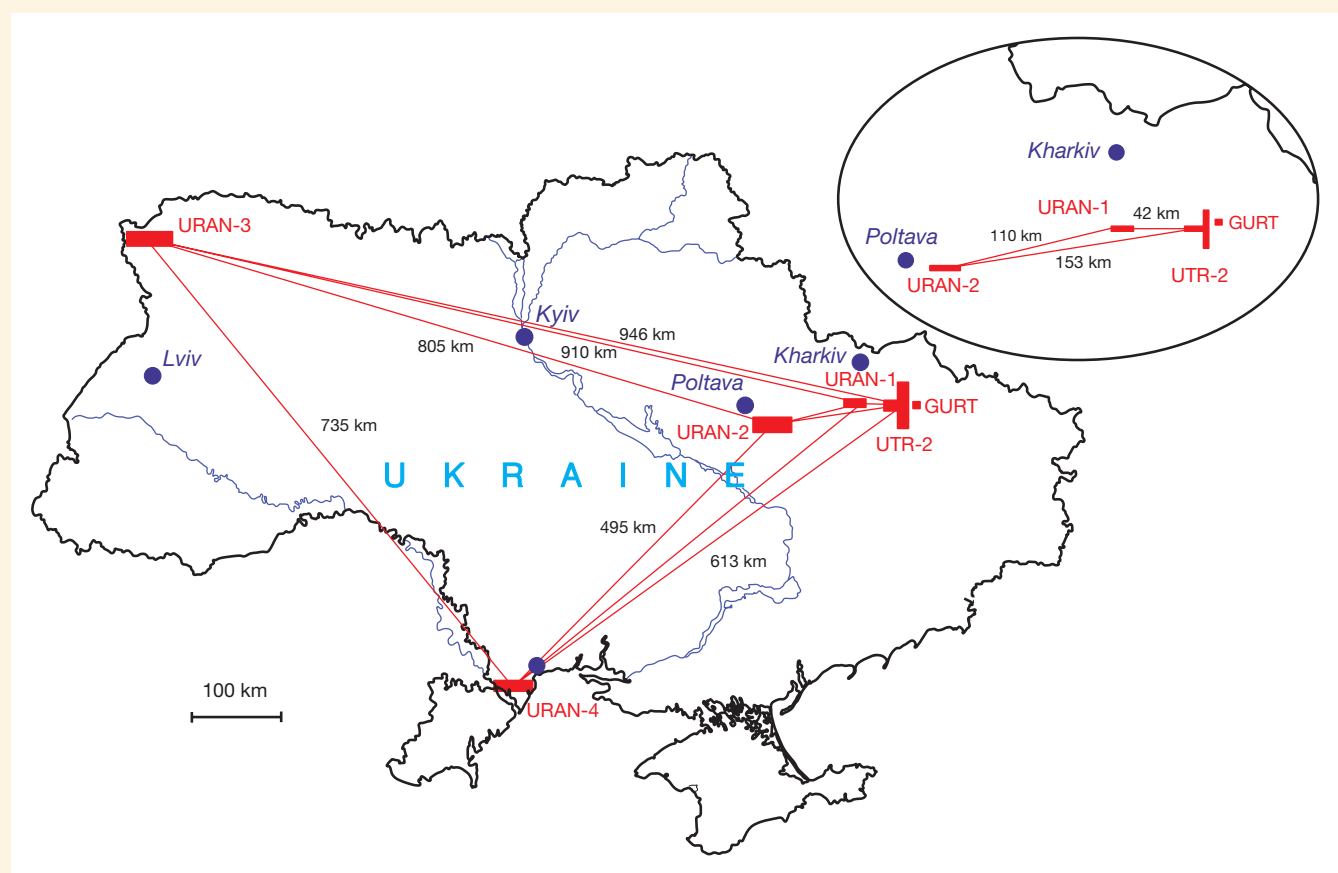


Figure 7. Low-frequency radio telescopes on the map of Ukraine



Figure 8. A cluster of GURT subarrays.

More recently the Ukrainian research team has started the development of a new radio telescope using modern digital signal processing and active receiving antenna theory. This telescope has been named the Giant Ukrainian Radio Telescope (GURT) (Konovalenko et al., 2016) and it is located close to UTR-2, but has a wider bandwidth range from 8 to 80 MHz (Figure 8). Construction of GURT is now in progress and the first subarrays have already produced first results. To date five subarrays have been constructed and it is already a very good instrument for monitoring of solar and Jovian radio emission (Figure 9), as well as for RFI monitoring. Although each single subarray comprises only 25 active dipoles, it is sensi-

tive enough for observations of up to fourteen of the most powerful pulsars with an integration time of 2-4 hours.

The antenna parameters, which have been calculated using a technique developed at IRA NASU, agree very well with the results of actual measurements (Tokarsky, P.L. et al., 2015)

Increasing enhancement of equipment and numbers of observations have resulted in an increasing number of discoveries and therefore publications (see reference list at end), which indicate the variety of research undertaken to date.

IRA NASU scientists have obtained good results at high-frequencies using the 70-m Yevpatoria (RT-70) and the 22-m Simeiz (RT-22) telescopes equipped with receiving equipment developed at IRA NASU. These telescopes have taken part in many VLBI experiments, including those made in conjunction with the spaceborne radio telescope, “RadioAstron”, as an element of a VLBI network (Volvach, A.E. et al., 2015). RT-70 has also been used in 2012 as a radar transmitter for a radio location of the 212 DA1 asteroid in conjunction with radio telescopes at Medicina (Italy) and Irbene (Latvia), which were used as receiving stations (Nechaeva, M. et al., 2013).

Operating as a single-dish radio telescope, RT-70 has also been used by IRA NASU staff for pulsar and cosmic maser spectral line studies in particular and the RT-22 telescope has been used for OH, H₂O, methanol and other molecular spectral line observations. The first methanol maser in the supernova remnant, Kes 79, at 95.1 GHz was

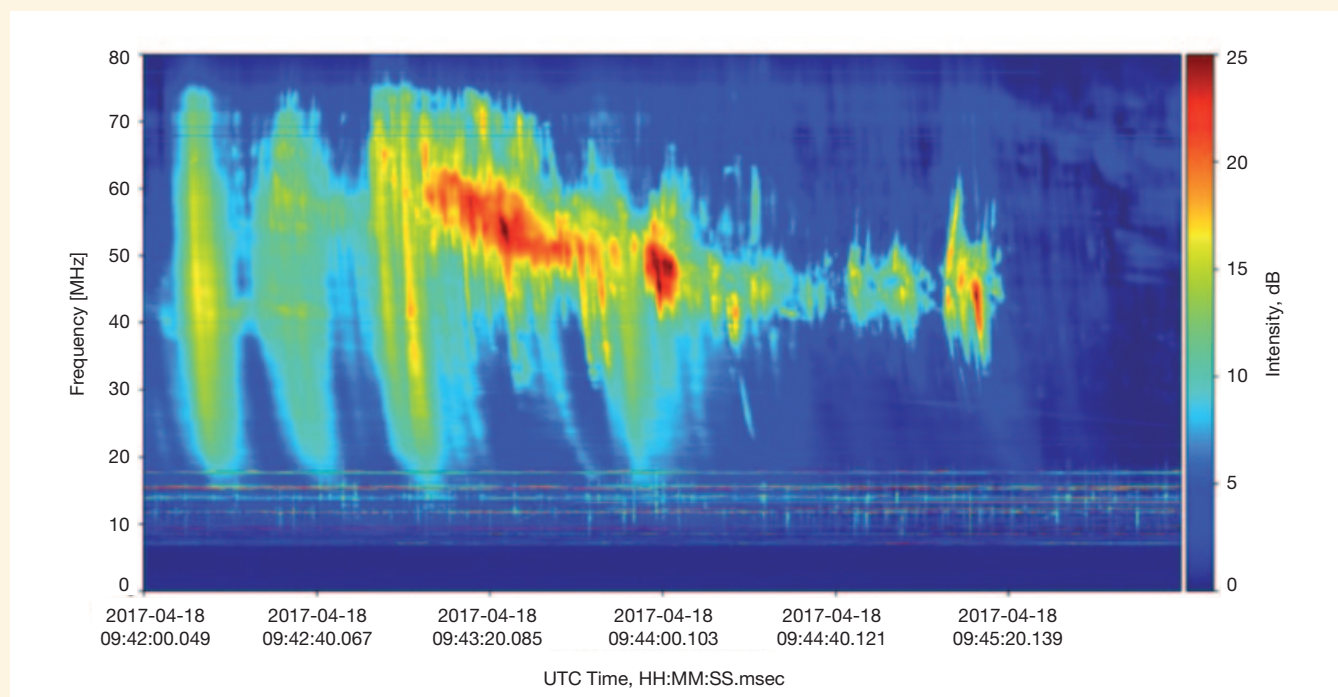


Figure 9. Solar burst received with single GURT subarray of 25 active dipoles (single linear polarization) on April 18, 2017.

discovered with RT-22. Unfortunately Ukrainian scientists no longer have access to these instruments because of the annexation of the Crimean peninsula by the Russian Federation in 2014. However an Onsala radio telescope (Sweden) is now being used as part of an international collaboration.

The department of Microwave Spectroscopy of IRA NASU is measuring microwave molecular spectra and atomic Rydberg-state spectra under laboratory conditions, for which the necessary spectrometers were designed and constructed 'in-house'. One of the spectrometers is intended for high-resolution investigations of molecular spectra with Doppler-limited and sub-Doppler spectral resolution and covers a frequency range from 34 to 250 GHz (Alekseev, E.A. et al., 2012). A second one is being used for the study of the microwave spectra of Rydberg-state atoms.

Scientists and engineers at IRA NASU now participate in numerous international projects. The UTR-2, URAN-2, 3 and GURT arrays also take part in the Juno-Ground-Radio (RadioJove) project and contribute their results to the VESPA open database. Numerous synchronous joint observations of the Sun, pulsars, exoplanets and Saturn using UTR-2, URAN, LOFAR and NDA are in progress.

The main technical aims for the next decade are the construction of new GURT subarrays and installation of a digital phasing system at UTR-2 and URAN-2, which can extend its frequency range up to 40-50 MHz. The antenna pattern of a GURT subarray at low frequencies can be altered digitally to give multiple simultaneous beams in any direction of an upper hemisphere. This feature will be used for continuous solar and space weather monitoring in the 8-20 MHz range, which is extremely important for safety reasons. A network of GURT stations is planned to be built in the Ukraine for scientific and educational purposes. IRA NASU is open to cooperation and new ideas and seeks EU partners for integration in the European science community.

References:

- Zakharenko, V., et al., 2016, Journal of Astronomical Instrumentation 5, 1641010. "Digital receivers for low-frequency radio telescopes UTR-2, URAN, GURT".
- Konovalenko, A. et al., 2016, Experimental Astronomy, 2016, 42, 11. "The modern radio astronomy network in Ukraine: UTR-2, URAN and GURT".
- Tokarsky, Peter L. et al., 2015, IEEE European Radar Conference (EuRAD) 2015. "SNR in active receiving antenna used as an element of phased antenna array for GURT Radio Telescope".
- Konovalenko, A. A. and Sodin, L.G. Nature, 1980, 283, 360. "Neutral ^{14}N in the interstellar medium".
- Zakharenko, V. et al., 2012, Planetary and Space Science 61, 53. "Ground-based and spacecraft observations of lightning activity on Saturn".

- Zakharenko, V. V., et al., 2013, Monthly Notices of the Royal Astronomical Society, 431, 3624. "Detection of decametre-wavelength pulsed radio emission of 40 known pulsars".
- Melnik, V. N. et al., 2011, Solar Physics 269, 335. "Observations of powerful type III bursts in the frequency range 10–30 MHz".
- Megn, A. V. et al., 2006, Astronomy reports, 50, 692. "Extended component in the quasar 3C 380".
- Vasylieva, I. Y. et al., 2013, Odessa Astronomical Publications 26, 159. "Data Processing Pipeline for Decametre Pulsar/Transient Survey".
- Braude, S. Ya. et al., 2002, Astrophysics and Space Science, 280, 235. "Decametric survey of discrete sources in the northern sky".
- Volvach, A. E. et al., 2013, Cosmic Research 53, 209. "Testing of the ground-based VLBI stations Yevpatoria-Simeiz-Pushchino of the RadioAstron mission".
- Alekseev E.A. et al., 2012, Radio Physics and Radio Astronomy 3, 75. "Millimeter- and submillimeter-wave spectrometers on the basis of direct digital frequency synthesizers".
- Nechaeva, M. et al., 2013, Baltic Astronomy 22, 341. "First Results of the VLBI Experiment on Radar Location of the Asteroid 2012 DA14".

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