European Science Foundation

29 CRAF News

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Editorial

Although some activities for the protection of the radio astronomy frequencies are not time-critical, many issues do require continuous attention. Once every three to four years there is a climax in the frequency management world in the form of a World Radiocommunication Conference (WRC). In November this year the World Radiocommunication Conference 2015 (WRC-15) is being held at the headquarters of the International Telecommunications Union (ITU) in Geneva, Switzerland. A WRC is held to consider revisions to the ITU Radio Regulations, an international treaty which determines the use of the radiofrequency spectrum. The outcomes of a WRC are referred to as the Final Acts, which, in most cases after ratification at the national level by the ITU member states, are implemented in regulation at the national level. For CRAF a WRC is also a highpoint, since within a period of four weeks several decisions will be made, some of which may have an impact on radio astronomy.

Since the Conference in 1959 when Radio Astronomy was recognised as a radiocommunication service, radio astronomers have been fighting for the protection of frequency bands they consider important. IUCAF and CRAF are both sector members of the ITU and have a representation at the WRC. Additionally individual radio astronomers participate as members of national delegations.

The agenda for a particular WRC (e.g. WRC-15) is set at the previous WRC (e.g. at WRC-12 in 2012) and issues that are not on the agenda cannot be discussed. This enables administrations and other organisations such as CRAF and IUCAF to carry out technical studies during the period between the WRCs to determine the impact on radio services of the proposals contained in the agenda items. This means that immediately after a WRC, preparation for the next one starts. On the agenda of a WRC there are always a number of items that may have a negative impact on radio astronomy. CRAF actively participates in preparation for the WRC at the CEPT (European) and the ITU (global) levels, while individual members also participate in their national preparations. The impact of CRAF is greatest during this preparatory phase when contributing to sharing and compatibility studies, making requests for studies and developing methods that satisfy the WRC agenda items. In addition to the above CRAF lobbies for the best solutions for radio astronomy and creates awareness for the protection of radio astronomy in general. Although the preparatory activities for a WRC take a large part of the resources of CRAF, they are essential

Cover
The Westerbork Synthesis Radio Telescope (WSRT) with the new multi-beam Apertif receiver (see insert).
Credit: Hans van der Marel, ASTRON

for the continued protection of radio astronomy, which can easily be affected by both in-band and out-of-band emissions from active services because it is a passive service. Radio astronomy allocations can be easily lost or compromised by decisions made at a WRC.

A major agenda item for WRC-15 concerns new allocations to the mobile service to accommodate mobile broadband connections. Many frequency bands have been considered, including some that are intensively used by the radio astronomy service. Thanks to the efforts of some CRAF members these bands have been excluded from consideration. For some other bands regulatory provisions have been proposed to protect radio astronomy.

This illustrates that the work of CRAF is crucial to the radio astronomy community. The importance of CRAF for the maintenance of the radio spectrum infrastructure in Europe and beyond is also recognised by the European Radio Telescope Review Committee (ERTRC), a committee that has been set up by the board of ASTRONET to provide a review that is addressing the role of present and future radio astronomy facilities. Preserving the radio spectrum for astronomy and CRAF's role in that is considered vital for the future of radio astronomy. With the support of its members CRAF is more than happy to continue its role for the protection of the radio astronomy frequencies.

Hans van der Marel, *CRAF Chairman*

Report from the 56th CRAF meeting

The 56th CRAF meeting organised by the Netherlands Institute for Radio Astronomy (ASTRON), took place on 21-23 May 2014 in Dwingeloo (The Netherlands). A guided visit to the Westerbork Synthesis Radio Telescope (WSRT) and the LOFAR telescope was organised for interested participants during the afternoon of Wednesday 21 May. The CRAF meeting was opened by René Vermeulen, Director of ASTRON, who welcomed the participants. Eighteen CRAF Members and three CRAF Observers attended the meeting, the latter being R. Millenaar (ASTRON), J. McCauley (Trinity College, Ireland) and J. Urban (Chalmers Univ. of Technology, Sweden) who participated in the open sessions of the meeting. R. AMBROSINI (IRA-INAF- Italian Representative) and Jean-Claude Worms (ESF liaison) joined the meeting during the morning session on 22 May 2014. David Deboer (CORF), Tasso Tzioumis (RAFCAP) and Masatoshi Ohishi (IUCAF), representing 'sister organisations', joined the meeting via a video-link during the morning session of 23 May 2014. J. Blokzijl (Dutch Telecom Administration) joined the meeting as a guest during the open session on 22 May 2014.

The following key items were discussed:

• ESF and future CRAF host organisations
Following the European re-organisation decisions, the closure of EUROHORCs and the vote at the November 2014 ESF annual assembly, it was clear that there were two options for the future of the ESF. It could be dissolved or it could become a science services organisation, which would have support from some of its current expert boards and committees (EBCs). In both cases, the EBCs could continue to exist until the end of 2015 in line with the positive outcome of the 2011 statutory review, as the Executive would still have a mandate to host the EBCs until then. In the dissolution option, or if they so wished, the EBCs would find an alternative hosting organisation from the end of 2015. If the ESF transitioned into a science services organisation, it could create a legal entity for the EBCs from which they could operate after the end of 2015. Science Europe has indicated that it would seek to ensure fruitful dialogue with the EBCs with a view to successful collaboration where appropriate (albeit no hosting). CRAF has been encouraged to initiate such a dialogue if it wishes, e.g. by inviting Science Europe to a future plenary meeting.

CRAF has explored alternatives for being hosted. It was concluded that the Joint Institute for VLBI in Europe (JIVE) could be a possible host for CRAF and they were asked to investigate the possibility of hosting CRAF, but replied that CRAF should first more thoroughly investigate possible hosts and especially the possibility of a successor organisation to the ESF. JIVE should be seen as a last resort for hosting CRAF.

• Communications concerning CRAF

1. *New frequency manager*
   Talayeh Hezareh, based at the Max-Planck-Institut-für-Radioastronomie (MPIfR) in Bonn, was introduced and also introduced herself to the CRAF members as the new Frequency Manager during a Web Meeting at the end of March. An agreement between the ESF and the MPIfR for hiring Hezareh as CRAF FM was approved during the web meeting.
2. *New secretary*
   In August 2014 Vincenza Tornatore replaced Pietro Bolli as the CRAF secretary. The position of CRAF secretary includes membership of CRAF for her and for her affiliate Institution Politecnico di Milano (DICA)
3. *New members*
   Two new CRAF members, Juha Kallunki from Finland and Ivan Thomas from France, were welcomed by the other CRAF members.
4. *CRAF budget*
   It was agreed to allocate funds for external litigation and consultancy costs, for the update and reissue of the CRAF handbook, for the modernisation of the CRAF website and for costs relating to the movement to a new host.

• Frequency Manager Activities
At the end of April 2013 Harry Smith resigned from his post as CRAF frequency manager and was eventually replaced on 15 March 2014 by Talayeh Hezareh. In the intervening period the frequency manager's activities were undertaken by CRAF members and some external people who represented CRAF at 23 meetings during the period from 8 April 2013 until 13 May 2014. In this period CRAF also wrote and contributed to 17 technical or regulatory inputs to the spectrum management process.

• Issues of concern to the RAS in CEPT/ITU
The following issues are of concern to the RAS:
– Iridium and more specifically the future Iridium NEXT satellites (CEPT WGFM)

– Inmarsat MES and AES operation in the extended 1670-1675 MHz band (CEPT FM44)
– Revision of ECC/DEC/(05)11 on Ku-band AES (14.47-14.5 GHz) (CEPT FM44)
– Out-of-band emissions from short range radar (CEPT SE21)
– Short range devices in general and short range radar in the 77 GHz band in particular (CEPT SE24)
– Measurements on Iridium satellites with the Leeheim station (CEPT SE40)
– Spectrum Engineering Reference Document (CEPT Forum Group)
– Wind Turbines (CEPT Forum Group)
– Possible modification of Footnote 5.511F (ITU WP7D)
– Revision of Recommendation RA.1513 (ITU WP7D

• WRC-15 Brief

Preparation for the World Radio Conference 2015 is going full speed ahead. The deadline for delivery of the CPM texts on the different Agenda Items is 15 August 2014. All studies should be finished by then. The following WRC-15 Agenda Items are of interest to the RAS:

– AI 1.1 (International Mobile Telecommunication, IMT) – several bands between ~470 MHz and ~6GHz concern CRAF
– AI 1.2 (IMT in 694 – 790 MHz)
– AI 1.5 (Unmanned aircraft systems in FSS bands)
– AI 1.6.1 (Additional allocation of 250 MHz for the fixed satellite service (FSS) in 10 – 17 GHz)
– AI 1.8 (Review of provisions for earth stations on board vessels)
– AI 1.9.1 (New allocations to FSS within the ranges 7150 – 7250 MHz (space-to-earth) and 8400 – 8500 MHz (earth to space)
– AI 1.9.2 (Allocation of bands 7375 – 7750 MHz and 8025 – 8400 MHz to maritime-mobile satellite service)
– AI 1.10 (Additional spectrum for the mobile-satellite service in the 22 – 26 GHz range)
– AI 1.11 (Allocation for the Earth exploration-satellite service (earth-to-space) in the 7 – 8 GHz range)
– AI 1.12 (Up to 600 MHz additional bandwidth for EESS (active) in the ranges 8700-9300 MHz and/or 9900 – 10500 MHz)
– AI 1.14 (Continuous reference time-scale)
– AI 1.17 (Wireless avionics intra-communications, WAIC)
– AI 1.18 (Automotive short range radar in the range 77.5 – 78 GHz)

• Report from the Spectrum Management School in April 2014, Chile

Hase reported on the Spectrum Management School in April 2014 in Santiago, Chile. The School was attended by 36 participants from 13 countries in five continents. Two other CRAF members also attended the School as lecturers, van der Marel and Millenaar, the latter also presenting a lecture written by and on behalf of Thomasson. The participants highly valued the lectures that were provided by 21 experts in the field. For more details on the school see the paper by H. Hase in Newsletter 28.

• Status of Iridium NEXT

Van der Marel reported on the meetings between CRAF and Iridium on the future protection of radio astronomy in the presence of Iridium NEXT satellites and the discussions that took place on this topic at the CEPT WG FM meetings. Problems are likely to occur in the band 1610.6 – 1613.8 MHz from out-of-band emissions from the Iridium NEXT satellite constellation. Iridium claim that its NEXT satellites will be able to operate with reduced bandwidths of 6.5 MHz and 4.5 MHz in so-called RASP modes, which will result in no significant interference to the RAS. However, this will not be possible during peak hours (between noon and 18:00 hours) when the maximum bandwidth of 8.5 MHz is required on a daily basis. Moreover, the lower bandwidth can only be set at other times of the day after an advance notification of 24 hours by a radio observatory. It appears that in practice Iridium is not able to protect the RAS as required by ECC/DEC/(09)02. The discussion will be continued at the 80th WG FM meeting in May 2014.

• Workshop on compatibility and sharing calculations (A. Jessner)

Jessner gave a presentation on compatibility and sharing calculations in which he also explained the use of the Matlab software routines that he had developed. The presentation and the software will be available for all CRAF members, who are requested to use the software and to report any problems, bugs and other comments to Jessner.

Report from the 57th CRAF meeting

The 57th CRAF meeting organised by the School of Physics, Trinity College, Dublin, Ireland (TCD), took place on 12-13 May 2015 in Birr Castle, Birr, Ireland. A guided visit to the 1.8-m 'Leviathan of Parsonstown' optical telescope was organised for interested participants during the afternoon of Tuesday 12 May. A visit to the Rosse Solar-Terrestrial observatory (RSTO) was also offered to interested participants during the lunch break of Wednesday 13 May. The CRAF meeting was opened by Prof. Peter Gallagher (TCD Physics), who welcomed the participants. Fifteen CRAF members and two CRAF observers attended the meeting, the latter being B. Winkel (MPIfR) and J. McCauley (TCD, Physics), who attended the whole meeting. Jim Connolly (The Commission for Communications Regulation in Ireland – COMREG), Tara Kavanagh (COMREG), Zeeshan Nazneen (COMREG), Diana Morosan (TCD Physics), Dr Pietro Zucca (TCD Physics), Prof. Peter Gallagher (TCD Physics) also joined the meeting during the afternoon session of 12 May 2014. Martin Hynes (ESF) joined part of the closed morning session of 12 May 2015 by video-link. A joint discussion was organised by video-link during the afternoon session of 13 May 2015 with the CORF meeting in the Keck Center, Washington, DC, USA.

• Communications concerning CRAF

1. *Correspondence*
   Letters announcing their resignations as CRAF members were received from the director of the Astronomical Institute of the Academy of Sciences of the Czech Republic and from the director of EISCAT. It was decided to offer the Czech Republic and EISCAT the status of Observer in order that their involvement with CRAF would continue.
2. *New member*
   CRAF welcomed Dr Vincent Piétu from the Institut de Radio Astronomie Millimétrique (IRAM) as a new member.
3. *Communications*
   The CRAF chairman announced that he will send a CRAF news email to CRAF members and affiliates every 2 months. The CRAF FM also announced that she will send out reports from meetings more regularly. A concept for a new CRAF website was presented and the meeting agreed that the current CRAF website should be implemented using the new concept. CRAF members were asked to examine the material on the old web site before the move to the new site.
4. *CRAF Chairman*
   The Chairman, Hans van der Marel, announced that he would end his term of office at the end of the year and would not offer to continue as chairman for the possible two year extension. A committee of three CRAF members, Lindqvist, Thomasson, and Bolli, was formed to identify new candidates for the election of a new chairman.
5. *Modification of the Charter and Rules and Procedures*
   It was proposed that expenses for travel and accommodation could be claimed from the CRAF budget by CRAF members attending international meetings representing CRAF. It was also proposed that there should be a minimum of one annual general meeting and that additional meetings would be organised as necessary. In addition to the positions of chairman and secretary, it was decided that a position of vice-chairman should be introduced. The vice-chairman could replace the chairman or secretary whenever they were absent. These modifications were supported by the members and will be used as input for the discussions with the new host.
6. *CRAF budget*
   In 2014 CRAF stayed within its projected budget. For 2015 it is expected that income and expenditure will exactly balance. It was decided not to change the CRAF member contribution for 2015. For 2016 and beyond it is to be expected that the CRAF member contribution will have to increase because of larger overhead costs of the host organisation and also reimbursement of travel and accommodation to members arising from the absence of RadioNet funding. A decision on the magnitude of the contribution change was postponed until more details are available later in the year.

• ESF and future CRAF host organisation

It was decided that CRAF should continue talking to both the ESF and the JIVE-ERIC, which was inaugurated as an ERIC in April 2015, and to await the decision of the ESF Governing Council Meeting (mid-June). If there were to be a positive outcome, then both hosting options should be considered in greater detail. It was proposed to have a CRAF meeting in the autumn to discuss the hosting issue and also the WRC-15 preparation.

• Frequency Management Activities

CRAF approved the FM's report for the period 15 March 2014 to the 30 April 2015.

• **WRC-15 Brief**

From 2 to 27 November 2015 the World Radio Conference 2015 (WRC-15) will take place in Geneva, Switzerland. CRAF agreed that work on the development of the CRAF position on WRC-15 agenda items must continue at full speed.

• **Status of Iridium NEXT**

The FM and the Chairman reported on the meeting about the future protection of radio astronomy from the IRIDIUM NEXT satellites. CRAF indicated that neither of the protection schemes indicated by IRIDIUM, which required advance notification to the radio observatory sites would meet the requirements of ECC/DEC/(09)02 and that the only technical solution would be to continuously limit Iridium NEXT operations over Europe to their RASP modes with a maximum bandwidth of 6,5 MHz. CRAF's proposal was supported by the majority of participating administrations. Full deployment of the new constellation of NEXT satellites is expected to be completed by the end of 2017. With the support of the Netherlands, Germany and Switzerland at the WGSE meeting in May 2015 CRAF requested a measurement campaign on the first new IRIDIUM satellites with the Leeheim satellite monitoring station at the beginning of January 2016.

The next Annual General Meeting will be held in Helsinki (Finland) in spring 2016.

Vincenza Tornatore

Cognitive Radio and White Space Devices – Part 2

In part 1 of this article, it was noted that the radio-frequency spectrum had become a very valuable commodity, and that governments now see it as a major source of income. There is a great demand for spectrum, which is of course limited, so if it is possible to share spectrum between users, this should perhaps mean greater efficiency of use, and probably more government income.

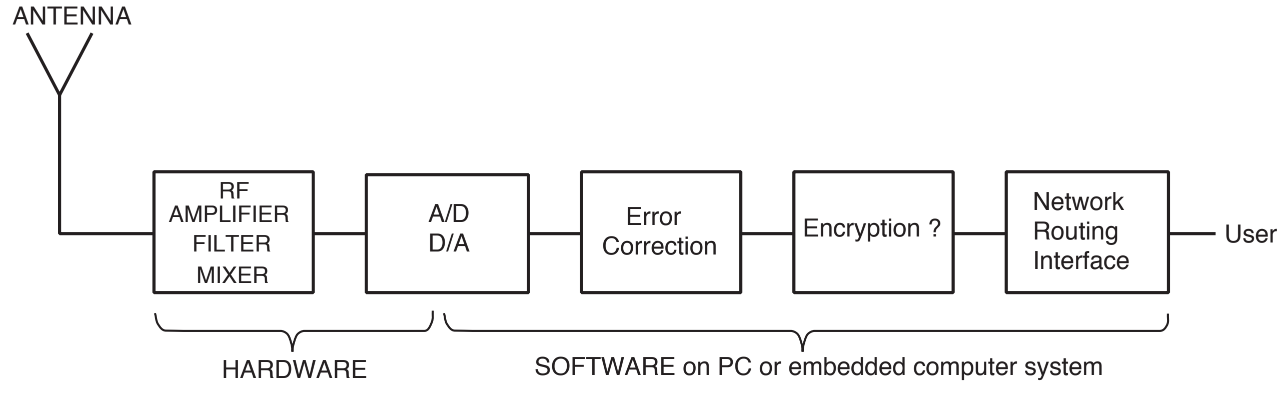
A Cognitive Radio is an intelligent radio with software that can be installed, so that the system can be configured dynamically to use any part of the communications spectrum in which it doesn't find anybody else transmitting at any given time. This implies that if a cognitive radio system does not detect that a particular band of spectrum is in use, then why not simply start using it. This can be extremely dangerous for the purely passive and other bands used by many services (in particular the radio astronomy service). The purely passive bands should effectively always be free of man-made transmissions and the other radio astronomy bands should be free of man-made transmissions at least within telescope co-ordination zones.

Cognitive radio - its first appearance

The concept of Cognitive Radio was first proposed at a seminar in 1998 at the Royal Institute of Technology in Stockholm, Sweden (KTH) by Joseph Mitola III and subsequently published by him and Gerald Q. Maguire Jr. in 1999. Joseph Mitola III can perhaps be thought of as the 'father' of cognitive radio and, although a US citizen, he was studying at KTH and his continued work resulted in a PhD, entitled 'Cognitive Radio - An Integrated Agent Architecture for Software Defined Radio'. From this title, one can correctly gain the impression that Cognitive Radio is an extension of Software Defined Radio (another term to remember), the concept of which had been in existence for some 15 to 20 years prior to this.

Software Defined and Cognitive Radio

In a software defined radio communication system, many of the components that are normally implemented in hardware (e.g. mixers, filters, amplifiers, modulators / demodulators, detectors etc.) are implemented by means of software running on perhaps a personal computer, or



Simple Software Defined Radio Implementation

more likely on an embedded computer system (normally a real-time computing system with a dedicated function). Nowadays, these would probably be microcontrollers with a few designated peripherals. One can think of a simple ideal design for a software defined radio in which an Analogue-to-Digital converter (AtoD) is attached directly to an antenna (+ amplifier, filter and possibly mixer), the data from which is transferred to and digitally processed in a computer to whatever format a particular application requires. Typically, account would have to be taken of communication errors, and the data would probably have to be encrypted for commercial use. A person running the system would want to know the network route in case there are problems / hardware failures. For transmission, the reverse process would take place. However, in reality for many transmissions, the AtoD conversion could probably not function at a high enough rate and high enough accuracy.

In theory a Cognitive Radio system has more built-in intelligence to enable it to be programmed and configured dynamically. Its transceiver should be designed to use the best wireless channels in its vicinity, configuring the radio-system parameters not only to alter the operating frequency, but also perhaps the waveform itself, the communications protocol and even the networking; i.e. the paths of the communications. It is clear that before any changes can be made to the system parameters of a Cognitive Radio, information must be exchanged about the environment of the networks it accesses and also other Cognitive Radios. A Cognitive Radio must also monitor its own performance continuously as a part of the determination of the RF environment, channel conditions, link performance etc. before any adjustment is made to the radio's settings.

TV White Spaces and Devices

The recent changes from analogue to digital TV transmissions, certainly in the UK, the US and Singapore, have resulted in the 'freeing' of significant amounts of spectrum, primarily because digital transmissions can be packed into adjacent channels, whereas analogue ones cannot. It is also the case that the same TV transmissions from two nearby locations are not usually assigned to immediately adjacent channels because they could destructively interfere with each other. The above results in the availability of frequencies, originally allocated to the TV broadcasting service, no longer being used in specific locations. These unused frequencies have been referred to as 'TV white spaces' (more recently as dynamic access spectrum) and the Federal Communications Commission in the US (FCC) and the Office of Communications in the UK (Ofcom) are now allowing the use of these white spaces for the development of Cognitive Radio transmissions. Singapore is also conducting trials using the UHF TV spectrum and it is rumoured that Microsoft are conducting trials for the use of white spaces for rural broadband in Africa.

The devices that operate within these 'white spaces' are often referred to as 'White Space devices' (WSDs), and are meant to include technologies to prevent interference, such as some form of spectrum sensing (i.e. checking that nobody else is using a particular frequency channel) and geo-location. However, there is a major problem with spectrum-sensing cognitive-radio in that there is great difficulty in designing high-quality spectrum-sensing devices and also in designing the algorithms necessary for exchanging spectrum-sensing data between nodes in a communications network. It has been shown that a simple energy detector cannot guarantee the accurate detection of the presence of a signal, i.e. more sophisticated techniques must be employed.

Operation of TV White Space Devices I

Standards and protocols

The current approach for TV white space devices is not to use sensing, but to interrogate a geo-location database. The database will take account of the locations and frequencies of potential victim receivers and calculate the maximum power for the white space device and the appropriate channel frequencies. This information and other relevant parameters now need to be sent out via the Internet to a 'white space master station', which in turn will transmit the control data to a 'slave white space device' on the defined frequency. It is in this area that yet another new aspect is encountered, namely standards and protocols.

Work in Progress on Regulation and Standards

Work is being undertaken in ITU-R by WP1B, but that is merely to produce a report. Similarly work in CEPT has only resulted in reports: - ECC Report numbers 159, 185 and 186. Perhaps this is why ETSI has taken the initiative and has produced a European Harmonisation Standard for TV WSDs,
http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.00.09_30/en_3015 98v010009v.pdf

In order to help with guidance for national implementation, CEPT FM53 has commenced work on a new report on a proposed regulatory framework for TV WSDs using geo-location databases, and the Internet Engineering Task Force (IETF) is producing a geo-location database specification 'protocol for accessing white-space databases (PAWS)'
https://datatracker.jetf.org/doc/draft-ietf-paws-protocol/?include text=1

WeightlessTM is a product level standard for machine-to-machine (M2M) communications using TV white space spectrum. It is optimised for range, battery life and chip cost. This open standard is being developed by the Weightless Special Interest Group (SIG), which operates on a not-for profit basis. Membership of the SIG ranges from observer through to promoter status, increasing membership level giving increasing levels of access with the promoters being members of the Board. The promoter members are Accenture (a management consulting technology services company), ARM (who make the RISC processors found in many computers and 'gaming' machines, to name but two), Cable & Wireless (a global communications company), CSR (a global provider of technology solutions) and neul (a communications company who provide NeuNET, integrated basestations etc.).

The SIG consists of several sub-groups that draft the standard's chapters, e.g. security, physical layer and applications, and contribute to other SIG activities. Having formerly worked at Ofcom developing spectrum policy for science services and attended many ITU-R SG7 and WP 7D meetings, and therefore being mindful of the 608-614 MHz passive band within the range of TV frequency allocations, Howard Del Monte became interested in the Weightless approach to security, and his current role is Chairman of the SIG's regulatory sub-group. Weightless security covers not only the user data level, but also the transmission of control data that defines the RF parameters including frequency and power levels. Although it is impossible for communications systems to be 100% secure, Weightless has striven to minimise security risks by adopting industry standards for encryption algorithms.

Operation of TV White Space Devices II

Returning to the current approach for transmissions in TV white space, a base station, which is also connected to the Internet, accesses a database to identify the frequencies or channels that it can use without interfering with TV broadcasts and other licensed devices in its local area. It then transmits information such as the times and frequencies at which the devices can transmit back to it to up to a few thousand devices using the Weightless protocol. In other words, the RF parameters of WSDs are controlled by a geo-location database and not by sensing. Bandwidths are based on the TV channels, i.e. 6, 7 or 8 MHz dependent upon the existing standard for the continent, and there is provision for 100 kHz sub-bands and also for using two adjacent channels for a larger bandwidth, but with reduced output power. However, it is important to note that the regulatory status for using white space spectrum is not yet finalised regionally or internationally. Everything is still being discussed.

Currently the Ofcom approach in the U.K. is to classify white space devices as licence-exempt, although it is possible that Ofcom will actually have more regulatory control over them than even for licensed stations. This is because, if Ofcom wanted to change the limits of the RF characteristics within the device capabilities, it could instruct the database accordingly and subsequently the devices could be operating under the new constraints in a very short time, which could be hours or less, maybe minutes. Indeed there is a 'kill switch' facility whereby the database could instruct cessation of transmissions from the devices if, for example, interference is reported. At the time of writing, Ofcom has submitted a discussion paper to CEPT FM53 suggesting various database options, including a single database operated by the regulator, rather than the multiple, commercially operated databases in the U.S. white space systems. Ofcom has also adopted the draft ETSI harmonised standard for its pilot trial.

White Space outside TV UHF bands

With regard to white space outside the TV UHF spectrum there are several factors involved in defining a suitable band, not the least of which is that it would have to exhibit suitable propagation characteristics. While UHF can provide up to 10 km range for the permitted output power, the shorter path lengths of higher frequencies could restrict the type of applications, and the longer path lengths of lower frequencies could create interference issues. Another factor is the range of transmitter deployment for the existing services. For example an existing mobile service would aim to provide full coverage and consequently there should be no gaps; no white space. So finding other suitable bands would need careful consideration.

Further Useful Reading?

The CEO of Weightless has written a book on dynamic white space spectrum access that can be downloaded at no charge from http://www.webbsearch.co.uk/?page_id=24. This webpage also includes links to other documents that may be of interest.
The presentation slides from the SG1/WP1B white space workshop held before the WP1B meeting in January 2014 can be downloaded from http://www.itu.int/en/ITU-R/study-groups/workshops/RWP1B-SMWSCRS-14/Pages/Presentations.aspx

Peter Thomasson & Howard Del Monte

Figure 1. On the left, a 14-metre radio telescope, and on the right, a 1.8-metre solar radio telescope.

Radio astronomy in Finland

Introduction

Metsähovi Radio Observatory (MRO) in Finland, which has been operational since 1974, is a separate research institute of Aalto University's School of Electrical Engineering.[1] It is located approximately 40 kilometres west from Helsinki (GPS: N60˚13.04', E24˚23.35'), not far from Metsähovi Optical Observatory (operated by the University of Helsinki) and Metsähovi Space Geodetic Station (operated by the Finnish Geospatial Research Institute and the National Land Survey). A Cassegrain radio telescope with a diameter of 13.7 metres is the main instrument at MRO (See Figure 1 left). In addition to microwave observations, the high surface accuracy of the main mirror (0.1 mm rms) enables observations to be made at millimeter wavelengths. Currently receivers are available for bands S, X, K, Ka, and W, although they are not all permanently installed. It takes approximately one day to replace a receiver with another, with the dual frequency receiver at 37 GHz / 22 GHz being the most frequently used. There is also a smaller radio telescope (dish diameter 1.8-metres; see Figure 1 right), which is used for continuous monitoring of the Sun at a frequency of 11.2 GHz. Mounted on each side of the rim of this dish are two log-periodic antennas, which are used for low frequency (50-850 MHz) solar radio burst monitoring. All the solar data from the 1.8-m dish and log-periodic antennas, derived from 2 e-Callisto spectrometers, are fed to the e-Callisto network[2].

In addition to the solar research, the main research areas of MRO are variable quasars, active galaxies, molec-

1. Metsähovi Radio Observatory, www.metsahovi.fi
2. e-Callisto network, http://www.e-callisto.orgs

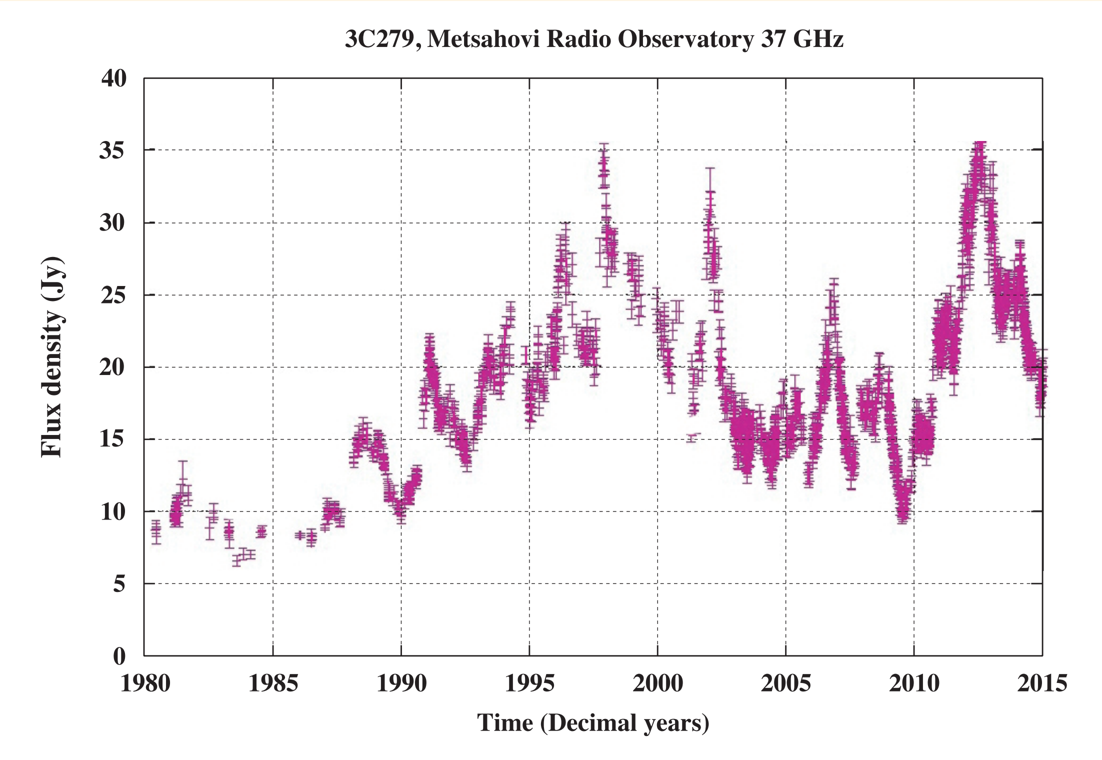


Figure 2. Total flux density variability of the quasar 3C279 at 37 GHz since 1980.

ular line radiation, and both astronomical and geodetic Very Long Baseline Interferometry (VLBI).

In the summer of 2014 four old GlobalStar dishes, each of 5.5-metre diameter, were donated to MRO to be used in a project called the Metsähovi Compact Array (MCA). The dishes will be modified to enable their use as radio telescopes within the next few years. The ultimate goal of the MCA project is for the four antennas to be used as a wideband interferometer network (4-15 GHz). The first construction phase begins this year, when it is planned to mount one of the dishes.

Radio Frequency Interference (RFI) issues have a high priority at MRO and the RFI spectrum is monitored continuously. The lowest RF band (S) is monitored directly, whereas for the higher frequency bands, it is the associated IF-bands that are monitored.

Observations

The variability of the total flux density of a large sample of quasars and other Active Galactic Nuclei (AGNs) at 37 and 22 GHz is monitored in order to study their long term behaviour, to test and develop radio variability models, and to constrain and develop multi-frequency variability models (including gamma-ray emission at GeV and TeV energies). Metsähovi observations are also used for the study of various AGN sub-populations in order to better understand unification scenarios and evolutionary models of AGNs.

The strengths of the Metsähovi observations are twofold: First of all, flux variability data (e.g. as shown in Figure 2), which can be used for the study of typical variability timescales and the overall radio behaviour of sources, exists over a very long uninterrupted time period. Secondly, the sampling is so dense that individual outbursts can be studied in great detail. Finally, the flexibility of the telescope time scheduling allows a quick response to Target-of-Opportunity observations and enables new source samples (most recently Narrow-line Seyfert 1 galaxies) to be introduced into the source sample lists.

Solar radio observations have been carried out using the 13.7-metre radio telescope at MRO since 1978, the long time-period of the data set enabling solar cycle studies, solar radio flare investigations and the study of short-term changes in the solar atmosphere (so-called oscillation studies). During the summer time, because of MRO's far northern location, 14-hour continuous solar observations are possible, which is quite a unique feature. From these the total radiation of the Sun at 11.2 GHz is obtained [3], and perhaps the most well-known outputs from MRO are the daily solar radio maps at 37 GHz (e.g. Figure 3)[4].

3. Total radiation of the Sun at 11.2 GHz, http://www.metsahovi.fi/Sunant/
4. Metsähovi solar radio map gallery, http://www.metsahovi.fi/solar-gallery

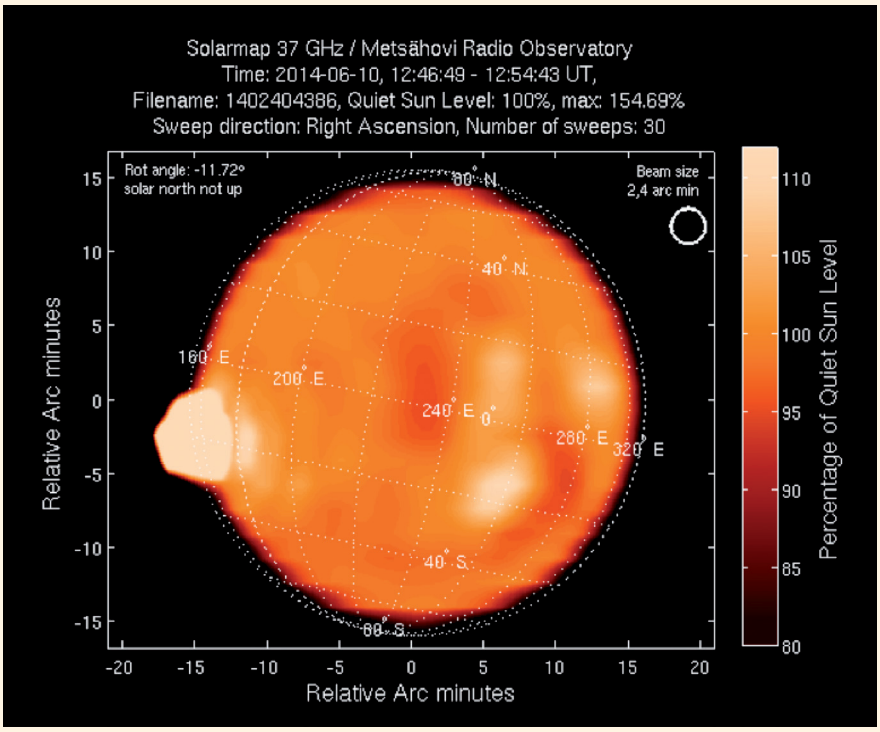


Figure 3. Solar radio map at 37 GHz (observed on 2014-06-10).
On the left, one can see a strong radio brightening.

Metsähovi takes part in both astronomical and geodetic Very Long Baseline Interferometry (VLBI) observations, contributing to several different VLBI networks: the European VLBI Network (EVN), the Global mm-VLBI Array (GMVA) and the International VLBI Service for geodesy and astrometry (IVS).

Since 1991, Metsähovi has been one of the few sites worldwide actively constructing and developing new data acquisition systems for VLBI observations. Using state-of-the-art techniques for space-VLBI and mm-VLBI, it has been possible to obtain ultra-high resolution images of the black-hole powered jets close to their formation site, and to study the launching, acceleration and collimation of jets. Variations in the rotation of the Earth, important for spacecraft navigation (e.g. GPS satellite navigation) have been investigated using geodetic VLBI data, and it has been possible to compare different software analysis packages to ensure the most accurate results.

Other radio astronomical facilities in Finland

A relatively new LOFAR station has been located in the Northern part of Finland (Finnish Lapland). The Kilpisjärvi Atmospheric Imaging Receiver Array (KAIRA)[5] consists of a Low-Band Antenna (LBA) array approximately 34-metres in diameter (centre GPS: N 69 4.24 E 20 45.72), and a High-Band Antenna (HBA) array approximately 30×50 metres (centre GPS: N 69 4.26 E 20 45.66). Both arrays have 48 antennas. Each LBA is an inverted-V dipole with a frequency range of 10 to 90 MHz. Each HBA is a tile containing 16 bow-tie antennas with a frequency range of 110 to 270 MHz. All antennas have dual linear polarisation. KAIRA is operated by Sodankylä Geophysical Observatory[6] of Oulu University. MRO and KAIRA collaborate very closely especially in the field of solar research.

Juha Kallunki

5. KAIRA, http://www.sgo.fi/KAIRA/

6. Sodankylä Geophysical Observatory, http://www.sgo.fi

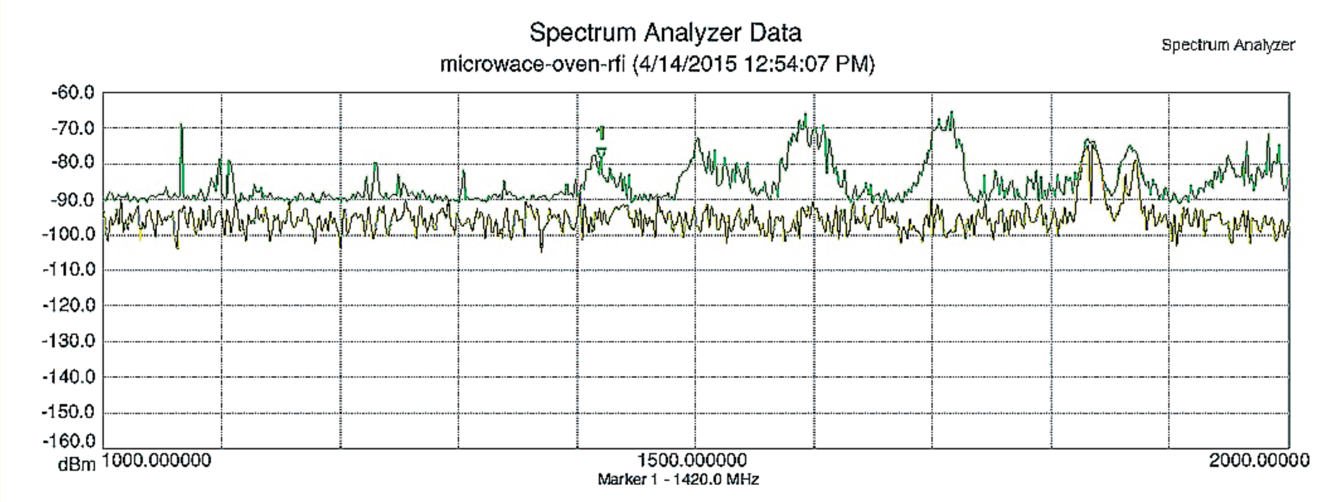


Figure 4. Plot of detected emission vs. time (running right to left) and frequency (running left to right).

Emission from microwave ovens

Fast Radio Bursts or perytons seen at the Parkes Observatory turned out to be emission from two unshielded microwave ovens, which occurred if the oven door was opened before the end of the 'cooking' time. Measurements on the microwave oven in the observatory tea room at Jodrell Bank have been undertaken to make a comparison, one of the results of which is shown in Figure 4.

Note that the spectrum analyser was set to 'Max Hold', so that frequency is effectively running from left to right and time is running from right to left in the plot. The bursts of interference, with the frequency changing with time, can be clearly seen. It was interesting to note that the level of interference seemed to vary dependent upon who opened the door, probably indicating a variation with the speed of opening. (Note that the Jodrell microwave oven is normally in a Faraday cage, whose door is normally shut when in operation.)

Peter Thomasson

Status of solar radio astronomy observatories in Europe

Introduction

For the last 65 years, Europe has been a major player in solar radio astronomy, combining innovative observing capabilities and a strong scientific community, which meets regularly in the frame of the Community of European Solar Radio Astronomers (CESRA). Although in recent years several facilities and research groups have seen their activity reduced with the retirements of scientists using or operating the instruments, new groups have emerged in countries which were previously not much involved in radio astronomy. This article briefly presents the current status of the observational capabilities in Europe. While it focuses mostly on the situation in the European Union, one should not forget the efforts that are being undertaken all over the world, especially in the Ukraine, Russia, China, the United-States and Brazil, to provide the solar physics community with high quality observations.

Importance of solar radio astronomy

The Sun provides a unique opportunity for the study of astrophysical plasmas, the evolution of magnetic fields, the energy release during eruptive events and the acceleration of particles. In all these processes, solar radio astronomy

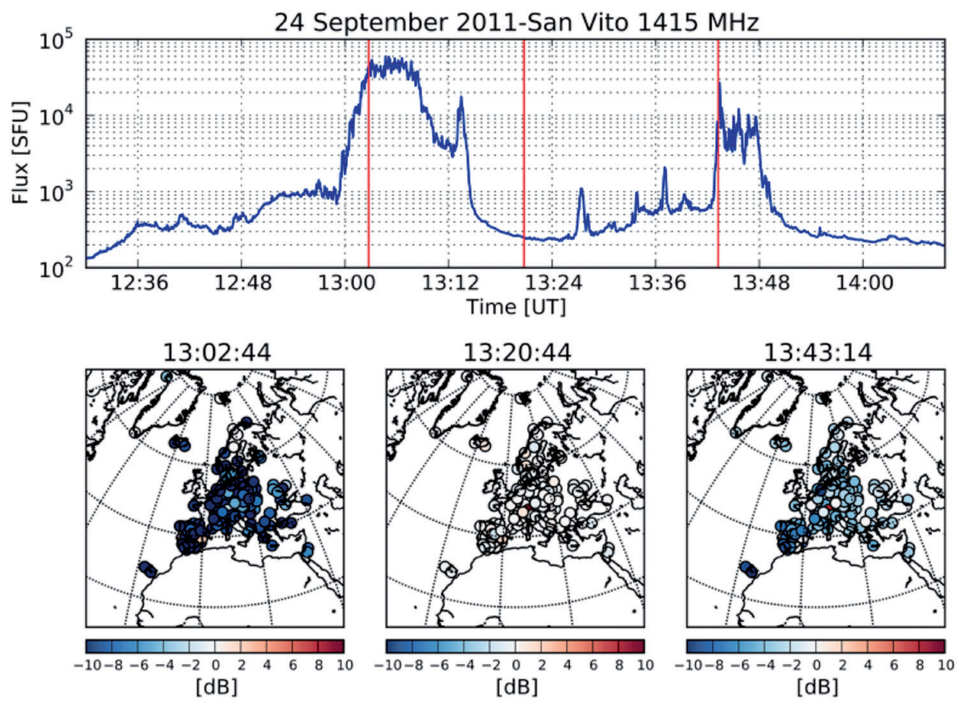


Figure 5. Impact of a solar radio burst on the EUREF GNSS network (adapted from C. Marqué, N. Bergeot, W. Aerts, J.-M. Chevalier et al., Poster at the European Space Weather Week, 2012).

provides insight into fundamental processes occurring on timescales ranging from milliseconds to hours and days. Complementary to those at other wavelengths, radio observations in the last 65 years have shown that they are an invaluable tool for the study of the physics of the solar terrestrial relationships, now better known as Space Weather. Observations of eruptive events in the metric range show the release and acceleration of electrons during flares, the propagation of large-scale coronal shock waves associated with Coronal Mass Ejections, or the restructuring of the coronal magnetic field in the aftermath of eruptive events. In the microwave range, incoherent emissions above solar active regions give measurements of the magnetic field strength at heights that are not accessible by other means. During eruptive events, microwave emissions complement soft and hard X-ray observations to decipher the source and the acceleration mechanism of electrons in the low corona, while on large time scales, the same emissions provide invaluable diagnostics of the decadal variations of the solar irradiance.

Solar radio emission can in exceptional circumstances provoke disturbances to man-made technologies such as power grids, telecommunications, broadcasting or geolocation. Figure 5 shows a radio burst recorded by the US Air Force station of San Vito (Italy) on September 24, 2011 and the impact of this burst on the GNSS receivers of the EUREF network. Coinciding with the flare, drops as big as 10 to 15 dB are observed in the Carrier-To-Noise ratios of the receivers.

A case for maintaining current observing capabilities

With the rising awareness of potential Space Weather impacts on human technologies, the need for constant solar monitoring has increased. The US Air Force has established a 5-station worldwide network providing dynamic spectral observations in the VHF-UHF bands and spectral irradiance from the VHF up to the Ku band. The only civilian radio counterpart today is the e-Callisto network designed and operated by one of us (C. Monstein, ETH Zürich), which is worldwide, but covers primarily the VHF-UHF band (dynamic spectral observations).

Up to now, Europe has fulfilled its needs in terms of observations on the basis of national policies, but has also somehow managed to cover the whole radio spectrum from the low VHF to the low C band (dynamic spectra). However, imaging capabilities are restricted to the VHF-UHF bands (Nançay Radioheliograph, France) and to the Ka Band (37 GHz, Metsähovi Radio Observatory, Finland). Single frequency observations are scarce as well, with only two stations making observations, Ondrejov Observatory in the UHF band and Metsähovi Radio Observatory in the UHF and in X-band. Table 1 presents a list of the different solar facilities in the European Union and Switzerland, operated by institutional bodies. It shows a rather good frequency coverage and redundancy in the low frequency part of the spectrum, but the situation is more complex than it seems at first sight. In recent years

Country, Observatory	Type of Observations	Frequency range
Belgium, Humain Radio Astronomy Station	Dynamic Spectra (e-Callisto) Dynamic Spectra	45 – 445 MHz 275 – 1475 MHz
Czech Republic, Ondrejov Observatory	Dynamic Spectra (e-Callisto) Dynamic Spectra Flux, single frequency	150 – 870 MHz 800 – 4500 MHz 3000 MHz
Denmark, National Space Institute	Dynamic Spectra (e-Callisto)	45 – 870 MHz
Finland, Metsähovi Radio Observatory, Aalto University	Dynamic Spectra (e-Callisto) Flux, single frequency Imaging, raster scan	50 – 850 MHz 11,2 GHz 37 GHz
France, Nançay Observatory	Dynamic Spectra Dynamic Spectra Imaging, interferometer	20 – 80 MHz 100 – 1000 MHz 150 – 450 MHz
Greece, Thermopyle Satellite Station	Dynamic Spectra	20 – 650 MHz
Ireland, Birr Castle	Dynamic Spectra (e-Callisto)	20 – 400 MHz
Italy, Trieste Observatory	Dynamic Spectra (e-Callisto) Dynamic Spectra (e-Callisto)	45 – 82 MHz 220 – 420 MHz
Slovakia, Slovak Central Observatory	Dynamic Spectra (e-Callisto)	45 – 870 MHz
Spain, University of Alcalá	Dynamic Spectra (e-Callisto)	20 – 870 MHz
Switzerland, Bleien Observatory	Dynamic Spectra (e-Callisto)	20 – 80 MHz
United Kingdom, Glasgow University	Dynamic Spectra (e-Callisto)	45 – 80 MHz

Table 1. Solar radio observatories, operated by institutes of the European Union and Switzerland.

several historical facilities, recognised for the quality of their data, have ceased operation or are currently phasing out their observations. The observatories still in operation often run ageing telescopes and receivers, putting the continuity of these observations at risk.

The involvement of the solar radio community in international projects such as LOFAR or ALMA, both of which have the potential for ground-breaking discoveries, is a strong signal of the vitality of this community. The imaging capabilities of these instruments in frequency ranges that have been poorly explored to date can lead to new discoveries in the physics of eruptive events, the disruption of large-scale coronal structures or the physics of the low solar atmosphere. However, these international projects are not designed to observe the Sun on a daily basis or for solar patrol observations. Many aspects of solar activity remain very difficult to predict on time scales exceeding a couple of days and impossible on time scales that are typical when applying for observing time in international projects. Patrol observations operated by small-scale facilities are therefore necessary, both for science and operational activities related to Space Weather.

Interference issues

Solar emission is essentially broadband and signatures of eruptive events can be recorded almost anywhere in the radio spectrum wherever they are technically observable.

In addition to the risk of interference in protected or shared bands for radio astronomy, the growing use of the radio spectrum for digital broadcasts and telecommunications hampers our ability to monitor the eruptive Sun in bands very important for Space Weather purposes. For example, type II bursts, which are associated with shock waves propagating in the solar corona and the interplanetary medium - sometimes towards the Earth - can be observed from the ground, anywhere between ~800 MHz down to the ionospheric cut-off.

If some of the recent state-of-the-art spectrometers can still observe in bands occupied by registered services (see Figure 6), most of the operating instruments have to deal with the growing use of the spectrum or adjust their frequency programme as a consequence.

Perspectives

Although one can be worried for the future of some current facilities in Europe, the situation might not be quite as bleak as it may sound. The scientific community is still very strong and active, and as already stated before, is well organized through CESRA, and heavily involved in the preparation of specific solar observations using LOFAR and ALMA. Important assets such as the Nançay Radioheliograph are being upgraded, and, as an illustration of the growing importance of solar monitoring for Space Weather, the French Air Force has financed the development of a new solar spectrograph, ORFEE in Nançay.

The need for a solar dedicated instrument, combining spectroscopy and imaging capabilities has led the European solar radio community to propose, in the framework of the European Union Horizon 2020 programme, to design and hopefully one day build a world class solar dedicated spectro-imaging instrument, named ESOLAR (European Solar Radio Array). As the last bid in 2014 was not successful, the scientific and operational needs that such an instrument represents are still, as of today, not fulfilled in Europe. This will certainly push the community to submit a new proposal for the next Horizon 2020 "Research Infrastructure Design Study" call, in early 2017.

C. Marqué, C. Monstein, P. Gallagher, J. Kallunki, K. Jiricka

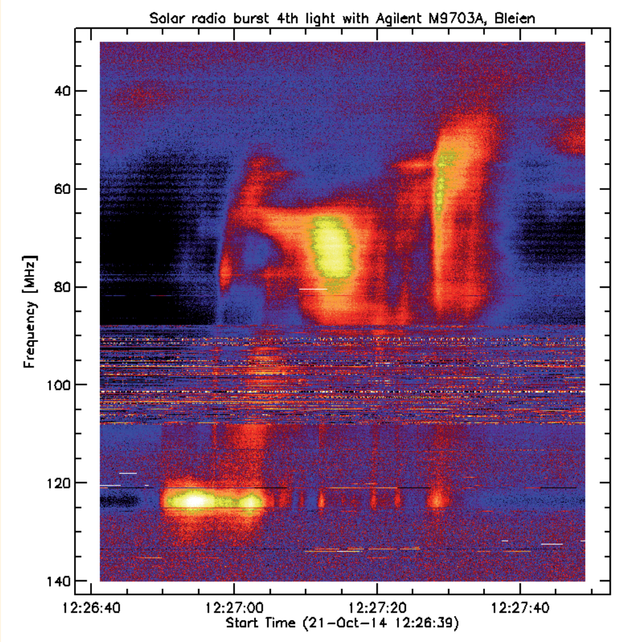


Figure 6. Dynamic spectra of a solar burst with a new receiver developed jointly with Keysight Technologies and ETH Zürich (C. Monstein). The dynamic range of 72 dB and the digital real-time processing enable the detection of a burst within the FM band.

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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