23 CRAF News

The newsletter of the ESF Expert Committee on Radio Astronomy Frequencies

June 2011

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Editorial
CRAF in a Changing World

As a result of an initiative in the mid-80's by three scientists, Hans Kahlman and Titus Spoelstra, based at the Netherlands Foundation for Radio Astronomy (NFRA – now ASTRON), and Willem Baan at the Arecibo radio observatory, who recognised the need for a European radio astronomical spectrum management committee with a full time representative participating in ECC and ITU meetings, NFRA acted by allocating highly qualified manpower for spectrum issues on a long-term basis. Other observatories expressed their willingness to support that leading effort by NFRA, and an MoU was signed by twelve institutes to establish CRAF as an expert committee at the ESF and to provide the joint funding for it and a CRAF frequency manager (FM). The late Titus Spoelstra became the first CRAF FM, and it seemed only natural that the CRAF head office (clearing house) should be established at NFRA.

Unfortunately, Titus had to retire for health reasons and his successor, Laurentiu Alexe from Romania, moved to Dwingeloo at short notice in 2005 in order to take over the CRAF office and to become the new CRAF FM. At the end of a five year term, Harry Smith from the U.K. and Oxford University was appointed to succeed Laurentiu as the new frequency manager in 2010, and Oxford University offered to host the CRAF FM and the head office moved to Oxford.

CRAF is particularly grateful to ASTRON for their past and present enthusiastic support, and now also to the Oxford Astrophysics Department for their far sighted decision to become a new focal point for European radio astronomical spectrum management. However, it must be pointed out that the establishment of, and the subsequent changes to CRAF would not have been possible without the willingness of the ESF to be CRAF's host organisation, and the competent support of ESF liaison officers and staff have been particularly valued.

CRAF is adapting to a changing world in which it is clear that the demand for spectrum outstrips supply. That is also true for radio astronomy, for which new large multi-national telescopes are becoming operational and electronic data processing is providing new and better detection methods. The same is, of course, also true for other radio services and, because of that, spectrum management demands are increasing for everyone.

At the same time, the ESF is also undergoing a significant transformation from an organisation that had direct pan-European research funding and an 'initiating' role into one that aims to become the single voice for European science in Brussels. Such a voice is clearly needed, and a combination of competent expert opinion on particular matters, combined with a better access to decision makers in Europe, would be ideally suited to improve the much needed influence of scientific opinion on political decisions in the future.

Axel Jessner, *CRAF Chairman*

Cover
The Lovell Telescope. © Anthony Holloway, Jodrell Bank

The new Frequency Manager

CRAF welcomes Dr Harry Smith from the astrophysics group of the University of Oxford (UK) as its new Frequency Manager. He was appointed at the CRAF-51 plenary in Madrid on the 4th of November 2010. Harry is no stranger to CRAF. In an earlier role as operations manager at the Mullard Radio Astronomy Observatory (University of Cambridge, UK) he was a full member of CRAF from 2006-2009 and in that period also attended WP7D meetings as a UK delegate. An engineer, Harry's original PhD research was into the characterisation of the mobile-satellite channels at L and S bands. He hopes to put his knowledge of radio propagation to good use in his new role for the protection of radio astronomy.

Report from the 51st CRAF meeting

The 51st CRAF meeting was held on 4-5 November 2010 in Madrid (Spain) at the National Astronomical Observatory. The meeting started with a moment of silence observed for three members of the radio astronomy community who have passed away recently: Titus Spoelstra, Don Backer and Yurij P. Ilyasov. The following persons attended the meeting (names of CRAF members in capitals): A. JESSNER (Chairman), H. SMITH (new CRAF FM as of 1 November 2010), V. BEZRUKOVS, G. BUTIN, M. LINDQVIST, K. JIRICKA, P. THOMASSON, A. TIPLADY, H VAN DER MAREL, H. HASE, C. MARQUE, J. SEIRADAKIS, A. DESCHAMPS, J. RITAKARI, I. FEJES, L. SANTOS ROCHA CUPIDO, R. BACHILLER, N. WILLIAMS (for ESF), A. FAULKNER, H. Liszt (NRAO), J. Urban (Chalmers University of Technology), A. de Frutos (SETSI), J.A. Lopez-Perez (Yebes), A. Barcia (Yebes), J. Fernandez (Yebes), F. Colomer (OAN).

The following key items were among the many different topics discussed during the CRAF meeting:

• ESF situation:
The potential restructuring of the ESF, including a merger with EUROHORCS (European Heads of Research Councils), has implications for the various specialist committees such as CRAF. With a small office being established in Brussels, the ESF General Assembly will be requested to agree to hold another meeting in April at which a decision will be made regarding the continuation of the merger process. Possible outcomes include the following: a) Dissolution of the ESF by 2012 – CRAF must find a new umbrella organisation; b) Strasbourg office retained, but old activities will be re-evaluated by 2015 after a new policy office in Brussels has taken over.

• New CRAF Frequency Manager:
All attendees with voting rights agreed to the employment of Harry Smith as CRAF Frequency Manager. Harry Smith presented himself to CRAF, and recommended that the FM attends fewer meetings in person, but has greater 'electronic attendance' through the input of documents. He also urged greater communication between the FM and CRAF members, and that CRAF's presence and influence should be increased within the greater telecommunications industry. Following the various problems experienced with the previous FM's contract and what was expected of the FM's role within CRAF, it is proposed that a performance agreement is drafted for the FM. It appears that more detailed requirements should be considered following a review of the FM job description, but that overly cumbersome administrative and bureaucratic processes should be avoided.

• CRAF Strategy 2011: Cooperation of Passive Services and EC Spectrum Group:
CRAF has entered into discussions with other branches of the passive radio services community, represented by Edoardo Marelli (ESTEC representative on CRAF) and Philippe Tristant (EUMETNET), to discuss strategies for combining forces and resources in terms of representation at various radio spectrum committee meetings. The current challenge faced by the passive services community is not the lack of people and enthusiasm, but rather the lack of real terms of reference for representation. This results in a lack of active participation at meetings. CRAF has identified a need to join forces, and so this will be a subject of on-going discussions within the community.

Meeting Reports:

- CEPT SE21 Meeting: spurious emissions from meteorological radars at 5.6 GHz can have an impact on the RAS at 5.0 GHz, and the required separation distances are significant.
- CEPT SE19 Meeting: the draft ECC Report on HAPS is presented. This report has significant support from the German administration. It is currently believed that a significant proportion of participants within the process are not supportive of HAPS, which could imply separation distances of 30km to 268km between ground stations and radio astronomy facilities.
- IUCAF Summer School (Tokyo, May/June 2010): although the summer school went well, there was a lack of students with a student to staff ratio of only 1:1. THOMASSON gave the following presentations: one presentation on CRAF; one presentation on RFID. Baan gave a presentation on UWB devices. The presentations are available on the internet.
- CEPT SE40 meeting in Copenhagen: see summary article about IRIDIUM below.

Pietro Bolli

Passive microwave radiometry for atmospheric research and composition monitoring

A brief overview of past and present spectrum usage

Passive microwave radiometers measuring thermally emitted radiation by the Earth's atmosphere from the ground, from airborne platforms and from space are nowadays key components of global observation systems for atmospheric research and the monitoring of the ozone layer and the climate system.

Numerical weather prediction models rely on the assimilation of data obtained from operational meteorological satellites, which employ instrumentation measuring emitted or back-scattered radiation in various spectral ranges from microwaves to the ultra-violet. Amongst the important microwave bands used by meteorological nadir (downward-looking) sensors are those containing the water lines centred at 22.235 GHz and 183.310 GHz. Using spectral measurements from these bands, atmospheric humidity in the troposphere, the lowest layer of the atmosphere, can be determined. Measurements in the oxygen bands at ~63 GHz and at 118.75 GHz enable vertically resolved information on atmospheric temperatures and pressures to be obtained. These channels provide an all-weather capability for the global observing system, since millimetre waves are relatively insensitive to cloud absorption compared with other spectral ranges. Window channels in the regions of low absorption between the strong spectral lines are targeted by nadir-looking satellite sensors for near-surface atmospheric measurements and for observations of land, ocean and ice. Long-term protection of the passive bands in the spectral region below 300 GHz (centimetre and millimetre wavelength ranges) remains important to assure continuous long-term measurements of a large number of geophysical variables for meteorological and climate applications.

Surface-based radiometric monitoring of tropospheric parameters such as temperature, water vapour and cloud liquid has a long history. Multi-frequency radiometers typically utilise similar bands to the meteorological nadir-looking satellite sensors. Dual-frequency radiometers observe, for example, a channel close to the 22.235 GHz water vapour line (often at 20.6 or 23.8 GHz) in combination with a window channel (at ~31 GHz) for deriving tropospheric water vapour and cloud liquid water. Observations of channels close to the centre and in the wing of the much stronger 183 GHz water line are useful for extremely dry conditions such as at high-altitude mountain sites. Multiple bands at ~63 GHz in the lower wing of the strong oxygen line are commonly used for temperature measurements, and window channels at ~90 GHz and 150 GHz provide information on liquid water.

Ground-based microwave instrumentation is also an integral part of equipment at stations of the global Network for the Detection of Atmospheric Composition Change (NDACC). An important goal of the network, established in the early 1990s, is to provide long-term, quality-assessed measurements of the atmospheric composition, with an initial focus on monitoring of ozone and related species in the stratospheric ozone layer. Regular measurements are made of rotational lines of stratospheric ozone (e.g. at 110.836 and 142.175 GHz), of strato-mesospheric water vapour (usually at 22.235 GHz) and of the ozone destroying radical, chlorine monoxide, at 204.35 and 278.63 GHz. Neighbouring lines of carbon monoxide (at 115.271 and 230.538 GHz), nitrous oxide and nitric acid are also often measured. Vertical concentration profiles with moderate vertical resolution can be retrieved from these pressure broadened emission lines. The long-term stability of the instrumentation is essential in order to monitor atmospheric composition and to enable the detection and quantification of weak trends in the presence of natural atmospheric variability, which is both spatially and temporarily large. The long-term protection of the relevant frequency bands in the 22 GHz to 300 GHz range is therefore essential to assure continuity of these important data sets, which rely on observations of only a few weak spectral lines accessible from the ground.

Above 300 GHz absorption by tropospheric water vapour in the lowest atmospheric layer becomes too strong for year-round ground-based measurements, except for a few high-altitude sites. As spectral line strengths increase with increasing frequency, higher frequency bands (at sub-millimetre wavelengths) are widely used by limb sensors on Earth-exploration research satellites. The first millimetre-wave, limb-scanning satellite instrument providing global measurements of the composition of the middle atmosphere was the Microwave Limb Sounder (MLS). The instrument was operated from 1991 to 1998 on board NASA's Upper Atmosphere Research Satellite (UARS), measuring for example lines of oxygen (~63 GHz), ozone (at 184.378 and 206.132 GHz), water vapour (183.310 GHz), chlorine monoxide (204.35 GHz) and weaker lines of other trace gases such as nitric acid. A similar instrument, the Millimetre-wave Atmospheric Sounder (MAS), was

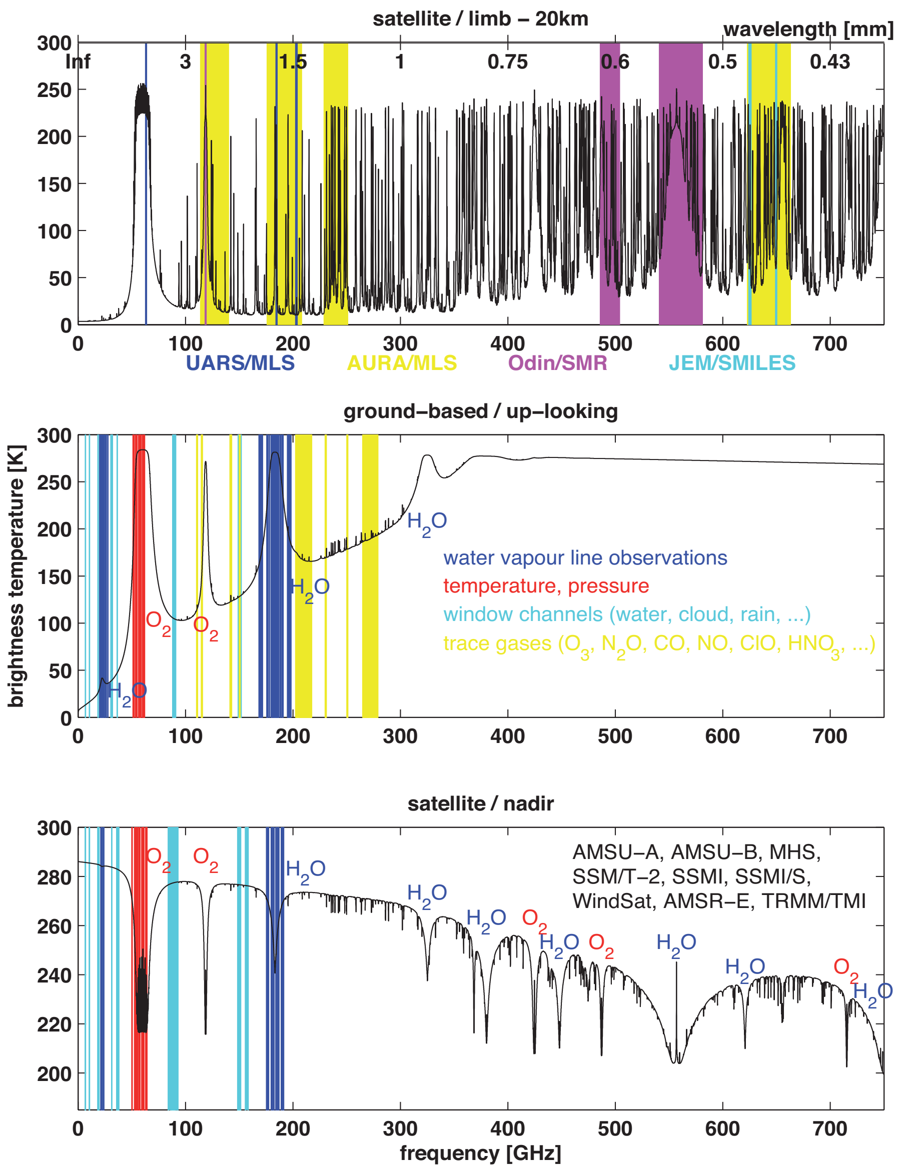

Figure 1.
Use of frequency bands for atmospheric sounding in the millimetre and sub-millimetre wavelength range. Shown are model calculations of atmospheric emission and absorption spectra up to 750 GHz for typical mid-latitude conditions and three different observation geometries.
Top: Thermal emission spectrum as observable by satellite limb sensors at a tangent-height of 20km.
Target bands of the limb sounders UARS/MLS, Aura/MLS, Odin/SMR and JEM/SMILES are shown.
Middle: Emission spectrum observable by ground-based passive microwave radiometers (zenith looking). Frequency bands used by presently deployed instruments are indicated, roughly distinguished by application.
Bottom: Absorption spectrum (against Earth surface emission) observed by nadir sounding instruments on meteorological satellites and presently employed frequency bands.

installed on the ATLAS research platform in the cargo bay of the Space Shuttle and operated during three campaigns in 1992, 1993 and 1994. The Swedish-led Odin Sub-Millimetre Radiometer (SMR), the first space-borne heterodyne radiometer operating in sub-millimetre bands for atmospheric limb observations, was launched in 2001. Four radiometers within the 486-581 GHz range and one millimetre wave radiometer at 118.8 GHz were employed for middle atmospheric measurements of O_3 (489.2, 501.5, 544.9, 551.4 and 576.5 GHz), ClO (501.3 GHz), N_2O (502.3 GHz), HNO_3 (544.4 GHz), NO (551.2 and 551.5 GHz), water isotopologues (488.5, 489.1, 490.6, 552.0 and 556.9 GHz), CO (576.3 GHz) and O_2 (118.8 GHz). A second MLS using various millimetre, sub-millimetre and far-infrared channels for measuring spectral lines including O_2 (118.8 GHz), H_2O (183.3 GHz), CO (230.5 GHz), HCl (625.9 GHz), ClO (649.5 GHz) and OH (2.514 THz) was launched in 2004 on board NASA's Aura satellite. Most recently, the Japanese Sub-Millimeter SIS Limb Emission Sounder (SMILES) was installed on board the International Space Station (ISS) and made measurements from October 2009 to April 2010. For the first time, this instrument used sensitive Superconductor-Insulator-Superconductor detector technology at 625/650 GHz together with a mechanical 4K cooler to observe O_3 (625.3 GHz), HCl (625.9 GHz), ClO (649.5 GHz) and many other important minor species such as HO_2, BrO and HOCl in the stratosphere and mesosphere. Several future projects are being planned. An example of these is the Stratosphere-Troposphere Exchange and Climate Monitor (STEAM). This radiometer will operate in bands in the lower sub-millimetre range from 310 to 360 GHz and will be dedicated to the exploration of the

Upper Troposphere/Lower Stratosphere (UT/LS) altitude region. It is currently being assessed by the Swedish Space Board and the European Space Agency. Other climate-related research projects have been proposed and are being considered in Europe, Japan and the US.

It should be emphasized that line selection is often difficult as important simple, linear molecules have only a few accessible rotational emission lines. Examples of lines typically observed by ground-based and space-borne sensors are the CO lines at 115.3, 230.5, 345.3, 576.3 and 691.4 GHz, HCl lines at 625.9 GHz, ClO transitions at 204.4, 278.6, 501.3 and 649.5 GHz and OH lines at 1.838 and 2.514 THz. As the lines are pressure broadened, enabling the determination of altitude-resolved vertical concentration profiles of the target species, frequency protection measures must also include the line wings. Required spectrometer bandwidths vary with the atmospheric target region. Whilst mesospheric observations require only very narrow bands of a few tens of MHz, lower stratospheric measurements require typically 1 GHz, and upper tropospheric observations from satellites are planned for up to 12 GHz wide bands (spectrally resolved) in order to allow far-out line wings to be accurately analysed.

The proposed frequency bands for accepted future missions for observations of key spectral lines for atmospheric research will need to be protected in order to allow for interference free measurements once these missions become operational. The use of the frequency region above 275 GHz is currently being discussed in preparation for WRC-2012 ("ITU AI 1.6: Resolution 950, Rev. WRC-07, on the use of frequencies between 275 and 3000 GHz"). Operational constraints and the future needs of atmospheric emission sounding for important weather, ozone and climate related applications will have to be taken into account.

Joachim Urban

RFI measurements at Yebes observatory and in the Azores archipelago

The Yebes observatory has been operating a 40 metre radio-telescope since mid 2007, when the 'first micro-waves' were received from the Moon and Venus using a 22 GHz receiver. A few months later, in May 2008, successful VLBI observations were made when fringes were obtained for the first time with the 100 metre Effelsberg radio telescope.

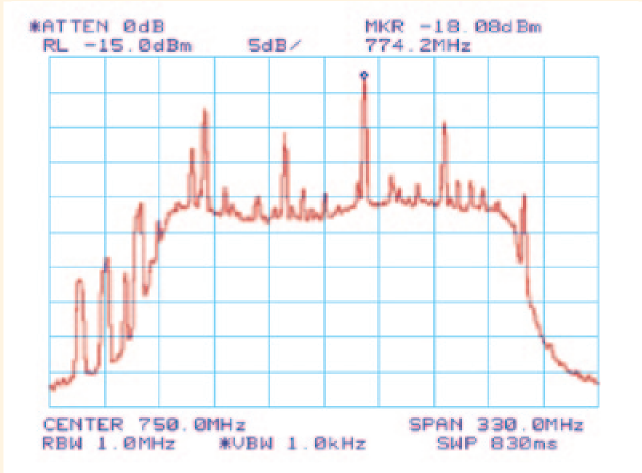

Figure 2
RFI signals in S band.

Currently, the radio telescope has 7 receivers, as shown in Table 1, which have been completely designed, developed and characterised in the Yebes laboratories (an exception is the 3mm receiver on loan from IRAM).

RFI has been seen and investigated since the beginning of operations, with a significant component coming from 'internal' sources such as the antenna servo electronics, ethernet switches, computers and mobile phones. Thus, Figure 2 shows the initial IF spectrum of the S band receiver with most, but not all of the RFI being caused by Beckhoff profibus modules and other telescope control electronics. The three broad RFI signals on the left-hand edge come from radio-links outside the observatory.

It is hoped that all this 'internally generated' interference has been removed from the observed spectra by careful shielding and filtering, although this has not been fully assessed as yet. A portable measurement system consisting of a 90 cm parabolic antenna (moveable in both azimuth and elevation) with a tripod on which is mounted an 850 MHz – 26.5 GHz log-periodic feed and a broad-band amplifier (noise figure 5 dB) was purchased last year to measure the RFI coming from outside the observatory. The characteristics of all the components and cables have been measured and, with the help of the antenna manufacturer's data, it has been possible to calibrate the measurements so as to provide results in units of electric field intensity (dBuV/m). The system backend, which is a spectrum analyser controlled by a laptop, has a sensitivity of ~30 dBuV/m.

Initial measurements made from the roof of the Yebes observatory building when pointing to the horizon have provided the calibrated RFI panorama shown in Figure 3. The bands of the 40m radio-telescope receivers are depicted in red.

Band	Frequency Range (GHz)	BW (MHz)	Polarization	Trec (Kelvin)	Tsys (Kelvin)	Eff (%)	HPBW (“)
S	2.2 – 2.37	170	Dual circular	<50	170	--	740
CH	3.22 – 3.39	170	Dual circular	<50	170	--	560
C	4.56 – 5.06	500	Dual circular	<10	35	60	370
	5.9 – 6.9	500	Dual circular	<10	35	46	280
X	8.18 – 8.98	500	Dual circular	<10	45	70	230
Ku	10.9 – 12.75	10	RHCP	<75	150	--	150
K	21.75 – 22.85	500	Dual circular	<20	65	57	75
	23.35 – 24.45	500	Dual circular	<20	70	56	75
W	84 – 116	600	Linear/Circular	<50	150	11	18

Table 1
Receivers installed on the 40m radio-telescope (the Ku band receiver is a room temperature receiver for holography measurements from prime focus).

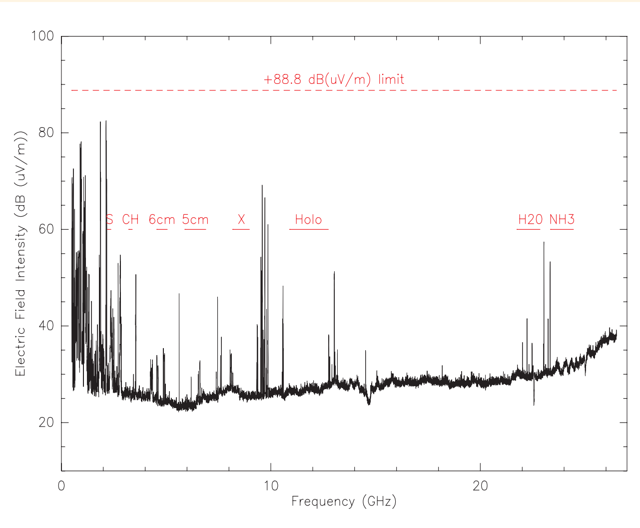

Figure 3.
Yebes observatory RFI panorama.

These measurements reveal three particularly harmful RFI signals in the 22 GHz band allocated to the Radio Astronomy Service. Their direction of arrival will shortly be measured and the situation reported to the Spanish administration of spectrum management. There are also severe problems in the radio astronomy S and C bands, but X band is found to be particularly clean.

The portable RFI measurement system has also been taken to the islands of Santa Maria and Flores in the Azores archipelago to determine the RFI spectra at candidate sites for the installation of geodetic antennas for the RAEGE project (Red Atlantica de Estaciones Geodinamicas y Espaciales). Data from two potential sites on Santa Maria and four on Flores have been analysed. The great potential of these two islands for radio astronomy, at least from an RFI viewpoint, has been established from a comparison of their data with that from the Yebes observatory. The sites of “Saramago” on Santa Maria and “Rochao do Junco” on Flores appear to be particularly clean. It is to be noted that some of the measurements were made at elevations only as low as 8 to 10 degrees because of the height of the surrounding hills.

Detailed information about these measurements and the RFI system can be found in the following technical reports available on the OAN web:
http://www1.oan.es/informes/archivos/IT-OAN-2010-5.pdf
http://www1.oan.es/informes/archivos/IT-OAN-2010-12.pdf
http://www1.oan.es/informes/archivos/IT-OAN-2010-17.pdf

In addition to the above, measurements will be made on Tenerife island in the Canary archipelago with a view to the installation of a RAEGE antenna on that island.

José Antonio López-Pérez

Update on IRIDIUM

Regular readers of this newsletter will be familiar with the issue of interference in the radio astronomy band between 1610.6 MHz and 1613.8 MHz from satellites of the IRIDIUM system. CRAF’s ongoing process of having this recognised and rectified has recently passed something of a milestone with the approval for public consultation of a new report on the issue by the CEPT ECC Working Group on Spectrum Engineering.

Last year, in view of the limitations of the earlier measurements of IRIDIUM emissions in the 1610.6-1613.8 MHz radio astronomy band, it was decided to undertake a new measurement campaign at the Leeheim satellite monitoring station using a spectrometer provided by the radio astronomy community. This instrument significantly increased the sensitivity of the system and permitted the collection of data for the whole of the band. In addition, a procedure for the calibration of the entire measurement ‘chain’ was defined that was similar to those used for the calibration of radio astronomy observations. The measurement set-up and procedure was accepted by all parties including IRIDIUM; CRAF recognises their ongoing cooperative approach.

Analysis of data from the measurement campaign showed that operation of the satellites in the IRIDIUM MSS network causes interference in the radio astronomical band 1610.6 - 1613.8 MHz in excess of the limits given in Recommendation ITU-R RA.769-2. Additionally, EPFD simulations conducted according to Recommendation ITU-R M.1583, using pfd data derived from the new measurements, estimated the combined effect of the visible satellites and showed that the anticipated data loss in a reference time interval of 2000 seconds was between 90% and 100% in the upper part of the RAS band near 1613.8 MHz and reduced to ~90% close to the lower boundary of the band at 1611 MHz. For shorter time intervals of 30 seconds the percentage data loss varied from 5% to 44% at the lower and upper edges of the band respectively. The analysis also furnished the conclusion that interfering signal levels would need to be reduced by 10 - 25 dB in order to keep the data loss below the ITU-RA.769-2 threshold and ITU-R M.1583.

CRAF has suggested that the interference is likely to be caused by non-linearities in the satellite transmitting elements, with the resulting interfering components appearing to be consistent with a 7th order effect related to output power. Consequently, it is believed that a reduction of satellite output power by ~3 dB can sufficiently suppress the interference in most instances. Another possible tactic to eliminate the interference in the RAS band would be a modified channel allocation scheme such that the generated products forming the interference avoid the RAS band. Both of these suggestions, of course, have significant implications for the satellite network operator.

CRAF is also of the opinion that the planned new generation of IRIDIUM MSS satellites should be designed, built and operated so as to avoid interference detrimental to radio astronomy in the future.

What happens now? We hope to have further news soon – watch this space!

The full ECC document for public consultation – "ECC Report 171" is available at:
http://www.ero.dk/A8E95B26-4103-435C-99ED-CA3F1C5E610B.doc?frames=no&
The deadline for responses is 8th July 2011

Harry Smith, Axel Jessner, Willem Baan

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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