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CRAF NEWS

Expert Committee on Radio Astronomy Frequencies (CRAF)

Editorial

There is no doubt that the *liberalisation* recently proposed by Ofcom (the UK Office of Communications responsible for Spectrum Management) raises major concerns for the future of all passive services using the radio spectrum. Ofcom phrases such as 'maximise economic benefits of the spectrum' or 'the market is better able to determine optimal outcomes such as boundary conditions than the regulator' are going to considerably alter the existing regime, currently under the control of the ITU (International Telecommunication Union).

Such a perspective is totally contrary to the typical mentality of almost all researchers in the fundamental sciences. None of them are really concerned about the 'economic value' of their activities; they simply follow their scientific curiosity (assuming that they are not driven too much by career expectations).

If radio astronomy and other disciplines want to survive, attitudes need to change towards, in particular, the European Commission (EC). In fact, the EC has clearly stated that it wants to act as a leader of the modern technological advances proposed by the most market-aggressive industries. For example, in the Ultra Wide Band (UWB) devices, which occupy many GHz of *continuous bandwidth* with no respect for any previous frequency assignments, such industries have found the solutions for many different consumer applications, to be used by *everybody* without the need for *any* licence.

So, it could be that in the future, only if radio astronomers are able to prove the 'economic value' of their scientific results, will European telescopes be granted the protection from radio interference that has allowed them, up until now, to make observations of the radio sky with the maximum sensitivity achieved by the 'top-level' engineers who have constructed their systems. The alternative looks rather simple from the viewpoint of the active services: 'Dear radio astronomers; you are proposing extremely powerful telescopes, like the SKA and other instruments, to be sited in very remote areas. Go there then, and let us sell the spectrum for much more remuneration here in Europe'. Of course there are good arguments to oppose this simplistic proposal.

Therefore, I urge the highest level of attention from all of our community; major actions should come from *all of us,* not just from a small group such as CRAF. The EC, through the Radio Spectrum Policy Group (RSPG), will initiate various forms of public consultation on specific issues of this kind via the Internet. All of you are invited to contribute appropriate input, if you like in consultation with CRAF.

Let me conclude with the following consideration: the old thinking that 'green policy' and anti-pollution propaganda can solve our problems is utopian; we have to bear in mind the totally different plans for the usage of the radio spectrum by an extremely powerful sector of society, which has much more support from an extremely large consensus of public opinion than we have.

Roberto Ambrosini

Report from the 44th CRAF meeting

9-10-11 May 2007

The last CRAF meeting (44th) was held on 10 and 11 May 2007 at the Latvian Academy of Sciences in Riga, Latvia, with an extra day (May 9) spent in Ventspils for a visit to the local university and the International Radio Astronomy Centre (VIRAC). VIRAC was established following the withdrawal of the Russian army from Latvia in 1994, as a result of which the Latvian Academy of Sciences was able to take over a 32-metre, centimetre-wave, fully steerable, parabolic antenna (RT-32) and a 16-metre diameter antenna (RT-16). The existence of these antennas and accompanying facilities of the former (Russian) Space Communication Centre has resulted in the establishment of the Ventspils International Radio Astronomy Centre. The main purpose of VIRAC is to take part in observations of both naturally occurring and artificial cosmic signals in order to accumulate observational data for research programmes in radio astronomy, astrophysics, cosmology, geophysics, geodynamics, geodesy, coordinate-time service etc. Currently, one of the main VIRAC goals is to become a member of the European VLBI Network (EVN).

During the CRAF meeting, the following key items were discussed:

- Prof. Roy Booth, director of the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa, had expressed interest in his institute joining CRAF. In spite of the fact that CRAF is a European committee, it was agreed during the meeting's plenary session, that participation in CRAF could cover the ITU regional division.
- Willem Baan, ASTRON and an invited guest at CRAF44, gave a talk on the The Role of CRAF in Spectrum Management in Europe. He affirmed that CRAF has gained a good name and is well recognised in Brussels and within European spectrum organisations, providing valuable

expertise on passive spectrum use. Protection of passive bands and passive operations is becoming more and more difficult with time and all changes in the spectrum environment are irreversible for the passive community. Extra effort is required from CRAF members to support the CRAF Frequency Manager in such things as: developing positions and input documents for European and ITU meetings; performing relevant technical evaluations of the Radio Frequency Interference (RFI) effects on radio astronomy observing systems; joining him/her when attending appropriate meetings that occur in their own countries. The issues of participation and a spreading of the workload can be addressed only with a mandate from the observatories and universities. Current and future CRAF members need to be able to spend a significant fraction of their time both in national and European participation.

- Recently, a First Interference Management Workshop was held in Brussels. The current situation for spectrum management is under threat because of the increasing commercial value of the radio bands. Ofcom (the UK Administration), in particular, has proposed a completely new *deregulation* method and possible total *liberalisation* of the spectrum. Allocation to new users would be accomplished by negotiation with existing ones based on their respective market values. If that were to happen globally, it is evident that all passive services and radio astronomy in particular would be in an extremely weak position.
- The RadioNet Consortium Board and the Mid-Term Review meetings were held in Grenoble (France) on 11 and 12 April 2007. (The Mid-Term Review was conducted by the EC Project Officer, E. Righi-Steele and an External Expert, Prof. J. Marcaide (University of Valencia, Spain)). Both meetings reviewed the current status of all components of RadioNet and Prof. Ambrosini was able to report the good news that RadioNet has been notified by the EC Research Directorate that it has achieved the highest possible mark, *'good to excellent'.* Concerning the next EC Framework Programme (FP7), the RadioNet community is confident that Networking Activity 8 (Spectrum Management) is expected to continue.
- UWB technology is not compatible with the Radio Astronomy Service. The work on Building Material Analysis (BMA) has been completed, the resulting decisions from which are presented in Decision ECC/DEC/(07)01 (30 March 2007) on BMA devices using UWB technology. There is ongoing work for the Revisions of the Decision ECC/DEC/(06)04 on the harmonised conditions for devices using UWB technology in bands below 10.6 GHz and on the Object Discrimination and Characterisation of UWB devices.
- Iridium issue: at the end of May in Munich, the CEPT SE40 (MSS) was held. This meeting was of great importance to the Radio Astronomy community because of the agenda item concerning 'the Iridium interference in the RA band at 1612 MHz' issue. It was decided at the SE40 meeting that an official contribution from CRAF should be presented. This report should contain the results of several experiments at Effelsberg (Germany) and the Jodrell Bank Observatory (UK) proving that Iridium interference compromises RA observations.

CRAF will be present at the ITU World Radiocommunications Conference in October and November 2007.

Welcome to the 45th CRAF meeting, scheduled for 26-27 November, 2007 in the European Space Research and Technology Centre (ESTEC), Noordwijk (Netherlands).

Pietro Bolli

Iridium transmissions into the radio astronomy band between 1610.6 MHz and 1613.8 MHz

Summary

1. It has been shown at several stations and on several occasions that the Iridium satellite is the cause of severe interference in the protected radio astronomy band 1610.6 -1613.8 MHz. The interference is not only present when the telescopes point to the horizon (ELV=8 degrees), but also at higher elevations (e.g. 50 degrees).

2. The Iridium interference with its current traffic loading adversely affects radio astronomy data with a probability of ~18% of the time during a 2000-second integration. While each reference bandwidth of 20 kHz may suffer from excessive interference above the ITU-R RA.769 thresholds for only 0.64% of the time, the aggregate interference in multiple channels is in excess of 2% of the time and constitutes complete data loss of part of the band for 18% of the time. As far as radio astronomy is concerned, whole observations will have to be repeated whenever an artificial interference-related spectral feature is present in data from spectral-line operations.

An evaluation of Iridium interference measurements

The Iridium satellites have been found to radiate into the radio astronomy band between 1610.6 MHz and 1613.8 MHz at a power level that is considerably (tens of dB) above the interference level quoted in ITU-R RA.769.

The radio astronomy stations at Bleien (Switzerland), Espiunca (Portugal) and Medicina (Italy) reported strong RFI at 1612.4 MHz in May 2007. These signals have also been seen at Effelsberg (Germany) in January and March 2006. Most radio telescopes cannot track a satellite that is in a low Earth orbit and therefore have to resort to an elaborate analysis of spectral patterns obtained with high-resolution equipment in order to determine the signature of the RFI source. However, the satellite monitoring station in Leeheim (Germany) can track such satellites and therefore unambiguously identify them and directly measure the strength of their signals.

Leeheim measurements from November 2006 have confirmed the earlier findings of radio astronomers, and totally independent observations at the Effelsberg Observatory on 23 March 2007 and the Jodrell Bank Observatory on 11 April 2007 have re-confirmed these findings.

The Effelsberg 100-m telescope was at a fixed position of 218 degrees azimuth and 8 degrees elevation and used a hardware spectrometer with 100 MHz bandwidth and 16 384 channels. The system temperature was 50 K and the integration time was 35 seconds. Individual ‘sub-integration’ spectra with integration times of half a second, but lower sensitivity, were successfully used to identify the time-variable spectral signature of the interference and its origin from outside the receiver and detector chain.

The Jodrell Bank telescope was fixed in azimuth at ~150 degrees and elevation 50 degrees. Note that these positions are very different from those at Effelsberg. The data from 4 x 5 MHz adjacent bands covering the frequency range 1610 MHz to 1630 MHz were obtained simultaneously over a time period of ~2400 seconds. A clear correlation was seen between interfering signals in the radio astronomy band at ~1613.2 MHz and the Iridium transmissions at ~1618.7 MHz.

In all these cases, the reception of the RFI signal was from directions away from the high gain main beam of the antenna. This implies that the weak signals seen in the spectrometer were the result of the presence of much stronger signals (50-60dB) from the satellites that exceeded the limits defined in ITU-R RA. 769 by at least 25dB. Radio astronomers have frequently been criticised for not having a pre-selection filter in front of the input stage of their receivers. There are good technical reasons for that, the main one being a significant increase in system noise resulting from such filters as the gain of the amplifier has to be limited in order to avoid oscillations. A satellite tracking station certainly needs steep input filters to avoid the generation of intermodulation products. However, the effectively high off-beam attenuation of a radio telescope serves just as well as a means of protection against overload and the spectra have all been taken in a linear, low-signal input regime. The spectra resulting from a typical LO-frequency-switched, spectral-line observation clearly show differences between external signals, which are seen as fixed lines, and any generated internally by non-linearities. The latter, when referred back to the input frequency, clearly exhibit the switching pattern.

Another so far unresolved issue concerns the terms for assessing the data loss. The current ITU Recommendation (1513) is ambiguous in the case of TDMA satellite signals. Some administrations assess the data loss as the maximum percentage of loss in an individual spectral channel, whereas astronomers maintain that any spectrum showing spurious lines anywhere within the band has to be rejected, as they cannot easily be discriminated from true astronomical detections. One usually needs at least another observation to confirm or reject a detection.

All these issues are now the subjects of further consultation between CRAF and the administrations in order to provide clearer guidelines for future cases.

Axel Jessner, Willem Baan, Peter Thomasson

The neighbourhood watch

European radio observatories are being forced to cope with an ever increasing threat from Radio Frequency Interference (RFI) that is harming their sensitive measurements. Many years ago, to protect scientific interests, special bands have been set aside for the Radio Astronomy Service (RAS) by the International Telecommunications Union (ITU) in their Recommendation series. These bands are a very valuable asset to the scientific community as they provide frequency ranges within which radio astronomy can be carried out with the highest sensitivity. However, nature does not adhere to the ITU’s rules and there are very important scientific questions which require sensitive observations in the non-protected ranges. Radio astronomers have therefore no choice other than to do their best in performing such observations in these often ‘hostile’ spectral regions. Dedicated, expensive RF- and data-processing techniques have been designed in order to detect, suppress or avoid the effects of RFI on those measurements. These mitigation techniques can be successful only up to a certain point and loss of data is experienced. The introduction of artefacts in the data is also to be feared.

It therefore remains important to keep track of the nature and number of RFI sources that appear in the radio spectrum. During the years that observatories have been operating, a number of uncoordinated, but also some coordinated initiatives, have resulted in the monitoring of the radio spectrum for RFI.

In many cases these efforts have resulted in an increased awareness of the importance of RFI-free regions and RFI-free spectral ranges, as well as the need to prevent legitimate transmitting sources from producing unwanted emissions outside their allocated bands, both nationally and internationally.

The trend to free up more of the radio spectrum for unlicenced (transmission) use, the promotion of modes of transmission in wide bands (the so-called Ultra Wide Band applications, UWB) and the promotion of transmission methods that produce radio interference as a byproduct (as in Power Line Communication, PLC) are now well recognised. These are new challenges which call for a harmonised European effort to guard and monitor the radio spectrum at current and future European radio astronomy sites. An organisational structure and methods of exchange of monitoring data are needed to maximise the efficiency of the monitoring processes and the coordination of European and, indeed, worldwide efforts.

Currently CRAF is engaged in studying the possibilities of defining and managing a project in which the European radio observatories combine their efforts to harmonise the monitoring of the radio spectrum at their respective sites. The results of measurements or the data from monitoring experiments would be submitted to a common infrastructure and database system that should provide insight into the current RFI situation in Europe, ultimately allowing the identification of trends and providing a reference point for studies in this field.

A first step for such a project is the specification of a recommended hardware setup to aid observatories that do not yet operate a monitoring station to assemble one. It should be noted that common hardware specifications help in achieving comparable sensitivities, resolution and survey speeds. Secondly, the project will define and design software tools that collect, calibrate and further process the measured data at the local monitoring station. Output products, such as plotted spectra, graphs and statistics will be produced by software tools, which are intended for local use at an observatory. The added value, however, is that measurements from all the participating stations can be collected and combined. The project also needs to define and develop the tools that are needed to compress the locally collected data for transfer to a central database. There, the data from all the stations can be processed and combined to produce statistics and visual displays. The results can be used for special continent-wide studies and for generating the information that is needed to aid in guarding the electromagnetic spectrum and keeping it free from interferers.

CRAF is seeking financing for this project through the European Seventh Framework Programme.

Rob Millenaar

A new generation of Earth exploration satellite systems can destroy receivers in a radio telescope!

A new generation of Earth Exploration Satellite Systems (EESS), which uses radar systems has the potential to burn out the sensitive front ends of radio telescopes operating at ~10.6 GHz frequencies. The satellites are designed to operate at 9.6 GHz, with a bandwidth of 600 MHz and have a peak power of 2.5kW. This power is radiated by an antenna with a gain of 47dBi yielding a power density of 0.011-0.035mW/m2 (Source: Draft New Recommendation ITU-R M.[8B.8-10 GHz]).

Although these systems do not operate in the radio astronomy bands, the sheer power of their emission can overwhelm receivers in adjacent bands. The centre frequency of the radio astronomy '10.6 GHz' band is only 10% in frequency away from the centre of the radar band. Filters steep enough (>60dB/octave) to suppress such out-of-band reception simply do not exist and cannot be matched to the input of a high gain/high sensitivity radio astronomy receiver. A quick calculation shows, that, not only do these systems produce copious RFI, but that they are even capable of destroying the input stage of the receiver should just one radar pulse of 70 microsecond duration be emitted when a satellite passes through the beam of a telescope. For a short moment, the receiver attached to the feed of a 100-m radio telescope would be exposed to an input power of 0.275W, which would heat the first transistor junction to nearly 600K, producing an input voltage of ~4V in a 50 ohm impedance. The junction would be destroyed by either of these effects. This may sound far fetched, but thermal effects in receiver input stages from strong airborne radars at frequencies only 15% above the 2.7 GHz band have indeed been observed in the Effelsberg observatory (Germany).

The probability of receiving one of the radar pulses in the main beam of the telescope when the telescope site is mapped by the satellite is fortunately small (0.1%). However, given the number of vulnerable large telescopes (>10) in the world and taking into account the fact that some may be in areas of special interest to customers of the satellite service, the danger is not negligible. The problem has been noted by interested governments and administrations, and CRAF is urging the administrations to make effective coordination procedure for EESS operations over radio astronomy sites mandatory. It is sufficient for the protection of the sensitive radio receivers of a radio telescope if advance warning of operation were to be given to the site so that mechanical (!) shutters in front of the feeds can be employed to protect the receiver.

Alex Jessner

Interference from CloudSat?

CloudSat is a cloud profiling radar satellite launched by NASA in Spring 2006. It transmits in a 100 MHz wide primary allocation at 94.05 GHz between the primary radio astronomy allocations at 92-94 GHz and 94.1-95 GHz. Its radiation thus poses a risk of interference to radio astronomy observations, particularly in the shared 94.0-94.1 GHz band for which radio astronomy has a secondary allocation. Therefore, in July 2006 a series of test observations were made with the Iram 30-m telescope on Pico Veleta to assess this risk and to define any mitigation needed for routine observations. These test observations were to investigate only telescope main-beam to satellite sidelobe coupling as, in the time available, it was not possible to check satellite main-beam to telescope sidelobe coupling, since this needs overpasses very close to the zenith, which are rare. Main-beam to main-beam coupling is clearly very dangerous for the receiver!

The satellite is in a sun-synchronous low Earth orbit designed to overfly and make measurements near a standard grid on the Earth's surface from a height of 750km. The grid is completely scanned after 233 orbits (approximately 16 days) and thereafter the pattern repeats with a precision of +-20km. There are two or three significant overpasses at Pico Veleta twice per day and the satellite is above the horizon typically for less than 14 minutes. It transmits 3 microsecond pulses at a 4 kHz rate with a peak effective power >1GW (average 25W). Its 0.11 degree beam is directed to the local nadir with an accuracy of 0.07+-0.05 degrees. The sidelobe levels are very small, being -75dB at offsets >8.5 degrees. Similarly the emission bandwidth (300 kHz at -3dB) is accurately defined, dropping -70dB at a 50 MHz frequency offset, which is the edge of the allocated band.

More detailed information is given at http://www.iucaf.org/CloudSat

As the satellite moves too quickly to track with the 30-m telescope, observations were made with the telescope directed close to the predicted position of closest approach. Since it was expected to transit the telescope beam (26 arc seconds) in typically a fraction of a second, spectra were taken with sampling times between 0.05 and 0.5 seconds and with spectral resolutions of 100 kHz and 1 MHz. The largest detections were for transits near the zenith. In favourable cases it was also possible to trace out the sidelobe response and compare it with that expected from a simple model for the envelopes of sidelobe structure of the 30-m telescope (supplemented by ITU Recommendation 509 at large angles from boresight) and the known transmitter sidelobes. In most cases the detected signal was within +6-10 dB of that expected. However, for transits above 85 degrees elevation the predictions apparently underestimated the observed value by up to 26dB. At such elevations the uncertainties in the predicted satellite position (+- 36 arc seconds and perhaps more) and in the details of the sidelobe responses become very critical. Saturation effects in the receiver chain also make the calibration of such observations unreliable.

On this basis the sidelobe model was adopted for estimating the pulse power at the receiver input, and hence for making observing precautions and recommendations. However, it should be stressed that it has not been possible to verify the telescope sidelobe model at large angles from boresight, which is crucial when CloudSat is within a few degrees of the zenith. There are four regimes to consider:

1) Main-beam to main-beam coupling.

The peak power delivered to the receiver is then approximately -6dBW, which exceeds the estimated power for destruction of an SIS mixer (-13dBW). A pointing offset of a few degrees is enough to avoid destruction.

2) Receiver non-linearity and or saturation.

A 1% compression is estimated to occur in the SIS mixer at receiver peak power input levels of -105dBW (-125dBW mean) and saturation at -85dBW (-105dBW mean). For an overpass within a fraction of a degree of the zenith, such compression will occur over the whole sky. However, compression is not expected to occur at elevations <80 degrees and telescope offsets >0.25 degrees. The loss in observing time is then ~ 30 seconds for at most six times per day. These limits are valid for the whole 3mm bandpass since the SIS mixers have little frequency discrimination.

3) Interference during observations in the shared band.

In the least favourable case of a frequency resolution of 300 kHz and an integration time of 0.1 seconds, the receiver input average power limit is approximately -165dBW. This is exceeded over the whole sky for satellite elevations greater than ~ 88 degrees, but for less than ~ 15 seconds per overpass. For satellite elevations <80 degrees and pointing offsets >2 degrees, no interference is expected. In this case the loss of observing time (the time to move 4 degrees at the slowest expected angular velocity of ~ 500 degrees per hour) is ~ 30 seconds per overpass.

4) Interference during observations in the primary radio astronomy bands.

The transmitter spectral fall-off gives an additional protection of 70dB. On this basis, no interference should occur for elevations <80 degrees and pointing offsets >0.25 degrees. The factor limiting this protection may be the frequency discrimination of the receiver chain. For longer integration times the interference becomes apparently less important. For example, for a 2000 second integration a further -16dB is gained.

In summary, interference during observations in the primary radio astronomy bands is possible whenever CloudSat is within ~10 degrees of the zenith, but can be avoided at telescope pointing offsets of >0.25 degrees. Additional simple restrictions on observations near CloudSat when its elevation is >80 degrees are necessary (pointing offsets >2 degrees) in the shared band. Such restrictions in all bands also prevent saturation or destruction of the receiver. Any observing time lost will be of the order of minutes per day. In this special case (time) sharing between radio astronomy and an active service is feasible at the price of some loss in observing time. This is possible because only one fast-moving satellite with 'excellent' sidelobes in angle and frequency is active.

David Morris, Gilles Butin

Abbreviations not explained in the text

ASTRON = Foundation for Research in Astronomy, the Netherlands

CEPT = European Conference of Postal and Telecommunication Administrations

SKA = Square Kilometre Array

TDMA = Time Division Multiple Access

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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