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CRAF NEWS

Expert Committee on Radio Astronomy Frequencies (CRAF)

Editorial

Participating in my first CRAF meeting three years ago in Bologna, I was struck by the congenial but efficient atmosphere that turned out to be the hallmark of all CRAF meetings. CRAF members are established and experienced radio astronomers who meet twice a year to discuss common problems in the protection of the narrow frequency bands reserved for radio-astronomical observations. The Bologna meeting was my first, and it gave me the privilege of meeting Titus Spoelstra and Jim Cohen, both of whom were very much the pivot of CRAF's activity and outreach. Sadly, Jim Cohen died in 2006 and Titus had to retire for health reasons. It took a while for CRAF to recover from the stunning blow of losing two personalities who, between them, had provided so much of our knowledge and experience and shouldered a lion's share of the work. Together with the newly-appointed frequency manager, Laurentiu Alexe, and the new CRAF secretary, Pietro Bolli, our previous Chairman, Roberto Ambrosini, managed to reorganise and reform CRAF so that we can meet the unresolved challenges of the past as well as those of the coming years. Thanks to the work of new CRAF members (P. Thomasson) and previous ones (W. Baan), CRAF managed to regain the lost ground, and the active participation of other members will help to spread the workload and make us more effective in the future.

Powerful digital signal processing has become comparatively cheap. It offers great opportunities for radio astronomers and industry alike, enabling the extraction of information in realms that had been inaccessible to radio-astronomy for a long time. The first LOFAR stations are now operational and provide almost instantaneous images of the radio sky at 30-80 MHz and 120-240 MHz. These bands are heavily occupied by many other services and only advanced digital techniques allow the scientist to peek through the forest of spectral lines created by all the legitimate services within them. Even so, one still finds areas of the radio sky blocked by low-level, broadband interference from local equipment or from reflections from nearby large metallic structures.

TV stations in Europe are currently being converted for digital transmission, which can squeeze up to four programmes into a slot occupied by one analogue channel. The strong spectral peaks of analogue TV broadcasts are, therefore, being replaced by a broadband plateau resembling a noise source. This provides an opportunity for cooperation with national administrations to improve the reception of radio-astronomical signals in the shared 610 MHz Band, which are badly affected by radio frequency interference (RFI).

Modern digital equipment allows radio astronomers to detect narrow spectral lines from distant maser sources as well as nanosecond pulses emitted by pulsars. These signals are poorly described by a continuum noise model, and they are indeed detected as coherent signals. Observations of such signals are even more likely to be affected by RFI from coherent sources in the form of short pulses or variable frequency, narrow-line emissions, because coherent digital detection methods are highly sensitive to them. Most of the current radio regulations were formulated at a time when analogue terrestrial transmissions were prevalent and most of radio astronomy dealt with broadband sources that varied on timescales of a minimum of several days. However, new technical applications using wideband or frequency agile transmissions are being introduced, and so CRAF has to take the initiative to have the regulations adjusted to reflect the technical realities of the present time and those in the future.

Another issue of concern to radio astronomy is the commercial use of the spectrum in the Terahertz range from 300 to 3000 GHz. Most Terahertz radio-astronomy observations will be from a small number of remote locations at very high altitudes because of atmospheric absorption. They are therefore only likely to be affected by airborne and satellite transmissions for which criteria for radio-quiet zones extending into space will have to be formulated.

Last, but not least, the Square Kilometre Array radio telescope (SKA) will be built in the southern hemisphere in a global cooperative effort. Legislation has been passed by the two possible host countries to set up radio-quiet zones in their lands. However, some administrations may see that as an opportunity to relax or even remove protection of radio-astronomical frequencies for telescopes in the northern hemisphere. It does not take much intelligence to see that the majority of celestial sources visible to telescopes in the northern hemisphere cannot be observed by the SKA, and that northern telescopes perform many functions that simply cannot be taken over by the SKA. It is important that awareness of these facts is increased everywhere and that the SKA operation cannot provide an excuse for sacrificing radio astronomy in the northern hemisphere. We are very pleased to have Rob Millenaar as SKA representative on the CRAF team in the future.

This year of 2009 is also the year of astronomy and CRAF has an obligation to inform a wider audience of the challenges and opportunities of the future. The cooperation and the generous support by the ESF and the EU Commission make our work much more effective. For that we are truly grateful, especially as it gives us a secure perspective for our activities in the coming years.

Axel Jessner
CRAF Chairman

1. Report from the 47th CRAF meeting

The 47th CRAF meeting was held on 13-14 November 2008 at the Royal Observatory of Belgium in Brussels (Belgium). The day before the official start of the meeting, most of the CRAF meeting participants visited the Humain Radio Astronomy station, which is operated by the Royal Observatory of Belgium. The visit to the facility provided an opportunity to see the historical instruments, including the large 408 MHz radio interferometer and also the "Würzburg" radar dish, refurbished as a solar radiometer at 608 MHz, but which will soon be removed from the site and become a WWII museum piece. F. Clette and C. Marqué reviewed the past scientific and technical activities at the site since its foundation in 1951, and presented the new developments which started in July 2008 and which are now being implemented.

During the CRAF meeting, which was also attended by a delegation from the radio frequency management of the Belgian Institute for Postal services and Telecommunications (BIPT) as invited observers, the following key items were discussed:

- CRAF Chairman
  According to the CRAF Charter, R. Ambrosini was reaching the end of his second term as CRAF Chairman (01.01.2004-31.12.2008). The Search Panel identified two candidates for the post of CRAF Chairman who were presented by P. Bressler on behalf of the Search Panel. The CRAF plenary unanimously approved the candidature of A. Jessner (MPI, Germany) and appointed him as the new CRAF Chairman. His term of office will begin during the first months of 2009.
- RadioNet / CRAF Funding
  There has been a cut of almost one-third in the full RadioNet budget in FP7. A proposed alternative of reducing the validity period from four to three years (2009 to the end of 2011) has been accepted by the EC. As far as Network Activity on Spectrum Management is concerned, a very good evaluation of our previous work has been made and we have been granted approximately 86 737 € (out of the initial 110 k€).
- CEPT and ITU Meeting Issues
  The frequency manager, Laurentiu Alexe, presented the main issues. From CEPT meetings: UWB; revision of the Recommendation ITU-R RA.1513; coexistence of the fixed service with passive services in the range 71-92 GHz; segmentation of the band 1620 MHz; new Leeheim measurements; UK consultations. From ITU meetings: SG7; WP7D.
- Round-table Meeting with European Commission (EC)
  The location of the ROB within Brussels provided a prestigious environment and a good opportunity to exchange views on common issues of Spectrum Management with the EC and so, during the second day of the meeting, a Round-table Discussion was scheduled. The last such meeting was held several years ago. The following participants joined the members of CRAF in the discussion: Frank Greco (Deputy Head of the Radio Spectrum Unit – RSU, EC), Ari Sorsaniemi (RSU, EC), Alain van Gaever (Policy Development and Regulatory Framework, EC), E. Righi (Scientific Project Officer, EC, and in particular of RadioNet), Mats Gyllenberg (new ESF-PESC Chairman), G. De Laet and M. Vandroogenbroek (BIPT). While the atmosphere of the meeting was rather informal, the following items were agreed between the parties:
  (i) there should be more efficient contact between CRAF and the EC Radio Spectrum Unit: an RSU delegate could attend future CRAF meetings and at least one annual meeting between CRAF representatives and the EC RSU should be arranged;
  (ii) the Radio Spectrum Policy Group (RSPG) opinion on Science Services has been a starting point that was well received by the EC, but additional improvements ought to be made - EC councillor Greco expressed his regret that many decisions were a bit too generic, so he invited CRAF to do more work on this issue;
  (iii) the EC Electromagnetic Compatibility (EMC) laboratory and instrumentation could be used by the radio-astronomy community to perform various compatibility measurements.

The next CRAF meeting is scheduled for 14-15 May 2009 at the Observatoire de Paris, France.

Pietro Bolli

2. Previous Chairmanship

There is real satisfaction when you realise that your work will be continued and that the new actions of the person who is going to take over your position will produce an even greater impact. That is the case with Axel Jessner, after my efforts to transfer CRAF from its founding members to the next generation of experts in Spectrum Management of the passive radio services. The past five years have not been easy and the coming ones will be at least as difficult, if not more so. However, we all now have a better understanding of our duties. I am going to offer all my experience in support of the new Chairman and I invite all others, new and old CRAF members, to do the same.

Dear Axel, thank you for accepting the new task and good work, Roberto Ambrosini (CRAF Chairman, 2004-2008).

Roberto Ambrosini

3. Detection of Very Short Pulsed Radio Signals

Introduction

New devices have recently appeared on the market which emit repetitive pulses with very fast rise times and which have a wide spectrum ranging indiscriminately from 1 GHz up to 10 GHz. They are commonly known as

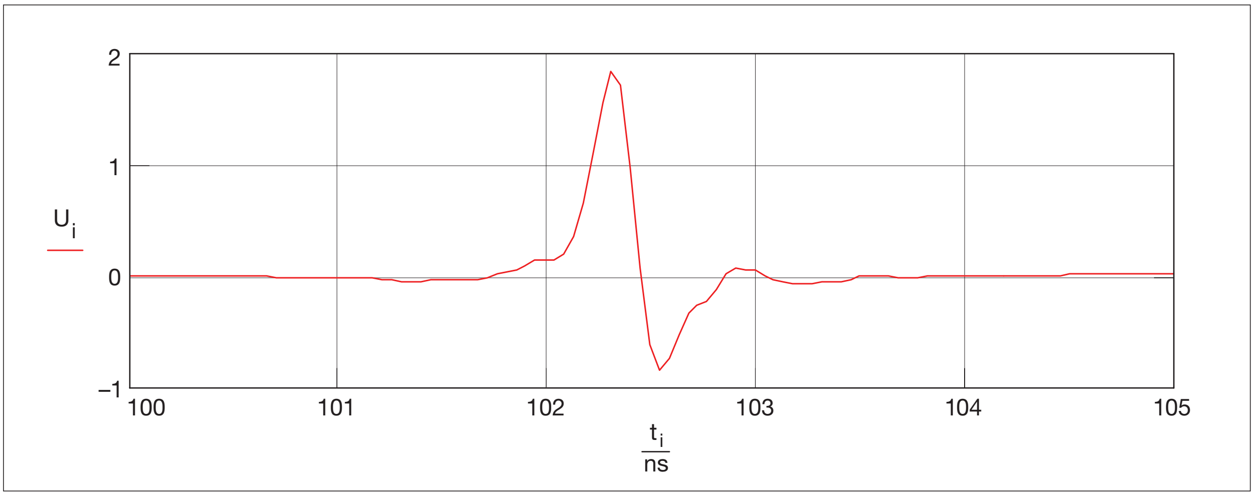

Fig. 1

pulsed, ultra wideband (UWB) devices and have pulse repetition times, τ_{rep}, ranging from several nanoseconds to approximately one microsecond. In its simplest, and therefore often most cost-effective form, such a device is just a fast step recovery diode (SRD) connected to a short piece of wire, and connected to a suitable pulse generator. Although the emitted power level per unit frequency is very low, it is easily detectable by a simple broadband detector in the vicinity. Modern digital logic families are also capable of generating short rise time signals, which, if insufficiently shielded, are also easily detectable. A single pulse at the output of a SRD pulse generator may appear as in Fig. 1 with a peak power into a 50 ohm load of $\max(P_p) = 0.068\,W$.

Such a pulse emitted from a suitable broadband antenna can easily be detected by a radio-astronomical receiver at a considerable distance.

Detection and Range of Pulsed UWB Signals

In order to evaluate the radio-astronomical sensitivity to pulsed signals, it is illustrative to scale their spectral powers to be close to the noise levels of a practical receiving system. Consider a radio-astronomy receiver with a centre frequency of 5 GHz and assume (according to ITU-R RA 769) that its noise temperature, T_{sys}, is 22 K. The average noise power in a given band, Δf_{IF}, is: $k \cdot T_{sys} \cdot \Delta f_{IF} = 1.519{*}10^{-14}\,W$ or $-125\,dBm/MHz$ (k = Boltzman's constant). Adjusting the amplitude of the pulsed signal, which in our example has a $\tau_{rep} = 750$ ns, to have the same average spectral power density as the system noise, results in noise and pulse peak power levels in a 50 MHz band centred at 5 GHz as shown in Fig. 2.

Both signals carry the same average power and, within the narrow detection band, their average power spectra are indistinguishable. However, the coherent

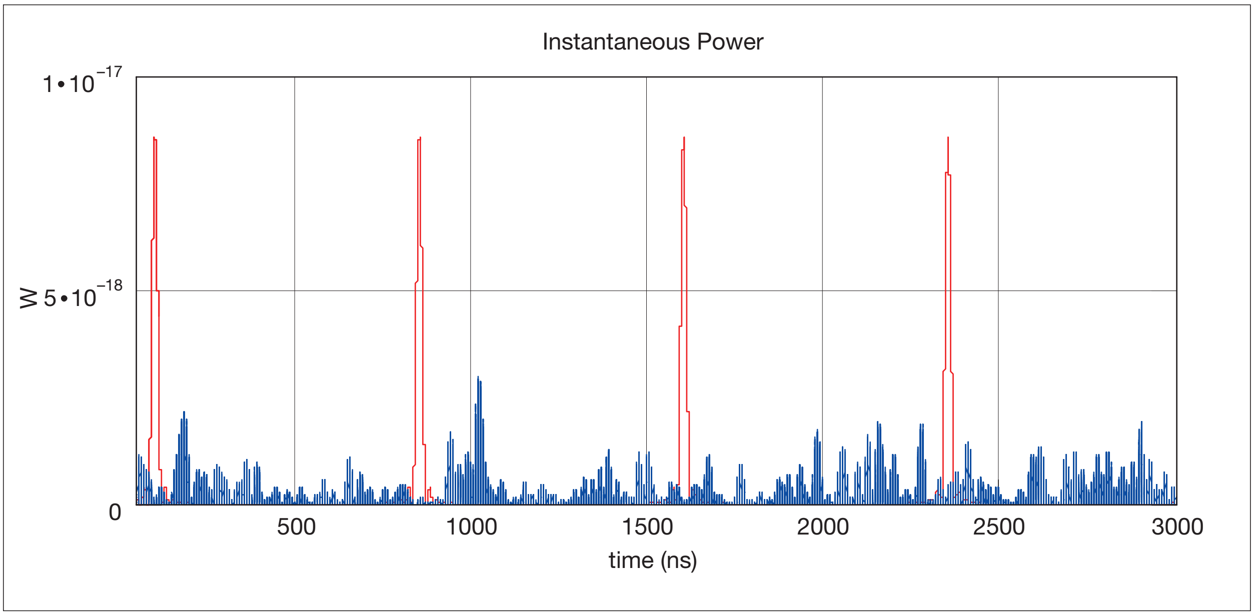

Fig. 2

pulsed signal concentrates the signal power into separate strong pulses which have an envelope given by

$$\left(\frac{\sin(\pi\cdot\Delta f\cdot\tau)}{\pi\cdot\Delta f\cdot\tau}\right)^2$$

as a consequence of the top-hat frequency constraint. Modern fast sampling digital detectors are capable of resolving these individual pulses and measuring the peak signal amplitudes and powers. They are routinely used in pulsar radio astronomy. However, typical continuum and spectroscopic observations detect variations in the mean power of a source, incoherently averaged over longer timescales.

Crest Factor

Depending upon the duty cycle of the pulses, the ratio of peak power to mean power can be quite large. This ratio is called the crest factor:

$$CF_{dB} = 10\log\left(\frac{\max(P)}{\text{mean}(P)}\right)$$

Although the peak power of the individual pulses will be unchanged with decreasing τ_{rep}, the average power over some integration time will increase linearly with increasing pulse repetition frequency $(PRF) = \tau_{rep}^{-1}$. The frequency separation between two spectral lines for a repetitive signal is just the PRF, and so any increase of the PRF above Δf_{IF} will result in at most only **one spectral line** within the measured band. In that case, the ratio of peak to mean power will be 1 (or 0 dB). When the bandwidth is less than the PRF, the outcome of a measurement depends on the coincidence of individual spectral lines and the measurement bandpass. The maximum crest factor turns out to be the number of in-band spectral lines of the repetitive signal. Hence for any given PRF and measurement bandwidth it has a maximum value of

$$CF_{max} = 10\log\left(\tau_{rep}\cdot\Delta f_{IF}\right)$$

This expression also reflects the fact that the detectable rise time of any signal within a band is limited by the bandwidth. At the same time, the measured crest factor will have an absolute maximum given by the lowest repetition time. This is the integration time when just **one pulse** is received during an integration. For a 3 μs integration time and a bandwidth of 50 MHz, the crest factor is 21.8 dB.

Effective Detection and Interference Limits

The previous discussion has shown that with modern signal processing the true peak strength of the signal (within the bandwidth constraints) is given by $\max(P_c) = 8.567 * 10^{-18}$ W or –140 dBm. The average noise power per sample is $\text{mean}(P_c) = 2.317 * 10^{-19}$ W or –156 dBm. The crest factor is 16 dB for the above choice of parameters and the signal to noise ratio of the detected peaks (SNR_c) is the same. The recommendation ITU-R RA.769 gives an interference limit for the chosen band, ΔP_H, of

$$\Delta P_H = -207\,\text{dBW} \quad \Rightarrow \quad P_{RA769} = 10^{\frac{\Delta P_H}{10}}\,\text{W}$$

However, this must be corrected for the 50 MHz bandwidth and the effective integration time of $2/\Delta f_{IF}$ compared with the ITU-R RA.769 value of 2 000 secs. to yield the **nominal** ITU protection threshold:

$$P_{prot} = P_{RA769}\cdot\sqrt{\frac{2000\,\text{s}}{2\,\Delta f_{IF}^{-1}}\cdot\frac{10\,\text{MHz}}{\Delta f_{IF}}}$$

$$\Rightarrow \quad P_{prot} = 1.995 * 10^{-16}\,\text{W} \quad \text{or} \quad -127\,\text{dBm}$$

Thus, the coherently detected peak value is 13.6 dB below that threshold and, with a difference of –29 dB, the average signal is even further below the nominal detection threshold.

The Range of Pulsed Devices as Interferers

The decision of the European Communications Committee (ECC) from 24 March 2006 (amended on 6 July 2007 at Constanta) on the harmonised conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz (ECC(06)04) means that a peak pulse power (e.i.r.p.) of –30 dBm over a bandwidth of 50 MHz at 4.8–5.0 GHz is allowed. In order to remain undetectable for an omni-directional 0 dBi gain receiver, the sensitivity limit requires a signal attenuation of

$$L_p = -10\log\left[\frac{\max(P_c)}{\Delta f_{IF}}\cdot\left(\frac{\Delta\nu}{P_{eirp}}\right)\right] + 10\log\left(SNR_c\right)$$

or

$$L_p = 156.527\,\text{dB}$$

Free space losses according to ITU-R 452-11, Eq. 9 are given by

$$L_b(d,\nu) = 92.5 + 20\log\left(\frac{\nu}{\text{GHz}}\right) + 20\log\left(\frac{d}{\text{km}}\right)$$

Here atmospheric absorption effects have been neglected! For a nominal line of sight distance of 3 km on flat terrain between an emitter and a radio telescope, only $L_b(3\,\text{km}, 5\,\text{GHz}) = 116.022$ dB attenuation is to be expected. A pulse from that distance is still detectable with 10 dB S/N. The much higher FCC limit of 0 dBm/50 MHz is therefore absolutely incompatible with the protection requirements of modern radio astronomy for a line of sight horizon. Even the ECC Rep. 64 mean spectral power limit of –30 dBm/50MHz requires an exclusion zone for such devices of

$$10^{(L_p - 92.5 - 20\log(5))/20} = 10.055\,\text{km}$$

in order to be marginally (Signal to noise = 1) undetectable.

Pulsed emissions can have a much greater range than noise signals with the same mean power because of their coherent nature and the availability of the above described digital signal processing. Their interference impact is therefore much greater, usually by an amount given by the maximum crest factor, defined by the minimum PRF and maximum bandwidth. Current regulations do not take these factors into consideration.

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Axel Jessner

4. The International Year of Astronomy 2009

The year 2009 has been declared the International Year of Astronomy (IYA2009), in a global effort to help people all around the world rediscover the glories of the sky, and thereby kindle a personal sense of wonder and discovery. It was initiated by the International Astronomical Union (IAU) and UNESCO, and is supported by the ESF. See http://www.astronomy2009.org/ for more details and links to the myriad of activities.

Besides showing images of the celestial wonders that can be observed on a dark night to the general public, it also provides a unique opportunity to show them the encroachment and severe effects of light pollution when they try to see faint stars from the place where they live. However, showing them the equivalent situation when observing the radio sky through a smog of RFI is far less trivial.

At IAU Symposium 260, which followed the IYA2009 opening ceremony, the session dedicated to Environmental Issues was mainly dedicated to light pollution, with only one talk on the protection of radio astronomy.

A conference on public sector spectrum use was held in Brussels in April, at which CRAF gave an invited talk on spectrum use and the requirements of radio astronomers to representatives from government and industry. There is also a multitude of different local events organised by radio observatories all over Europe. The difficulties in obtaining interference-free conditions for the reception of weak cosmic signals are emphasised on every occasion.

Wim van Driel

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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