New CRAF memberships

In the last few years, the number of participants at CRAF plenary sessions, which are normally held twice per year, has significantly increased, showing a renewed interest in the field of spectrum management activity relating to radio astronomy. At the last CRAF meeting, held in Greece, a record number of participants were present. Figure 2 shows the number of participants attending since the 40th CRAF meeting held in Bologna, Italy in April 2005. A positive trend is clearly seen.

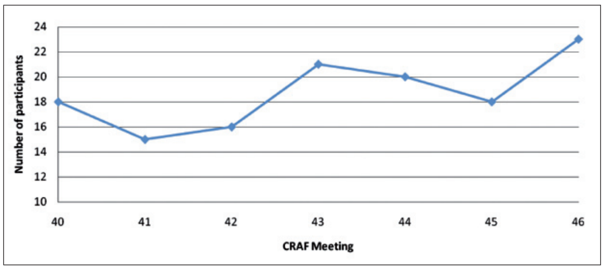

Figure 2. Positive trend of CRAF members' participation in CRAF plenary sessions.

Besides the steady interest of members from well-established institutions, several new European institutes have joined CRAF: Ventspils International Radio Astronomy Centre (Latvia); the Aristoteleion University of Thessaloniki (Greece); Observatório Astronómico Prof. Manuel de Barros (Portugal) and the Institute of Radio Astronomy of the National Academy of Sciences (Ukraine). Moreover, a new organisation, the International VLBI Service for Geodesy (IVS) is now represented on the committee, together with the already existing European Space Agency, the European Incoherent Scatter Scientific Association and the Institut de Radio Astronomie Millimétrique. However, the most unexpected new entry to CRAF is from the extreme south of the ITU Region 1, the Hartebeesthoek Radio Astronomy Observatory from South Africa. In the ITU division of the world into three Regions, both Europe and Africa come under Region 1, so the new affiliation is legally correct.

Figure 3 shows that CRAF officially represents all the European countries having some kind of radio astronomical observing facilities.

Pietro Bolli

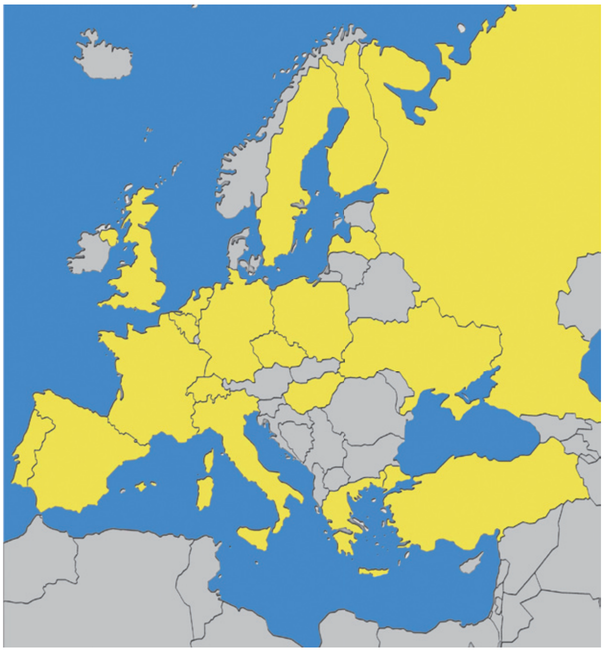

Figure 3. Countries painted in yellow are represented in CRAF.

On the Web

- **Save Jodrell Bank**
  http://www.savejodrellbank.org.uk
- **EuroNews – Futuris: Building the world's biggest telescope**
  http://www.youtube.com/watch?v=lfO-85RDhFk
- **Square Kilometre Array**
  http://www.youtube.com/watch?v=E7qNpYCYvOE

Laurentiu Alexe

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.

Chair: Dr. Roberto Ambrosini (Italy)
ESF Physical and Engineering Sciences Unit:
Head of Unit: Dr. Patrick Bressler
ESF Senior Administrator: Ms. Carole Mabrouk
Tel: 33 (0)3 88 76 71 69
Fax: 33 (0)3 88 37 05 32
Email: cmabrouk@esf.org
www.craf.eu or www.esf.org/craf

The European Science Foundation (ESF) provides a platform for its Member Organisations to advance European research and explore new directions for research at the European level.
Established in 1974 as an independent non-governmental organisation, the ESF currently serves 77 Member Organisations across 30 countries.

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

1 quai Lezay-Marnésia | BP 90015
67080 Strasbourg cedex | France
Tel: +33 (0)3 88 76 71 00 | Fax: +33 (0)3 88 37 05 32
www.esf.org

Print run: 350 – December 2008

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

NEWSLETTER No. 18 – November 2008

CRAF NEWS

Expert Committee on Radio Astronomy Frequencies (CRAF)

Editorial

At the last General Assembly of URSI in Chicago, I was asked to propose to CRAF a new type of membership, namely that of an 'observer'. The request came from Richard Schilizzi, the International Director of the SKA project, who wished to have a non-territorially related participation in CRAF by this really global project. I am sure that CRAF will accept this new idea, because it is also a recognition by the foremost project of the coming decades of the good work that CRAF does for the radio astronomy community not only in Europe, but also well beyond.

At the URSI 2008 General Assembly there were many presentations on interference mitigation techniques in addition to the usual session on the regulatory aspects of preserving good observing sensitivities for our radio telescopes. Also, at the COSPAR Scientific Assembly in Montreal, IUCAF organised a session on 'Spectrum Management and COSPAR: Keeping Passive Radio Observations Free of Interference'. Whilst the mitigation research area is full of new and good ideas, the regulatory field is full of new threads and obstacles. In addition, we have to prepare ourselves for new types of confrontation. For example, whereas it has always been imperative for each CRAF member to maintain a strong connection with his national administration, now we also need to improve communication channels with the European Commission. We hope to have a first encounter with them on the occasion of the next CRAF assembly to be held in Brussels.

The 'commercial value' of the fundamental sciences, and of radio astronomy in particular, has been mentioned in a few discussions by some colleagues. The occasionally used expression 'of no commercial value' is not appropriate in our case. In my opinion it is just the opposite and such words are idle talk. The value of fundamental science is not commensurable with any goods and if we really want to express its quantity, only the word 'infinity' can be a true representation. As a matter of fact, science has come before everything else and has been the source of all that we see today. Even if results usually come only after a lot of engineering development and long periods of time, we cannot now fail to recognise the extraordinary commercial spinoff from it in many different fields and applications in everyday life (see also the Report* on this subject published by the EC Radio Spectrum Policy Group, to which CRAF contributed).

Do not forget that the year 2009 is the International Year of Astronomy, under the title 'The universe, yours to discover'! In Italy we have begun a few activities: one is a short video to be presented, first in our Visitor Centre at the Istituto di Radioastronomia, INAF, Bologna (Italy), and later on the Web. Each CRAF member is invited to present a contribution, either his own, or better still a coordinated effort with others.

* http://rspg.groups.eu.int/doc/documents/opinions/rspg06_144_final_rspg_report_opinion_scientific_use_pectrum.pdf

Roberto Ambrosini

Report from the 46th CRAF meeting

The 46th CRAF meeting was held on 17-18 April 2008 at the Aristotle University of Thessaloniki, Thessaloniki (Greece) by kind invitation of John Seiradakis.

During the CRAF meeting, which was attended by a record number of 24 participants, the following key items were discussed:

- The International Astronomical Union (IAU), Unesco and the United Nations have proclaimed 2009 as the International Year of Astronomy (IYA2009) with the theme 'The universe, yours to discover' (http://www.astronomy2009.org). Since the ESF will be an Organisational Associate, CRAF can use the IYA2009 logo for events during 2008-2010. It can also organise IYA2009 events (Dark Skies Awareness etc.), promote or submit proposals to the ESF, and work together with the ESF Communication Unit towards the public awareness of astronomy and the radio astronomy community.
- During recent CEPT studies on the impact of Iridium-unwanted emissions on the radio astronomy band 1610.6-1613.8 MHz, limitations were noted in defining the data loss acceptable to the RAS according to Recommendation ITU-R RA.1513. The astronomers and national administrations involved felt that a revision of this Recommendation was necessary, since it currently does not address the case of narrow-band time- and frequency-variable interfering signals. The current definition of data loss also does not fully take into account spectral line observations. CRAF submitted contributions for a revision of this, as did France and Germany. A separate proposal made by A. Jessner (on transients) was also discussed. All contributions were incorporated in a working document drafted by a group chaired by W. Baan, who will coordinate further work by correspondence for a consolidation of the European proposal.

- L. Alexe reported on the last CEPT and ITU meetings attended. The following were the main items of interest:
  – the impact of Object Characterisation and Discrimination (ODC) devices, a new type of unlicensed UWB application, which is proposed for use between 1-10 GHz, with an estimated deployment in the coming years of 3 million devices on the European market;
  – the revision of Recommendation ITU-R RA.1513;
  – the coexistence of the Fixed Service with passive services in the range 71-92 GHz;
  – the segmentation of the band 1620 MHz allocated to Mobile Satellite Systems;
  – Radio Astronomy Service-related agenda items of the World Radiocommunications Conference 2011(WRC-11).

  The agenda of WRC-11 comprises nearly 30 items, several of which are of particular interest to radio astronomy:
  – update of spectrum use by passive services between 275 GHz and 3000 GHz;
  – new Aeronautical Mobile (R) Service (AM(R)S) systems in the bands 112-117.975 MHz, 960-1164 MHz and 5000-5030 MHz;
  – fixed services in the bands between 71 GHz and 238 GHz;
  – the introduction of software-defined radio and cognitive radio systems;
  – the effects of emissions from short-range devices (SRD) on radio services.

  Agenda items of secondary interest are:
  – spectrum usage in the 21.4-22 GHz band for the broadcasting-satellite service;
  – the radiolocation service in the range 30-300 MHz;
  – possible allocations in the range 3-50 MHz to the radiolocation service for oceanographic radar applications;
  – High Altitude Platform Stations (HAPS) in the range 5850-7075 MHz;
  – consideration of a primary allocation to the radiolocation service in the band 15.4-15.7 GHz.
- CRAF Frequency Manager Activity Report for 2007. As a result of the fast-changing European environment, and of the huge commercial and political pressure on the radio spectrum in general, and on the spectrum allocated to the passive services in particular, the number of meeting days and the volume of correspondence work increased greatly in 2007. The following issues required particular attention: the impact of Ultra-Wide Band (UWB) devices (GPR/WPR, BMA, ODC) and the revision of existing regulations relating to them; Iridium interference into the RAS band 1610.3-1613.8 MHz; the revision of the European Common Allocations table; the preparation of and participation in the World Radiocommunications Conference 2007.
- The next CRAF meeting is scheduled for 13-14 November 2008 at the Royal Observatory of Belgium in Brussels.

Pietro Bolli

Summary of technical seminar on data loss

On many occasions radio astronomers have been asked to quantify what they consider to be the information which is lost through interference. This contribution attempts to deal with that question in the most general terms so that it can be applied to any kind of observation, be it continuum mapping, spectroscopy, polarimetry or monitoring of transient radio sources.

Astronomers analyse the received radio waves from cosmic sources in an attempt to detect patterns and features that deviate from randomness. These patterns can be in the time domain, the frequency domain (spectrum); the spatial domain (radio maps of the sky), or even in a multidimensional configuration space when, for example, polarisation is considered. These patterns contain the empirical information that is used to support or falsify theoretical models of observed astrophysical objects. These days, experiments of empirical science yield quantitative results, and astronomy is no exception to that rule. An individual astronomical ‘observation’ results in a set of numerical samples $\boldsymbol{S} = \{d_0, d_1, \ldots d_{N-1}\}$.

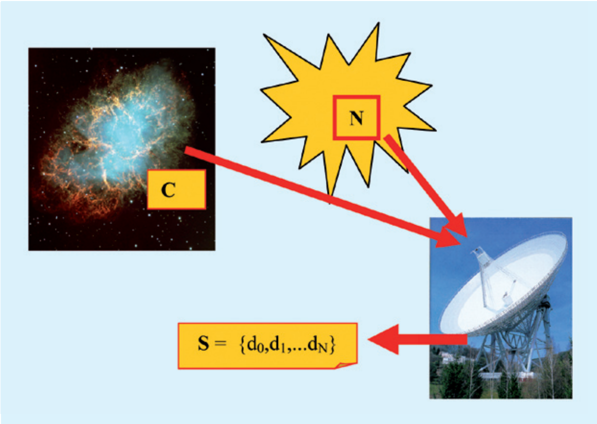

Figure 1: The observation process is a mapping, ***C*** -> ***S***, of an unknown complex reality, ***C***, to a set of numbers, ***S*** (the signal), affected by noise, ***N***.

In general the observation process is a mapping of an unknown complex reality, ***C***, to data, ***S***, *(**C** -> **S**)* in the presence of additional noise ***N*** and associated errors $\boldsymbol{\sigma}$, with the aim of establishing a mathematical model that fits the data ***S*** within the bounds given by the errors. However, in contrast to most other measurements and experiments in physics, the astronomer has at most only partial control over what and when observations can be made. In many cases, observations cannot be repeated. The conditions that determine ***C***, and the emission that carries the information about it, are not under the control of the observer. Radio astronomical measurements are in most cases measurements of the noise power, ***w***, at the output of the receiver. Its probability distribution function (pdf), $p_n(w,w_m)$, is a chi-squared distribution with one degree of freedom. It has only the average noise power $\boldsymbol{w_m}$ as a free parameter:

$$p_n(w, w_m) = \frac{e^{-\frac{w}{2 \cdot w_m}}}{\sqrt{2 \cdot \pi \cdot w_m}} \quad (1)$$

Measurements are often quantised (e.g. by analogy with digital conversion), with a step δw. In that case, the probability p_i of obtaining a sample value d_i is given by integration of the pdf over the quantisation interval (w_q,$w_q+\delta w$) containing the sample value d_i:

$$p_i = \int_{w_q}^{w_q+\delta w} p_n(w, w_m)\,dw \quad (2)$$

Intuitively speaking, obtaining a low probability result from a measurement $S = \{d_0, d_1, ... d_{N-1}\}$ from individual samples, d_i , would be a greater surprise than just obtaining an average value. Shannon (1948) introduced the negative logarithm of a probability, *p*, as the information associated with the occurrence of an event, e.g. the measurement of a power sample d_i.

$$I = -ln(p) \quad (3)$$

If the logarithm is to the base 2, then the information, $-log_2(p)$, is expressed directly in bits and one can see that low probability data do indeed carry more information.

> Example: An A/D converter may return 256 equally probable sampling results, each with a probability of 1/256. Then any sample from the converter contains $-\log_2(1/256)=8$ bits of information.

Information is an additive quantity. Therefore the total information given by a measurement $S = \{d_0, d_1, ... d_{N-1}\}$ is given by the sum of the negative logarithms of the sample probabilities:

$$I(S) = -\sum_i \log_2(p(d_i)) \quad (4)$$

We can expect that there will be differences in information content, $\Delta I(S_a, S_b)$, between individual measurements $S_a = \{a_0, a_1, ... a_{N-1}\}$ and $S_b = \{b_0, b_1, ... b_{M-1}\}$ of different size *N* and *M* and with different probabilities of their samples *p(a)* and *p(b)*:

$$\Delta I(S_a, S_b) = -\sum_i \log_2(p(a_i)) + \sum_j \log_2(p(b_j)) \quad (5)$$

In nearly every case, an experimenter (astronomer) will calibrate his measurements using a well-known source or background object in order to have an estimate of the statistics involved in his observations (gains, errors, statistical distributions). We call such a data set the reference, S_{ref}, and the ***information gain*** between the observation S_{obs} and the reference is then given by $\Delta I(S_{obs}, S_{ref})$. Because of the random nature of the noise, one can expect the variation of the information from different sets to be given by the *standard deviation* of the information of the samples as obtainable from S_{ref}: If we call H_{ref} the mean information value of the samples in the set $S_{ref} = \{d_0, d_1, ... d_{N-1}\}$, then the standard deviation of the information of the reference data is simply given by the usual expression:

$$\sigma_{ref} = \sqrt{\frac{1}{N} \sum_{i=0}^{N-1} (-\log_2(p(d_i)) - H_{ref})^2} \quad (6)$$

For an interfering signal to be insignificant, the additional information content of the affected dataset S_{rfi} should be below that threshold:

$$\Delta I(S_{rfi}, S_{ref}) < \sigma_{ref} \quad (7)$$

Hence, in order to limit the impact of radio interference, the information measure of any data sample affected by it must not deviate by more than σ_{ref} from the unaffected value. This means that for typical power measurements, individual deviations of the samples affected by interference must be below the mean power of the noise signal. In nearly all practical cases, this means that the strength of the additional interference signal has to be kept well below the r.m.s of the reference data. Recommendation ITU-R RA 769 gives the appropriate flux thresholds for an individual sample at different frequencies based upon reasonable r.m.s. estimates. Quite independent of which individual d_i was actually affected, any measurement $\{d_0, d_1, ... d_{N-1}\}$ that has been contaminated by radio interference at a level above that threshold, has to be discarded.

In particular, when reference data are affected, the estimate of the reference probability distribution will no longer be correct, leading to an erroneous interpretation of the source data. Features may either be missed as they appear to be insignificant, or non-existent features of artificially low probability may be found. If, and only if, the affected samples themselves can be unambiguously identified, as for example in the case of a constant and strong interfering spectral line, is it possible to discard only the affected samples and reduce the size of the data set accordingly. Such a reduction may, however, not exceed more than 2% of the data under consideration.

A quick summary of steps to be taken to *quantitatively* estimate the impact of interference on data would thus be:

1. Obtain a data set with interference, S_{rfi}, and uncontaminated reference data, S_{ref}, (by measurement or selection).
2. Estimate the probability distribution of samples using the theoretically expected probability distribution function, or from a histogram of the samples in S_{ref}. If one uses a theoretical model for the probabilities, it should be checked against the data histogram. Literature on Bayesian statistics can give guidance on the procedures.
3. Calculate probabilities p_i and information content I(S) for S_{rfi} and S_{ref} using (4).
4. Calculate the mean information H_{ref} of S_{ref} and its standard deviation σ_{ref} using Equation (6).
5. Application of Equation (5) will give the information difference caused by interference. If the criterion $\Delta I(S_{rfi}, S_{ref}) < \sigma_{ref}$ is not met, then the data, S_{ref}, ought not to be trusted.

Note that we have deliberately not used any particular type of measurement, (e.g. spectroscopy, continuum, VLBI etc.) but rather generally discussed arbitrary data sets that an astronomer could obtain as a result of his or her measurements. This analysis is equally applicable to temporal (time series of fluxes), spectral (radio spectra), spatial (radio continuum mapping) or to any other way astronomers acquire and arrange their data. Furthermore, the choice and selection of observation and reference data sets depend on the type of data acquisition and the object under study. The reference data may be obtained by repeating the measurement on a different point in the sky, or by selecting data from a measurement on the source position that are expected to be free of the desired signal. The degree of complexity can vary considerably, depending on the type of measurement, but common to all is an information gain which is proportional to the ratios of the probabilities between reference and observation data sets.

The implications are quite obvious: detectable interference signals cause either a spurious and untrue information gain when they occur in the measurement, or a loss of information when they affect the reference data. They can also modify any estimate of the probability distribution of the data itself. Even when the interference is not directly identifiable, it will lead to a quantifiable loss of information. Hence the extra protection against very low level radio interference in radio astronomical bands, afforded by the Footnote 5.340 ('no emissions permitted'), is fully justified.

Reference: C.E. Shannon, A Mathematical Theory of Communication, Bell Syst. Techn. J., Vol. 27, pp 379-423, (Part I), 1948.

Axel Jessner

Data loss for radio astronomy as found in Recommendation ITU-R RA.1513

Recommendation ITU-R RA.1513 describes the percentage data loss resulting from detrimental interference that is acceptable to the Radio Astronomy Service. Besides confirming the use of ITU-R RA.769 to define detrimental interference, RA.1513 also stipulates that a single interfering system may account for maximally 2% data loss in time, and that the aggregate interference from all interfering systems may account for 5% data loss. RA.1513 defines data loss as losing part or all of the observing band for part of the time. However, the existing version of RA.1513 does not clearly prescribe a methodology for determining this percentage of data loss under various RFI conditions.

The availability of a clear description of a measurement method and of the interpretation of data loss is of great interest for those administrations that want to evaluate interference measurements as well as for the radio astronomy community. The CEPT project team SE21 has taken up the task of revising the text of RA.1513 in order to clarify the methodology for measuring the data loss resulting from detrimental interference. A submission to SE21 from The Netherlands for a revision of RA.1513 presents background information on radio astronomy observatory practices, definitions of data loss under a variety of conditions, and a description of the impact of different types of interference on radio astronomical data. Two methodologies are presented to determine data loss on various time scales and for various conditions. An important consideration is that the levels of RA.769 are based on a threshold of 10% of the noise floor of the instrument, which practically requires many (up to 100) measurements in order to detect interference close to the level of RA.769.

A first methodology uses the levels of interference in standard 2000s integration times and determines whether these are above the levels established by RA.769. Multiple measurements need to be carried out to determine the time occupancy of the interference on long time scales.

A second methodology may be used to measure strong and variable interference in much shorter time intervals. While the detection thresholds become increasingly higher for short measurement intervals, the power for detrimental time-variable interference in these intervals will also increase. Again, multiple measurements will allow the determination of the percentage of data loss using these short time intervals. For this measurement it should be verified that the variable interference adds up to levels that are above those of RA.769 for 2000s integrations.

A number of CRAF members have actively participated in the discussions on the methodology and have contributed text for the submitted document. After acceptance by Working Group SE (Spectrum Engineering) the proposed revision will be sent as a 'Working Document towards a Preliminary Draft Revision of ITU-R RA.1513' to ITU-R Working Party 7D for further action.

Willem Baan

RFI data monitoring system for the CRAF website

During the 46th CRAF meeting held in Thessaloniki, Greece, a task force team was charged with the development of a new RFI Web-based database system, where CRAF members (and also other astronomers) would be able to store records of interference. This idea follows the RFI monitoring initiative discussed in *CRAF Newsletter N°17*. From a general point of view, the initiative to have a common RFI monitoring system is quite challenging, ranging from the hardware side (antennas, filters, amplifiers, cables etc.) to the software side (data acquisition, data storing, data calibration, and data processing). As a start, the group has focused on the development of a simple and efficient Web-interface and the implementation of a powerful and modern database structure. The main goal of the project is to simplify RFI-reporting from the European radio telescopes. A preliminary database, using MySQL, is in the development phase. The input fields are based on the older RFI database, (see http://www.craf.eu/form.htm). The next step will be to write an interactive Web-interface, allowing the user to input relevant data.

Pietro Bolli
Michael Lindqvist