COMMENTS ON THE

Progress Report

RSPG OPINION
on

"a coordinated EU Spectrum approach
for scientific use of the radio spectrum"

by

CRAF

The Committee on Radio Astronomy Frequencies,
an Expert Committee of the
European Science Foundation

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Introduction

CRAF, the Committee on Radio Astronomy Frequencies, an Expert Committee of the European Science Foundation hereby submits comments on the Progress Report on the RSGP Opinion on “a coordinated EU spectrum approach for scientific use of the radio spectrum”.

CRAF welcomes this opportunity to respond to the public consultation of the RSPG Opinion on behalf of the radio astronomy community in Europe. Radio Observatories are operational in 17 member states of the European Union and astronomy is done in all member states.

The current European regulatory framework for frequency management results from a lengthy and complex development process involving all national administrations and represents a careful balance between all users including those within the scientific services. This framework has allowed the development of a wide range of high quality wireless applications in harmonized frequency bands that also includes high sensitivity radio telescopes for receive-only passive uses.

In these comments, the CRAF particularly emphasizes the aspect in the RSPG Opinion that relate to the radio astronomy service. A number of comments relate to textual changes that would improve the clarity of the document but also remove factual errors and causes for misinterpretation of the text.

CRAF Comment 1:

CRAF proposes editorial corrections and small additions to improve the text of the document:

2.4 Radio Astronomy
Astronomy provides knowledge of our planet, the solar system, our galaxy and our place in the universe. Radio Astronomy is an integral part of astronomical science, which studies the universe and its components using the most advanced radio techniques. In order to facilitate these studies in a wide range of frequencies and with a variety of observing techniques, it is necessary to operate many radio observatories with different instrumentation and at different locations, including in space[1].

Radio waves of natural origin are extreme weak and their detection requires large reception surfaces (antennas) and the most sensitive receivers. This sensitivity also increases the interference potential for a passive operation. The combination of frequencies fixed by nature and weak signals asks for a well-protected environment.

The technique of very-long-baseline-interferometry (VLBI) provides a tool to gather data on the detailed structure and positions of astronomical sources, but it also has applications in many other fields of research. VLBI using sources in the sky has also been used to measure the mechanisms of the global climate and to do high-resolution positioning of spacecrafts. In addition, astronomical VLBI is being used for determining the detailed structures and the motions of tectonic plates for geodetic research and to determine accurate positions on Earth.

CRAF Comment 2:

CRAF proposes to clarify the existing text:

2.6 Radiolocation
Apart from Meteorological radars as described above, other scientific applications make use of the Radiolocation service to determine positions of various types of objects. In particular, the detailed surface and terrain characteristics of planets and asteroids are determined using radar astronomy.

CRAF Comment 3:

CRAF proposes editorials and clarifications:

3.1 Introduction
The spectrum is used by scientific services for two types of measurements.

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[1] Each atom radiates on a certain frequency band, which are determined by the laws of physics. . For example, the hydrogen atom radiates at a rest frequency of 1420.4058 MHz. Radio Astronomy receives naturally occurring signals from celestial objects, in order to use the signature and power of the radiation for interpreting the physics and chemistry of the gas and its spatial structure. The Doppler effect causes a general shift towards lower frequencies in the spectrum when observing specific spectral lines from sources that are moving away from us at very high velocities.

Passive techniques are used to measure radiations that occur naturally, i.e. using "receiving-only techniques"[2]. Active techniques employ electromagnetic emissions for scientific purposes.
In addition to the spectrum used for these measuring/detection techniques, spectrum is also needed for data communication for certain services.

CRAF Comment 4:

CRAF proposes text improvements:

3.2 Passive techniques
Passive measurements or passive sensing require the measurement of naturally occurring radiations, usually of very low power levels, which contain essential information about the physical process under investigation and involves the use of receive-only techniques, with no transmitters involved. All matter is continually radiating electromagnetic waves and as each molecule in the atmosphere or each surface property has unique frequency characteristics, it can thus be recognised from their spectral signature. Consequently, there are no alternative spectral options available for these specific measurements and therefore these frequency bands are an important natural resource that require protection.

Of interest are radiation peaks indicating the presence of specific chemicals, or the absence of power at certain frequencies indicating for example the absorption of the signals by interstellar or atmospheric gases. The strength or absence of signals at particular frequencies is used to determine whether specific gases (molecules, moisture and pollutants being obvious examples) are present and if so, in what quantity and at what location. A variety of environmental information can be sensed in this manner. Signal strength at a given frequency may depend on multiple parameters, which makes it necessary to use several frequencies at the same time and at the same location to match the multiple unknowns. The use of multiple frequencies is the primary technique used to measure specific characteristics of the Earth surface.

Already low levels of interference received at the input of the passive sensors may degrade passive sensor operations since, in most cases, the sensors are not able to discriminate between these natural radiations and man-made radiations. In this respect Radio Regulations footnote 5.340[3] offers the passive services protection to deploy and operate their systems in the more critical frequency bands. Even a little interference in a 'passive' frequency band may have far-reaching impact on the overall quality and the interpretation of the measurements of global components in the Earth atmosphere and in astronomical data.

CRAF Comment 5:

CRAF proposes a small content addition for clarification:

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[2] Colloquially the verb 'listening' is erroneously used for this activity. The passive observing systems receive electromagnetic radiation, while listening would imply detecting sound (acoustic) waves.
[3] This footnote of the Radio Regulation states that 'All emissions are prohibited in the following bands', followed by a list of frequency bands.

3.3 Active techniques

This active use of spectrum consists of active sensors (measuring the reflection of signals generated by the sensor itself) and communication (data and feeder links) between different sections of the system. The active services can be sub-divided on the basis of the type of usage. A distinction can be made between meteorological bands, earth-to-space bands, space-to-Earth bands, space active sensors bands and ground based sensor bands (see Table 1). In astronomy, radar techniques are used to image the surface of planets and other nearby objects such as asteroids.

CRAF Comment 6:

CRAF proposes to add the radar astronomy component to Table 1.

Table 1, Different types of scientific use.

<table>
<tr><td></td><td></td><td></td><td>Scientific Usage</td></tr>
<tr><td rowspan="15">Scientific Spectrum</td><td rowspan="3" colspan="2">Passive services</td><td>Radio Astronomy (2.4)</td></tr>
<tr><td>Earth exploration satellite (2.3)</td></tr>
<tr><td>Space research (2.5)</td></tr>
<tr><td rowspan="12">Active services</td><td>Ground-based radars</td><td>Radar Astronomy (2.6)</td></tr>
<tr><td rowspan="2">Meteorological bands</td><td>Meteorology and climatology (2.2)</td></tr>
<tr><td>Radiolocation (2.6)</td></tr>
<tr><td rowspan="3">Earth to space data transmission bands</td><td>Space operations (2.7)</td></tr>
<tr><td>Earth exploration satellite (2.3)</td></tr>
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<tr><td>Space research (2.5)</td></tr>
<tr><td rowspan="2">Space science active sensors bands</td><td>Earth Exploration satellite (2.3)</td></tr>
<tr><td>Space research (2.5)</td></tr>
<tr><td>Ground based sensors</td><td>Meteorology and climatology (2.2)</td></tr>
</table>

CRAF Comment 7:

CRAF proposes the following corrections and clarifications to the text of section 4.5:

4.5 Benefits from Radio Astronomy

Radio astronomy is a science whose progress is driven by the pace of technological improvements for the benefit of its research instrumentation. These instruments represent the most advanced radio technology existing today and are at the forefront of all associated technologies.

Radio astronomy has no control over the naturally generated radio signals that need to be detected. As a result radio astronomers have been forced to design and build antennas with the largest collecting areas, receivers of the highest sensitivity and with the lowest noise temperatures, and -in general- instrumentation that defines the state-of-the-art in signal reception and data analysis. The technical requirements of radio astronomy have directly or indirectly fostered technological **innovations** of very wide applicability. Examples are:

- Sensitive microwave receiving systems, including high-gain antennas, low-noise receivers, solid-state oscillators and frequency multipliers, cryogenics now available also on some of the most sophisticated telecommunication systems;
- Data correlation and recording technology, as a precursor of all types of modern digital techniques;
- Image restoration techniques that are extremely important on all environmental surveys;
- Time and frequency atomic standards, reaching the ultimate performance in measurement accuracy and precision (uncertainty levels of few parts in 10^{-16});
- Remote sensing, satellite navigation, position determination, and geodetics;
- Computer languages and software development

Current trends in radio astronomy are towards even higher sensitivity at all frequencies. Since current receivers are reaching the quantum limit and cannot be further improved, there is a drive towards larger collecting areas and the use of broader operational bandwidths. International efforts are underway to construct new generation radio telescopes that have significantly larger collecting surfaces. Examples are: 1) the Square Kilometre Array project, which seeks to build a giant radio interferometere with a total collecting area of a square kilometre and baselines up to 3000 km operating in the 100 MHz – 25 GHz frequency range, 2) the Low Frequency Array (LOFAR) in The Netherlands, a radio interferometer with a total collecting surface of 100,000 m^2 and baselines up to 450 km operating in the 30 – 250 MHz frequency range, and 3) the Atacama Large Millimetre Array with 64 antennas operating from 30 to 850 GHz on a 5 km high plateau in the Andes.

In the development process towards larger sensitivities, the actual use of frequencies will not change significantly. The existing bands allocated to the RAS that enjoy protecting status will continue to be used for long-time integrations to detect weak signals of interest. Because these bands have been chosen for physical reasons and for the presence of important spectral lines, the continual protection for these bands is essential for the continuation of radio astronomical research in a large number of key areas.

Monitoring of solar activity and reliable solar forecasting have a strong impact on many ground based activities such as wired transmissions, radio communications, power distribution, and astronautics. These activities are a pre-requisite for manned space activities.

The radio astronomy service is an integral part of astronomical research that is being done in almost all countries around the world. The results of this research are all in the public domain and have invaluable social and cultural value because it helps define the place of mankind in the universe and to determine the history of the solar system, our Galaxy and the whole universe. Astronomy speaks to the imagination of young and old.

CRAF Comment 8:

CRAF proposes a small addition and some editorial changes:

5.1 Introduction
The allocation and protection of spectrum used by the scientific services is mainly regulated by the ITU Radio Regulations which is an international treaty.

Among the numerous ITU Radio Regulations footnotes related to the scientific services, two of which recognise the extremely importance of protection required by some of the frequency bands used by the passive services.
The footnote 5.149 urges administrations to take all practicable steps to protect the Radio Astronomy Service from harmful interference in a number of specific frequency bands. The footnote 5.340 lists a number of essential frequency bands in which ***"all emissions are prohibited".***
It should be noted that the EC and ECC decisions on SRR 24 GHz created a precedent authorising exceptionally and on a temporary basis, in-band emissions in the 23.6-24 GHz band[8]. With this occasion CEPT and EC did promise that "*shall make sure that any such temporary authorization of 24 GHz SRR systems is exceptional and can not be used as a precedent for possible introduction of other transmitter devices in bands where RR footnote 5.340 is applicable, for temporary or permanent use*".

CRAF Comment 9:

The existing RSPG text under section 5.3 was well-intended but leaves room for misinterpretation. CRAF proposes to remove inaccuracies from the current text and to consider the following changes:

5.3 Sharing Conditions
iv) *Sharing in radio astronomy bands*.
Sharing scenarios have been investigated for radio astronomy operations but have only been implemented on an ad-hoc basis. The sharing with other then passive services must be done on non-interference basis. In practice, at certain observatories and in certain bands the early morning hours may have less interference from terrestrial transmitters that are off the air, and from certain telecommunication satellite systems. A specific problem with time-sharing for radio astronomy stations is that observations of celestial objects rely on sidereal time, which drifts by 2 hours per month as compared with solar time. In general, the European radio telescopes are significantly over-subscribed.

CRAF Comment 10:

CRAF proposes to insert following new paragraph after current paragraph 2 in section 6.1:

6.1 Introduction
….

The Radio Astronomy Service strongly depends on the exclusive bands for sensitive observations. In addition, a number of RAS bands have a shared allocation in which observations are possible under controlled circumstances and using coordination procedures. RR Footnote 5.149 enumerates 46 spectral bands that used for research by the RAS but are shared with others operators and are under control of national administrations.

CRAF Comment 11:

CRAF proposes a small text addition:

9.3. Most of this societal value is incommensurable in financial terms, as they relate to preventing large losses of lives or threats to socio-political stability and security. However, scientific use of spectrum also has a direct impact in many economic areas, which can be estimated, and in producing economic spin-offs in technology and economic developments in energy, transportation, agriculture, communications, medicine, etc. The RSPG has attempted to assess the overall benefits of scientific uses of spectrum. The RSPG recommends that this assessment be taken into account and complemented, as appropriate, using the guidelines set out below, in order to facilitate future decisions by administrations which may impact on such uses. The RSPG also recognizes that with increasing pressure on spectrum use, there needs to be the political will to ensure the continued protection of a small fraction of the spectrum for scientific usage, regardless of economic impacts.

CRAF Comment 12:

CRAF proposes the following text improvement:

> 9.7 The RSPG considers that the current and expected pressure on spectrum may lead to consider increased levels of sharing between scientific uses and other services. In such cases, the RSPG is of the opinion that there would be a need to assess the impact of a potential decision on both scientific uses and other services. This assessment should, in a proportionate manner, and within the provisions contained in the RR:
>
> - identify the **objectives** of a proposed decision and identify a **range of options**;
> - draw up a list of different groups of **stakeholders** likely to be affected;
> - identify the **impact of the various options** on the interests of the particular groups of stakeholders;
> - take into account **commitments/obligations** in international initiatives/agreements;
> - identify and, where possible, quantify the **costs and benefits** flowing from the impacts which each option would have;

- Assess the **risks** associated with each option.

CRAF Comment 13:

CRAF finds no reason to maintain the last sentence containing the reference. This information is not unique and is available from a diverse number of sites.

Annex 2

Radio Astronomy

CRAF Comment 14

CRAF suggests adding the following items to the list of benefits.

Technological Contributions from Radio Astronomy

(f) Development of *radio sextants* for marine navigation, allowing accurate determinations of positions at sea even on overcast and rainy days. A recent application is the use of radio interferometry for emergency position determination of mobile phones.
(m) Monitoring and prevision of solar activity, and of its impact on human activities: telecommunications, power distribution, astronautics

CRAF comment 15:

CRAF proposes the following modifications to this section in order to complete the information content.

Trends in Radio Astronomy

Trends in radio astronomy are towards higher sensitivity and at all frequencies. Since receivers are reaching the quantum limit and cannot be further improved there is a drive towards larger collecting areas and the use of broader bandwidths. International efforts are underway to construct new generation radio telescopes that have significantly larger collecting surfaces. Examples are: 1) the Square Kilometre Array project, which seeks to build a large interferometer of radio telescope stations, with baselines up to 3000 km, in a frequency range between 150 MHz and 25 GHz in a radio quiet environment, 2) the Low Frequency Array (LOFAR) in The Netherlands that has 100 planned stations on a maximum baseline of some 450 km and will be a precursor of SKA at low frequencies, between 30 and 250 MHz, and 3) the Atacama Large Millimetre Array on a 5 km high plateau in the Andes, operating in the frequency range 30 – 850 GHz.

In the development process towards larger sensitivities, the actual use of frequencies will not change significantly. The existing bands allocated to the RAS that enjoy protecting status will continue to be used for long-time integrations to detect weak signals of interest. Because these bands have been chosen for physical reasons and for the presence of important spectral lines, the continued protection for these bands is essential for the continuation of radio astronomical research in a large number of key areas. The increased sensitivity in these bands allows observations of more remote galaxies and looking back in time towards the early universe.