Draft CRAF/IUCAF Recommendation on
Publications on interference mitigation

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The [ESF Committee on Radio Astronomy Frequencies] [Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science]

considering:

a. that the ITU Radio Regulations lists the frequency bands allocated to the Radio Astronomy Service, their allocation status and footnotes related to these bands;

b. that Radio Regulations article No. 5.340 stating for selected frequency bands that "all emissions are prohibited" and that article No. 5.149 states for selected frequency bands that "administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference" do in practice not always fully guarantee that radio astronomy does not suffer interference from active applications of radio;

c. that radio astronomy requires sometimes that observations are done at frequencies in bands where no allocation to the Radio Astronomy Service exists and in which radio astronomy observations are unprotected;

d. that Recommendation ITU-R RA.769 gives protection criteria for radio astronomical measurements**;**

*e***.** that Recommendation ITU-R SM.1633 explains that "if the level of interference, under the assumptions of Recommendation ITU-R RA.769, becomes 10 dB or more above the Recommendation ITU-R RA.769 definition, then increased observing time will no longer be effective in ensuring that valid scientific data are provided to the scientist. The radio astronomy station will be unable to operate in the affected frequency band, and its ability to provide service will have been lost if no appropriate mitigation techniques can be applied."

f. that article 29 of the ITU Radio Regulations states in No. 29.7 that "All practicable technical means shall be adopted at radio astronomy stations to reduce their susceptibility to interference. The development of improved techniques for reducing susceptibility to interference shall be pursued, including participation in cooperative studies through the Radiocommunication Sector";

g. that therefore mitigation techniques for radio astronomy need to be developed to enable radio astronomy observations at a protection level given in Recommendation ITU-R RA.769 or better;

recommends:

1. that radio astronomers should be encouraged to publish results of interference mitigation research;

2. that in these publications radio astronomers seek utmost accuracy while considering to:

   a. define the frequency band(s) to which the published study applies;
   b. use terminology based on the definitions in the ITU Radio Regulations;
   c. explain the allocation status for the Radio Astronomy Service in the frequency band(s) used;
   d. provide a description of the assumptions made.
   e. describe the relevant system parameters and setup of the radio astronomy system;
   f. explain in careful wording the purpose of the specific mitigation study and the effectiveness of the mitigation achieved as compared with Recommendation ITU-R RA.769;

Annex

1. Background

Radio astronomy is by its nature a passive service[i]. The Radio Regulations[ii] of the International Telecommunication Union (ITU) identify a range of radio frequency bands allocated to the Radio Astronomy Service (RAS). These allocations can have a *primary* status or a *secondary* status or their use by RAS is indicated by a footnote only. Some frequency bands are exclusively allocated to passive services, but most of the frequency bands allocated to passive services are shared with active services[iii]. The protection of radio astronomy observations is regulated by specific footnotes in the Radio Regulations. Outside the frequency bands allocated to RAS, radio astronomy is unprotected. Recommendation ITU-R RA.769 gives the protection criteria for radio astronomy measurements[iv]. Although this Recommendation is widely used by Administrations to protect radio astronomy it should be noted that it is only a ***recommendation*** without any obligatory status. In some frequency bands the Radio Regulations state that “all emissions are prohibited”, while in other bands it is said that “administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference”, while noting that “emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service”.

The frequency allocation table in the ITU Radio Regulations gives the allocation status for all frequencies between 9 kHz and 275 GHz. Some frequency bands allocated to active services are not or occasionally used by these services. This enables radio astronomy in some cases to observe in frequency bands that are not allocated to RAS. When in such cases transmissions from active applications are received, radio astronomy can observe at a limited sensitivity only. Technological developments very often imply that the use of the radio frequency spectrum is increasing with time, posing more limits to such out-of-band usage. In all these cases radio astronomy observations are made at own risk, without any guarantee of protection from interference. In such frequency bands the levels given in Recommendation ITU-R RA.769 usually cannot be met.

Due to an increased use of the radio spectrum for both terrestrial and space-borne communications and the leakage of emissions from bands adjacent to bands allocated to RAS, it becomes increasingly difficult to protect radio astronomy observations in the bands allocated to this service. To answer this challenge, the radio astronomy community has organized itself to take up the challenges invoked by modern spectrum management issues, e.g. in IUCAF[v] and CRAF[vi]. These organizations work on the preservation of the protection of radio astronomy in frequency bands allocated to RAS. As stated in the Radio Regulations[2], the Radio Astronomy service is also required to investigate and apply interference mitigation techniques in order to reduce their susceptibility to radio interference.

In recent years, interference mitigation techniques have become an important research topic in radio astronomy. The investigated techniques show a significant potential, but their successful application to operational telescopes (or to new designs) is not trivial. Often, interference mitigation research is focussed on certain aspects such as numbers quantifying interference attenuation, but for a successful application in a telescope the technique needs to be considered in a wider context.

An accurate, complete and clear description of the effect and applicability of mitigation methods is essential for the radio astronomy community, but even more care should be applied when these results are reported in open literature in order to avoid unwanted side effects on the spectrum management policy.

Inaccuracies in publications can easily lead to misunderstandings at the reader who is quite often not a radio astronomer or has no understanding of the radio astronomy peculiarities, weaknesses and strengths, at all. It has occurred that misinterpretation of published mitigation research results, lead to expectations and claims that are too optimistic and which may be harmful or even disastrous for radio astronomy, especially in the spectrum management context.

In order to help avoid these misinterpretations, this document gives some considerations/recommendations on publicizing interference mitigation research in radio astronomy. In the attempt to give a complete overview of the most relevant aspects involved, in some cases the obvious will be stated. The mentioned recommendations are aimed to serve as guidance for publications in a wide sense, from journal papers to web pages and oral presentations.

Publication

It is obvious that the results of interference mitigation research are published through the customary channels: this is part of the general obligations science has to society. Publications referring to observations that are made within bands allocated to radio astronomy are encouraged, as well as publications about observations that have been made elsewhere in the radio spectrum. Mentioning that radio astronomy also observes outside bands allocated to RAS is in principle not a problem, provided that sufficient careful wording is used as will be explained below.

Terminology

In interference mitigation publications often the word interference is used. This is correct for observations suffering degradation by man-made transmissions in a frequency band allocated to radio astronomy. When a radio astronomy observation taken in a band not allocated to radio astronomy is degraded by transmissions of applications rightly using such a band, one can only state that this degradation is due to a specified transmitter or application in an active service.

Assumptions

All relevant assumptions in the research should be listed or described as they are indicative for the effectiveness of the application.

Examples of assumptions worthwhile of mentioning are:

- Which telescope type or telescope concept is considered, together with relevant design parameters (sensitivities, integration times, effective receiving areas, configuration,...)
- Which observing mode is used (aperture synthesis-map making, single dish spectral line work, pulsar observations,...)
- Observation specifications: coordinates (Az/El, RA/DEC), bandwidth,…
- Interferer/transmitter parameters and assumptions (bandwidth, modulation scheme, spatial extent of interfering source, multipaths,...)

Mitigation effectiveness
In describing the mitigation effectiveness, the achieved results must be described *quantitatively*, specifically (to the maximum extent possible) the relation with the protection criteria for radio astronomy as given in Recommendation ITU-R RA.769. This information is important since in the compatibility studies involving radio astronomy Recommendation ITU-R RA.769 is taken as the basis. A clear understanding (as much as possible) on how close the interference can be mitigated with respect to the levels given in this Recommendation is essential.

In particular we stress the fact that a clear distinction needs to be made between achievements obtained in frequency bands with a different allocation status:

- Mitigation research in bands allocated to radio astronomy:
  Results should be given in a form that makes direct comparison to the RA769 recommendation possible.

- Mitigation research in bands not allocated to radio astronomy:
  Results preferably are to be described (a) in a form that enables direct comparison with Recommendation ITU-R RA.769, or (b) in reference to system noise levels (SNR/SINR before mitigation and after). If the results are compared with the levels of Recommendation ITU-R RA.769 it should be mentioned that this comparison is relevant for radio astronomy as this is indicative for observation sensitivities.

- Mitigation research in which the bands are not specified:
  If it is difficult or not desirable to specify a specific band, for example because the method under consideration is a general signal processing analysis of detector types, then the mitigation effectiveness should be described quantitatively in terms such as SNR or SINR, before and after the mitigation.

In any case if a certain frequency band is referenced, its allocation status should be explained.

Note: sometimes researchers claim attenuation factors of mitigation methods. It is important to realise - and to clearly state in publications - that these attenuation factors are only valid for certain observed transmitter powers or circumstances. The interference detection, estimation and removal effectiveness is to a large part determined by noise in the estimation process. This means that a 30 dB attenuation factor obtained by mitigation of strong transmitters may be 0 dB for weak transmitters or other circumstances.

Mitigation applicability/maturity
In assessing the effectiveness and applicability of a method in a particular radio telescope, the following aspects are relevant.

- *Cost*
  A method may be effective, but if the cost of the method is of the same order of magnitude of the system parts it operates on, for instance due to the requirements on the signal processing involved, then its practical use is

questionable. In some cases the financial investments could be justified if there is a special type of science that can be carried out only in bands which would not be accessible without interference mitigation.

- *Calibration processes*
  Interference mitigation application(s) may distort calibration processes, as these processes usually have some stability requirements which may be violated by time-varying adaptive (or fixed) mitigation methods. If possible the impact of the mitigation method on the calibration process should be investigated.

- *Induced distortions*
  Interference mitigation reduces interference, but it usually also affects the astronomical signals. For example, excision of data could influence the power scaling of astronomical sources, and adaptive spatial filtering could distort the visibility data. These effects can be corrected, at least to some extent. In estimating the interference reduction capabilities, this distortion effect should not be forgotten.

- *Mentioning observed spectrum statistics*
  As spectrum occupation information is a strategic and politically sensitive, publication of this kind of information should be very limited and very carefully worded. In some cases and in some countries, it is even not legal to gather spectrum information.

- *Stressing the need for band allocation*
  It is encouraged to add in the introduction of a publication the need of frequency bands allocated to radio astronomy since the industrial arguments are extended to the issue whether radio astronomy needs allocations to frequency bands at all. The text could be something like "For reasons of proper calibration of radio astronomy observations and to achieve results with the highest sensitivity, the frequency bands that are (exclusively) allocated to passive services are of the utmost importance".

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i A ‘receive-only’ radiocommunication service
ii the ITU Radio Regulations are an international treaty binding to those countries that ratified it
iii a service that uses both a transmitter and a receiver
iv the signal strength received from a cosmic radio sources is usually 10^{-9} to 10^{-12} weaker than a terrestrial transmitter.
v ICSU Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science
vi Committee on Radio Astronomy Frequencies of the European Science Foundation (ESF)