Monitoring EMI and the radio spectrum in Europe

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Abstract
This paper provides some comments on monitoring electromagnetic interference and spectrum occupancy. It also gives details on the monitoring facilities available in Europe and on the functions of the CRAF monitoring database tools.

1. Introduction

A quiet and interference-free "radio"-climate and "radio"-weather are necessary prerequisites for high quality radio astronomy observations. Daily practice, however, shows that radio astronomy observations often suffer from harmful interference, even in frequency bands allocated to radio astronomy.

Understanding and quantifying the impact of man-made transmissions on radio astronomy observations enables radio astronomers to take adequate action to alleviate this problem, either by quantifying the interference and bringing such data to the attention of the Administrative Authority that is mandated to take action to cure the problem, or by developing operational measures at the victim radio astronomy station.

One of the means to develop knowledge about the "radio"-climate within which observations are done is to perform dedicated monitoring. In some instances, monitoring is seen as *the* key to obtaining knowledge about the probability of being able to make high-quality interference-free observations.

2. Before you start

Before speaking of "*the* key to obtaining" and starting on monitoring, an initial question must be answered: "*What is the question you want to answer with this activity*"? The answer to this specific question must determine which data are monitored, with what time frequency, with what accuracy, etc. The collection of large amounts of data should be avoided by all means, since at some moment in time (usually much sooner than one expects) it will be noted that the complexity of the issue at stake implies that the database is no longer manageable.

Furthermore, it is strongly recommended that one store and exchange the monitoring data in a harmonized data format to ease the exchange of information between interested parties.

3. Instrumentation

Several radio astronomy stations operate monitoring facilities in parallel with their regular observations. Usually one observes as a function of frequency where the spectrum is occupied or clean. Although this monitoring is very useful, it should be noted in such a project that one does not monitor radio frequency interference, RFI, or electromagnetic interference, EMI, but rather spectrum occupancy: *monitoring spectrum occupancy is <u>not</u> EMI/RFI monitoring.* Spectrum occupancy does not give information about the interference one suffers in an observation.

Interference is "*the effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, or loss of information which could be extracted in the absence of such unwanted energy*", as the ITU Radio Regulations define in their Article 1.166. This implies that a radio astronomer can only obtain information about EMI by inspection of the observations themselves. EMI is then understood as the 'quantification' of the degradation of the quality of an observation due to unwanted emissions, radiations, or inductions upon reception in a radiocommunication system. Thus monitoring EMI is exclusively done by inspection of radio astronomical observations.

Spectrum occupancy information identifies the probability of becoming a victim of interference. This information can be useful both for the management of a radio astronomy station and to its operators when they make decisions about scheduling, frequency selection, and project planning.

While the monitoring of spectrum occupancy is done by dedicated instruments, the monitoring of EMI can only be done with the radio telescope itself during an observation. This implies that the telescope is really the best monitoring station for its EMI troubles.

4. Purpose of monitoring

Monitoring EMI provides quantified evidence and details about interference that can be used in discussions with the responsible Administrations in the case of interference trouble. It should be noted that when interference is not adequately reported to the Administrations, the interference does not exist and the Administration concerned cannot take action!

Monitoring of the development of the EMI "climatology" or "weather" provides useful additional information which is also relevant for the Administrations.

Quantified knowledge about the "radio"-climate and "radio"-weather sets the stage for improving the observing conditions at the radio astronomy station concerned. It may also serve to inform special projects, such as the development of interference-robust receivers, and interference-suppression techniques.

5. Europe

At present, about a dozen European radio astronomy stations have their own facilities (fixed or mobile) for monitoring spectrum occupancy; and about half a dozen of them are also stations in the European VLBI Network. This information is usually kept in house: but "all data are stored".

5.1 CRAF facilities

CRAF has developed and currently manages a facility to manipulate monitoring data for all European radio astronomy stations. This facility is accessible via the CRAF website. Data are fed to the CRAF clearing house in the so-called 'CRAF data-format', which is a slight variant on the data-format used by NASA for similar work. This means that with a little transformation software the CRAF database and the NASA databases can be combined in principle.

CRAF has developed a range of analysis tools for both the EMI and spectrum occupancy database. Both databases have the same data format. The EMI database can be queried through the following options:

- Interference intensity as a function of time of the day
- Interference intensity as a function of days of the week
- Interference intensity as a function of frequency
- Development of interference intensity as a function of time
- Observational degradation as a function of time of the day
- Observational degradation as a function of days of the week
- Observational degradation as a function of frequency
- Development of observational degradation as a function of time
- Interference occurrence as a function of time of the day
- Interference occurrence as a function of days of the week
- Interference occurrence as a function of frequency
- Development of interference occurrence as a function of time

The spectrum occupancy database can be queried through the following options:

- Signal intensity as a function of time of the day
- Signal intensity as a function of days of the week
- Signal intensity as a function of frequency
- Development of signal intensity as a function of time
- Signal occurrence as a function of time of the day

- Signal occurrence as a function of days of the week
- Signal occurrence as a function of frequency
- Development of signal occurrence as a function of time

It is obvious that the latter facility has fewer options to query than the EMI database since the number of different questions that can be answered properly is less. Ausername and a password because in many countries it is strictly forbidden to monitor spectrum occupancy or to 'publish' monitoring data. One of the reasons behind this is obviously commercial sensitivity.

5.2 Administrations

Administrations usually operate some kind of monitoring facilities, though this effort generally addresses ground-based interferers. The German Administration's facility is at Leeheim, near Darmstadt, which specializes in monitoring space systems.

In some countries there is an increased interest in monitoring by the Administration (e.g. in The Netherlands, where there is close cooperation between the Administration and the radio astronomers on the exchange of information). At the pan-European scale, the Administrations forming the "Conférence Européene des Postes et des Télécommunications", CEPT, agreed in a Memorandum of Understanding on satellite monitoring. This MoU arranges coordination between Administrations on satellite monitoring and adequate funding of this activity. The German Leeheim monitoring station is the key node in this activity and is therefore developing into *the* European station for satellite monitoring.