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Electronic Communications Committee

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N

Summary:

This document describes the future satellite monitoring needs of the Radio astronomy service.

It further confirms that Leeheim Satellite monitoring station can provide those measurements required to meet the future satellite monitoring needs of the Radio astronomy service.

Proposal:

CRAF invites ECC to

- note that ECC and CRAF agreed within their "Letter of Understanding regarding co-operation" to seek, to the extent possible, a common European approach concerning radio matters. This includes to protect the Radio astronomy service;
- consider the elements provided below;
- take action to assure the protection of the Radio astronomy service also in future.

Background:

The Committee on Radio Astronomy Frequencies (CRAF) is an ESF Expert Committee that acts on radio frequency issues for European radio astronomy and related sciences on behalf of its member institutions located in 20 countries. Its member institutions are involved in radio astronomy, i.e., non-commercial scientific research of the Universe in the radio spectrum. In 1959 ITU started to recognize the importance of this science and allocated several frequency bands to the Radio Astronomy Service (RAS), some of which have the status of a passive band, i.e., no emissions are permitted.

The mission of CRAF is:

- to keep the frequency bands used for radio astronomical observations free from interference;
- to argue the scientific needs of the European research community for continued access to, and availability of, the radio spectrum for radio astronomy;
- to support related science communities in their needs concerning interference-free radio frequency bands for passive, non-commercial use.

ECC is the recognised organisation in Europe responsible for the allocation of spectrum at European level in the field of radiocommunications. ECC and CRAF have a common interest and objective in ensuring efficient use of the RAS stations, which are completely funded by the European tax payers (See: LoU regarding the co-operation between ECC and CRAF.) By signing the LoU in the year 2000, ECC and CRAF look back on two decades of co-operation.

ECC at its 51st meeting agreed to find out:

- what the future satellite monitoring needs are likely to be (by taking into account the rapid evolution of satellite technologies with respect to GSO and NGSO constellations);
- whether Leeheim can provide those measurements required to meet future satellite monitoring needs;
- information on how CEPT administrations, which did not sign the MoU, do monitor satellite services.

Based on this information, ECC aims to agree on appropriate measures to take at the next ECC plenary meeting in March 2020 (See: ECC(19)081 (item 17, p. 20).)

The Radio astronomy service depends heavily on satellite monitoring as currently provided by ECC.

1 RADIO ASTRONOMY AND ITS OPERATIONAL ENVIRONMENT

Radio astronomy stations are designed to receive extremely weak signals originating in distant parts of the universe, from sources in the solar system to those at extreme distances of billions of light years away. Large radio astronomical observatories feature antennas with gains of 60 dBi or more at L-band frequencies and are routinely used to detect cosmic signals weaker than –270 dBW / 20 kHz in L-band. The antennas used by radio astronomy point towards the sky, tracking the apparent movement of the radio sources while Earth rotates. Even very weak emissions from air- or space-borne man-made sources can easily outshine cosmic sources, not only for passages of satellites through the main beam of the RAS station, but also for side-lobe entry with little or no antenna gain. The Recommendation ITU-R RA.769 not only specifies stringent limits (–220 dBW / 20 kHz for a spectral-line observation with an integration time of 2000 seconds) in L-band, but also points out *"that some transmissions from spacecraft can introduce problems of interference to radio astronomy and that these cannot be avoided by choice of site for an observatory or by local protection"* (*considering k* of Recommendation ITU-R RA.769). In the same recommendation it is stated *"that administrations, in seeking to afford protection to particular radio astronomical observations, should take all practical steps to reduce all unwanted emissions falling within the band of the frequencies to be protected for radio astronomy to the absolute minimum. Particularly those emissions from aircraft, high altitude platform stations, spacecraft and balloons"* (*recommends 3* of Rec. ITU-R RA.769).

One expects the number of satellites to increase drastically over the next few years, but their bandwidth and traffic will also increase to service the vast number of terrestrial terminals that have been envisaged to become another mass market.

Protection from unwanted satellite emissions will be a matter of survival for services such as radio astronomy that may be potential victims of interference. Operators of satellites will however find it increasingly difficult to square the growing demand for traffic by a growing number of subscribers, which usually leads to higher levels of emission, with the protection requirements of other services.

Radio astronomy in Europe operates five of the largest and most sensitive antennas in the world. These are mostly located in areas with very few terrestrial human-made emissions, but of course still particularly vulnerable to air- and satellite borne emissions from services designed to serve the densely populated and industrialised European countries. These RAS stations have been extremely successful in their contribution to our understanding of the universe in the past, in spite of their locations. The support and effective protection of the spectrum for radio astronomy in Europe by CEPT administrations has provided the environment for the successful operation of European RAS stations. One could argue, that this support and protection is also motivated by the fact that RAS stations are very costly to build and operate,– costs that are met to 100% by the public purse!

Resolving the conflict of interests between satellite operators and publicly funded services such as the RAS is undeniably a matter of spectrum regulation by administrations and requires factual and unbiased evidence of spectrum use and emissions by satellites provided by independent monitoring stations. Here one has to bear in mind that the operational costs of such a satellite monitoring station is only a fraction of that of a major radio astronomical facility.

2 MONITORING REQUIREMENTS

Satellites are complex technical systems and therefore prone to changes in their emission characteristics, caused by aging, possible mal-functions, firmware updates and in some cases operational modifications by the operator. A regular surveillance of satellite emissions, including spot checks, ought to exist in order to detect and address problems of interfering emissions. The number of protected bands on one hand, and the vast increase of the number of satellites, their traffic and spectrum occupancy would lead us to expect an increase of monitoring activities, just to keep up with the developments.

A satellite monitoring station has to be a sensitive state-of-the-art system that can track individual satellites even in low orbits, has sufficient antenna gain to detect and measure even comparatively weak unwanted emissions from satellites in the presence of strong wanted signal emissions, i.e. feature high-dynamic range receivers. Such a station requires not only highly sophisticated measurement equipment, but also sufficient numbers of experienced and highly skilled staff for its operation and the analysis and reporting of the measurements. Therefore, a monitoring station can only be operated with a long-term commitment to staffing and continuous technical maintenance and improvements, very similar to the operation of a radio telescope.

Most radio telescopes cannot track low earth orbit satellites because of the size and inertia of their large antennas. And even if they could, their sensitive receivers would be overloaded or even be damaged by the strong wanted satellite emissions (see e.g. Reports ITU-R RA.2188 and RS,2308). Last but not least, satellite measurements are a time-consuming task, time that will not be available for the purpose of an RAS station:

astronomical research of distant radio sources. Satellite monitoring certainly requires one or several stations dedicated to around-the-clock observations, not only in Europe but world-wide. Experience has shown, that some operators of e.g. MSS had tried to minimise unwanted emissions only over Europe where monitoring by Leeheim is known to be effective, and not in other regions where victim services were consequentially stronger affected. One may expect a decrease of effective protection of radio astronomy (i.e., more interference) when monitoring activities by CEPT are decreased or even cease.

3 THE NEED FOR A SATELLITE MONITORING STATION IN EUROPE

Radio astronomy stations pick up a large number of human-made signals, but are in most cases unable to identify their origin because RAS antennas cannot point to or track the sources, especially when signals are transient as e.g. from a satellite. A monitoring station is therefore often the only mean to identify satellites unambiguously and quantitatively as the source of unwanted interfering emissions. This is particularly important when satellite operators deny or dispute interference from their spacecraft as it has happened in the infamous Iridium case. It is the opinion of CRAF that an independent monitoring station operated and funded by administrations is needed to provide unbiased evidence for the justification of measures and decisions by administrations when dealing with satellite operators.

The Leeheim satellite monitoring station in Germany and its staff have been invaluable in the past when it e.g. came to shed light into the ten years old Iridium–RAS dispute about unwanted emissions by IRIDIUM satellites into the RAS band 1610.6 -1613.8 MHz and has led to ECC reports 171, 226, 247, as well as ECC Dec. 09(02). No other monitoring station in the world has achieved anything like that and the results have also found their way into the ITU Handbook of radio astronomy (second edition) as a particularly instructive example of how to measure satellite emissions accurately. The problem is unfortunately not being solved with the new generation of Iridium satellites (Iridium NEXT) and work on the subject is continuing in ECC SE40,– certainly for the next year, if not longer. Again, it had been the Leeheim station that provided evidence that the new Iridium NEXT satellites had unexpectedly and surprisingly increased their unwanted emissions nearly to the level of the previous satellite generation. Iridium has confirmed in a meeting of ECC SE40 in December 2019 that they had unilaterally modified their satellite operations with a resulting diminishing protection of RAS. Only the monitoring from Leeheim could discover and pinpoint the source of unwanted emissions in a timely and unambiguous manner.

It is also expected that the demand for satellite monitoring will significantly grow in the near future. There are several huge projects on the horizon, which plan to launch hundreds to thousands of small and medium sized satellites, for high-bandwidth communication such as Internet service providing around the globe. SpaceX has already started to launch the first batches of its Starlink constellation (with 60 satellites per batch!). It has expressed plans to use up to 40 thousand satellites for this, and got permission for the first 12 thousand devices by the FCC. But also Amazon and OneWeb consortium are participating in this new “space race”. The increased spectrum use may potentially affect *all* existing services – even if the satellites fulfil protection criteria by design, the sheer number of satellites means an increased risk of malfunctions or production outliers leading to unexpected emission levels.

4 SUPPORT AND COOPERATION

CRAF and especially the Max-Planck-Institute for Radio astronomy (MPIfR) in Germany have been co-operating closely and fruitfully with the staff of the Leeheim station. We a have supported the station in matters of measurements, calibration techniques and software development. This well-established cooperation between a monitoring station and radio astronomers is unique in the world and certainly one of the reasons for the unparalleled success of the satellite monitoring of e.g. the IRIDIUM constellation by the Leeheim station. CRAF would like to mention the fact, that this cooperation also involved representatives from Iridium, who

participated in the measurement and evaluations in ECC SE40 and have accepted and respected the Leeheim results.

CRAF hopes to continue the fruitful co-operation and will continue to provide help in technical matters within our capabilities.

5 EUROPEAN RADIO ASTRONOMY STATIONS

An up-to-date list of European RAS stations is available on the CRAF website: https://www.craf.eu/radio-observatories-in-europe/.