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| A close up of a sign  Description automatically generated | **World Radiocommunication Conference (WRC-23) Dubai, 20 November - 15 December 2023** | |  |
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| PLENARY MEETING | | **Addendum 3 to Document 65(Add.27)-E** | |
|  | | **29 September 2023** | |
|  | | **Original: English** | |
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| European Common Proposals | | | |
| PROPOSALS FOR THE WORK OF THE CONFERENCE | | | |
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| Agenda item 10 | | | |

10to recommend to the ITU Council items for inclusion in the agenda for the next world radiocommunication conference, and items for the preliminary agenda of future conferences, in accordance with Article 7 of the ITU Convention and Resolution **804 (Rev.WRC‑19)**,

Part 3: Agenda for the 2027 World Radiocommunication Conference  
Impact of non-GSO aggregation on RAS

Introduction

The following wording of the new agenda item is proposed for insertion in draft new Resolution **[EUR-A10] (WRC-23)** agenda for the 2027 World Radiocommunication Conference:

...

1 on the basis of proposals from administrations, taking account of the results of WRC‑23 and the Report of the Conference Preparatory Meeting, and with due regard to the requirements of existing and future services in the frequency bands under consideration, to consider and take appropriate action in respect of the following items:

...

1.13 to perform studies on the impact of non-GSO aggregation on the radio astronomy service (RAS) and related appropriate measures for the protection of RAS from harmful interference from large satellite constellations, in accordance with Resolution **[EUR-A10-1.13-RAS-NGSO] (WRC-23)**;

...

[Editor's note: Numbering to be corrected after finalizing the list of agenda items.]

Background

In recent years, the number of satellites in Earth’s orbits, especially in low-Earth orbit (LEO) has seen an enormous increase. While the plethora of new applications and services undoubtedly have a benefit for people, there are also concerns. As an example, professional astronomers report that sunlight that is reflected at the satellites produces artefacts in optical and infrared data, which cannot be fully mitigated with software owing to the significant increase in numbers. This also may have consequences for space agencies projects to continuously observe the night sky in order to detect early potential hazardous objects (asteroids) that might collide with Earth. Unfortunately, no regulations exist whatsoever that address the influence of satellites on optical/infrared astronomy, or even the night sky as a whole, which is of high importance for many people, cultures and societies.

But also radio astronomy is increasingly affected, despite the fact that it is addressed in the radio regulations and other ITU‑R documents. This is because some key issues are currently not well handled, such as apportionment (when several constellations produce unwanted emissions in the radio astronomy frequency bands) or the limited consideration of radio astronomy service (RAS) protection in ITU‑R satellite filing processes. In addition, some aspects are currently not considered at all, e.g., how national radio-quiet zones can be protected from space-borne emissions, how one can protect RAS receivers from saturation causing intermodulation products or harmonics when too much power is fed into the extremely sensitive systems, or the absence of electromagnetic compatibility regulations: as any other electronic or electric device, satellites can also produce leakage radiation. The aggregate effect of all these can actually exceed the threshold power levels in protected RAS bands, but as ITU‑R regulation does not apply to electromagnetic leakage, the observatories are effectively unprotected from such radiation.

As a reaction, the worldwide astronomy community via its International Astronomical Union (IAU) founded the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS) under the lead of NSF’s NOIRLab (optical/IR) and the Square Kilometre Array Observatory[[1]](#footnote-1) (SKAO; radio astronomy), to study the impact of large satellite constellations on astronomy and to seek for solutions with administrations and the industry.

The threat to fundamental sciences and their major investments receives increasing recognition. The topic is discussed in the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), which focusses on the non-ITU aspects. Most recently, the Science and Technology Ministers of the International Group of Seven (G7), which met during the G7 Summit 2023 have announced in a Communique:

“We [the Science and Technology Ministers of the G7] recognize the importance of continued discussion, in the UN COPUOS and International Telecommunications Union (ITU) frameworks, as well as with the International Astronomical Union (IAU) on the impact of large constellations of satellites on astronomy for the protection of the dark and quiet sky.”

The aforementioned threats to optical and radio astronomy are mostly tied to what media named “megaconstellations”. As this term is technically incorrect (even the largest constellations will consist of hundreds of thousands, but not millions of satellites), the relevant systems will be called “large satellite constellations” in the following. However, there is currently no definition or classification of a “large” non-geostationary satellite (non-GSO) system in the Radio Regulations. Thus, some work should be invested into possible categorization of satellite constellations. What should definitely be out-of-scope of the proposed agenda item is the classical satellite constellations, with less than one or two hundred satellites, as this would unnecessarily increase the workload during the study cycle with little benefit for the protection of the RAS.

In the following, some of the most important aspects related to large satellite constellations will be briefly summarized.

Aggregation and Apportionment

The method to assess the impact of aggregate interference when multiple constellations operate simultaneously is ill defined. In Recommendation ITU‑R RA.1513 it is stated that 5% data loss from all satellite systems impacting a given RAS band is acceptable to RAS observations, and 2% of data loss from a single system. However, the recommendation also states that the 5% level would automatically be met when each system respects the 2% figure. While this was probably the case up to a certain time, with the enormous increase in numbers of satellite constellations, one can become doubtful that this assumption will still hold.

On the technical level, several ITU‑R Recommendations offer methods to calculate the data loss by one or more satellite constellations. Based on previous work, it is well known that for non-GSO constellations of a certain size, calculations should be performed based on the so-called equivalent power flux-density (epfd) method, which is described in Recommendation ITU‑R M.1583. The approach can (and should) incorporate all kinds of operational and technical properties of the satellite constellations, such that sufficiently accurate compatibility studies can be performed. In addition, aggregation effects (when multiple satellite constellations impact the same RAS frequency bands) are fairly simple to be incorporated. However, the procedural issues are unclear. If two systems already operated and each barely meet the 2% criterion, what happens if a third system wants to enter the market? Is it “first come, first served” or should there be different approach? Also, it is likely that epfd calculations have to be repeated with all relevant systems included, i.e., every time a new system is added, which increases the required workload for all stakeholders.

It is recognized that the question of apportionment is a very complex one to solve. Thus, to ensure a workload that is still manageable in on study cycle, it is proposed to only consider the largest satellite constellations affecting a given RAS band. One practical method for this could be to use the ITU‑R database of satellite filings to extract this information during the study cycle. In this manner, the studies would also naturally be restricted to RAS bands that are actually endangered right now, which would further reduce the amount of work to the absolute minimum while ensuring that RAS is efficiently protected.

Missing ITU‑R process to protect RAS early on

Currently, the regulatory processes for coordinating non-GSO satellite systems with RAS during the satellite filings are very limited. Administrations, which wish to protect their RAS stations, can only do this in the commenting phase, while the ITU‑R Bureau has no mandate to assess even the most basic compatibility metrics when following the procedure outlined in RR Articles **9** and **11**. This leads to unnecessary and redundant work when every single administration has to repeat the same calculations for every RAS station in the world that should be protected. Furthermore, even for actual cases of interference of existing non-GSO systems the potential solutions, which are outlined in Resolution **739 (Rev. WRC-19)** that allows affected administrations to initiate a consultation process with the responsible administration, apply to a small subset of RAS bands only: the bands employed by the non-GSO satellite services (mainly in the frequency range 10-50 GHz) are not listed in the non-GSO table in the Annex of Resolution **739 (Rev. WRC-19)**.

Satellite systems cannot be fixed once in orbit

A major difference of satellite-based infrastructure compared to terrestrial applications is that cases of interference can hardly be fixed. While this might change in the longer future (assuming more space based infrastructure for in-orbit maintenance), at the moment a broken or not well designed satellite could have severe impact on RAS observations without the chance to stop harmful interference. Therefore, from radio astronomy’s perspective, a fair amount of planning and coordination should be invested before satellites are launched. Best practices and design principles should be studied, put into regulation and be policed by administrations.

Direct-to-cell and direct-to-device initiatives

Non-terrestrial networks (NTN), i.e., direct-to-cell (D2C) and direct-to-device (D2D) add a whole new dimension to the aforementioned topics. Both technologies refer to incorporating satellite-based infrastructure into International Mobile Telecommunications (IMT) networks. D2C is intended to connect IMT base stations to the network via satellite links, while D2D uses IMT base stations on board the satellites to directly communicate with IMT user equipment. Both are of particular interest specifically relay or backhaul stations in underserved areas that are hard to reach. It should be noted, that for D2C distinct frequencies are required for the normal base station downlinks (terrestrial BS to terrestrial UE) and the feeder links (satellite to terrestrial BS). Also, all current activities for D2D seem to focus on frequencies below 5 GHz, where path propagation losses are lower.

Existing IMT networks, in particular the base stations, have been widely studied and a great amount of work has been spent on studying all kinds of cases: small and large networks, urban and rural deployments, classical vs. beam-forming antenna systems, in-band and unwanted-domain scenarios, etc. Recently, even IMT base stations onboard aircraft and high-altitude stratospheric platforms have been investigated. What has not been studied at all, though, is how RAS protection can be achieved when a satellite component is added to support the networks. From the experience with terrestrial and aerial base station deployments, it is very likely that necessary coordination or exclusion zones sizes would exceed current values by far. Thus, multilateral coordination cannot be avoided. Yet, several of the planned system operators attempt to obtain a filing under RR Article **4**, No. **4.4** of the Radio Regulations, only, leaving the burden of organizing and coordinating RAS protection local and regional stakeholders, requiring individual and redundant processes, which is very inefficient. This also poses the risk that some administrations will not have the means to perform all the necessary studies and calculations.

It is recognized that NTN in IMT frequency bands is not yet possible via the Radio Regulations. Nevertheless, several industry stakeholders have already invested heavily in this and are advancing quickly (with prototypes in orbit). As discussed above, some projects are envisaged to be operated under RR Article **4**, No. **4.4**. Therefore, this topic should be considered under this agenda item. Ideally, however, NTN should be studied first at ITU‑R and in this case, RAS protection can and should be addressed in the associated agenda items as appropriate.

Proposals

ADD EUR/65A27A3/1

Draft New Resolution [EUR-A10-1.13-RAS-NGSO] (WRC‑23)

Studies on the impact of non-geostationary-satellite orbit (non-GSO) aggregation on the radio astronomy service (RAS) and related appropriate measures for the protection of RAS from harmful interference from large satellite constellations

The World Radiocommunication Conference (Dubai, 2023),

considering

*a)* that there is an increasing number of non-geostationary-satellite orbit (non-GSO) satellite launches planned during the next decade;

*b)* that some non-GSO satellite constellations may consist of thousands of satellites;

*c)* that multiple large[[2]](#footnote-2)1 non-GSO satellite constellations are operating or being planned to operate in the same frequency bands;

*d)* that these large constellations in *considering b)* and *c)* may operate in frequency bands adjacent to or nearby the frequency bands allocated to the radio astronomy service (RAS);

*e)* that in some cases there are no limits specified in the Radio Regulations for out-of-band emissions from large satellite constellations, which may cause interference detrimental to the radio astronomy service;

*f)* that out-of-band emission limits alone do not necessarily suffice to protect the RAS as the aggregate power produced at a RAS station from a satellite system depends on the number of satellites in a constellation and other operational parameters such as transmitter antenna pattern and pointing, or orbit heights and inclinations;

*g)* that with large number of satellites the likelihood increases that satellites cross the main beam of the radio astronomy telescope, where the antenna gain is significantly higher than 0 dBi;

*h)* that aggregate out-of-band emissions from single and multiple large satellite constellations may cause harmful interference to the RAS, even in remote sites;

*i)* that non-GSO satellite systems may be used as a part of IMT networks to provide mobile connectivity to underserved communities and in rural and remote areas,

noting

*a)* that Recommendation ITU‑R RA.769 provides thresholds for the non-GSO satellite interference received through the far side lobes of the radio astronomy telescopes, where a simplified antenna model is assumed with a representative gain of 0 dBi;

*b)* that the current regulatory provisions and procedures may not be sufficient to ensure protection of the RAS from harmful interference produced by the increasing number of large non-GSO satellite constellations;

*c)* that there is no classification of a large satellite network in the Radio Regulations;

*d)* that several frequency bands allocated for satellite downlinks are not adjacent to nor nearby the frequency bands allocated to RAS;

*e)* that there are no examinations currently performed by the Bureau with regard to RAS protection from large satellite constellations under Articles **9** or **11**;

*f)* that Recommendation ITU‑R RA.1513 provides the acceptable levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the RAS on a primary basis,

recognizing

*a)* that addressing the compatibility issues between RAS and large non-GSO systems may require technical mitigation measures before satellites are launched and operational;

*b)* that in order to facilitate studies, categorization of non-GSO networks, e.g. regarding size of the whole constellations, their sky distribution and other significant parameters, is necessary in order to allow proper studies regarding their impact on RAS;

*c)* that coordination procedures may need to be established for protection of RAS from harmful interference caused by large non-GSO satellite constellations during the satellite filings;

*d)* that for (large) satellite systems the equivalent power flux density (epfd) method, which is developed in Recommendation ITU‑R M.1583, provides sufficiently accurate estimate of the total power that is introduced into RAS receivers and can be used to incorporate the effects of other technical parameters mentioned in *considering h)*;

*e)* that electromagnetic radiation originating from onboard electric and electronic components, especially at lower frequencies, can leak into RAS bands,

resolves to invite the ITU Radiocommunication Sector to complete in time for WRC‑27

1 the determination of a classification of large satellite networks based on size of constellations (starting with 200 satellites), their sky distribution over existing and future planned radio astronomy stations, and other technical or operational parameters;

2 studies on interference scenarios for radio astronomy stations that might arise as a consequence of increased sizes and numbers of large non-GSO satellite constellations operating adjacent to or nearby RAS frequency bands;

3 studies on how the aggregated interference from unwanted emissions of single and multiple large non-GSO satellite systems operating in adjacent and nearby frequency bands, affects the operation of RAS stations;

4 the development of appropriate regulatory procedures to limit the aggregate interference from unwanted emissions of single and multiple large non-GSO systems operating in adjacent and nearby frequency bands at RAS stations, accounting for up to six largest non-GSO systems,

invites administrations

to participate actively in the studies and provide the technical and operational characteristics of the systems involved and other information required for the studies by submitting contributions to ITU R,

resolves to invite WRC‑27

to determine and implement, based on the results of studies, appropriate measures for the protection of RAS from harmful interference from large satellite constellations,

instructs the Secretary-General

to bring this Resolution to the attention of the United Nations Committee on the Peaceful Uses of Outer Space and other international and regional organizations concerned.

Proposals on an agenda item for WRC‑27

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| **Subject:** Studies on appropriate measures for the protection of RAS from harmful interference from large satellite constellations | |
| **Origin:** CEPT | |
| ***Proposal*:** Studies on appropriate measures for the protection of RAS from harmful interference from large satellite constellations, in accordance with Resolution **[EUR-A10-1.13-RAS-NGSO] (WRC‑23)** | |
| ***Background/reason:***  In recent years, the number of satellites in Earth’s orbits, especially in low-Earth orbit (LEO) has seen an enormous increase. While the plethora of new applications and services undoubtedly have a benefit for people, there are also concerns. As an example, professional astronomers report that sunlight that is reflected at the satellites produces artefacts in optical and infrared data, which cannot be fully mitigated with software owing to the significant increase in numbers. This also may have consequences for space agencies projects to continuously observe the night sky in order to detect early potential hazardous objects (asteroids) that might collide with Earth. Unfortunately, no regulations exist whatsoever that address the influence of satellites on optical/infrared astronomy, or even the night sky as a whole, which is of high importance for many people, cultures and societies.  But also radio astronomy is increasingly affected, despite the fact that it is addressed in the Radio Regulations and other ITU‑R documents. This is because some key issues are currently not well handled, such as apportionment (when several constellations produce unwanted emissions in the frequency bands used by RAS) or the limited consideration of RAS protection in ITU‑R satellite filing processes. In addition, some aspects are currently not considered at all, e.g., how national radio-quiet zones can be protected from space-borne emissions, how one can protect RAS receivers from saturation causing intermodulation products or harmonics when too much power is fed into the extremely sensitive systems, or the absence of electromagnetic compatibility regulations to protect the RAS (as any other electronic or electric device, satellites produce various levels of leakage radiation). | |
| ***Radiocommunication services concerned*:**  All satellite services (in particular mobile-satellite and fixed-satellite), mobile (IMT), radio astronomy | |
| ***Indication of possible difficulties*:**  None currently identified | |
| ***Previous/ongoing studies on the issue*:**  None | |
| ***Studies to be carried out by*:**  SG 7 | ***with the participation of*:** Administrations and Sector members of the ITU‑R |
| ***ITU‑R study groups concerned*:**  SG 4, SG 5 and SG 7 | |
| ***ITU resource implications, including financial implications (refer to CV126)*:**  This proposed agenda item will be studied within the normal ITU‑R procedures and planned budget. No extra cost is foreseen. | |
| ***Common regional proposal*:** Yes | ***Multicountry proposal*:** No  ***Number of countries*:** |
| ***Remarks*** | |

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1. The SKAO, operating the world’s largest radio telescope, receives significant funding of many administrations (currently, Australia, Canada, China, France, Germany, India, Italy, Japan, The Netherlands, Portugal, South Africa, South Korea, Spain, Sweden, Switzerland, and the United Kingdom). [↑](#footnote-ref-1)
2. 1 For the purposes of this Resolution and to define a starting point of the related studies, the term “large satellite constellations” refers to non-GSO satellite networks consisting of hundreds and more satellites, at least 200 satellites. [↑](#footnote-ref-2)