Ideas for Securing Undisturbed Geodetic VLBI Observations

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Abstract Existing and upcoming telecommunication services will have an impact on geodetic VLBI observations, mostly adding unwanted noise to the cosmic radiation of interest. The subject of unwanted electromagnetic radiation is serious because man-made signals for telecommunications are stronger in magnitude than the targeted cosmic radiation from quasars.

Keywords interference, RFI, VGOS, spectrum management, geodetic VLBI

1 Interference

The definition of interference for the purpose of spectrum management is given in the Radio Regulation Art. 1.166: *"The effect of **unwanted energy** due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy."*

Figure 1 shows a generic interference situation of two transmitters and two receivers with unwanted energy entering the other receiver. For example, in the case of geodetic VLBI, the transmitter Tx1 is a quasar, and its signal is received by the radio telescope Rx1. A near cell phone and/or a base station Tx2 radiates unwanted energy to the radio telescope Rx1, disturbing the reception of the cosmic radiation. But due to the low cosmic power level which is 15 orders of magnitude less than the transmission power of a cellphone, the cellphone or base station Rx2 is not affected by the quasar's radiation Tx1.

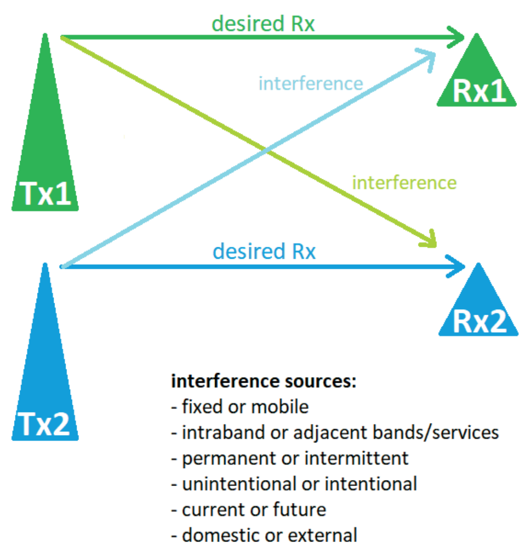

Fig. 1 Interference situation of two transmitters and two receivers. Both receivers may catch unwanted energy from the other transmitter. Interference sources may have very different characteristics.

Spectrum management considers *interference* only among allocated spectra of different communication services. The Radio Regulation lists spectra to services as 'PRIMARY' or 'secondary' allocation[1]. While the primary allocated services using a specific spectrum

[1] In the RR, primary allocated services are denoted in uppercase letters, while secondary allocated services are denoted in lowercase letters.

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should not interfere among themselves, the secondary allocation of the same spectrum is not allowed to interfere with the primary or secondary allocations. This hierachy of allocations allows for multiple use of the same spectrum.

Geodetic VLBI is classified as a Radio Astronomy Service (RAS) due to its reception of cosmic radiation. An RAS owns allocated spectra, but unfortunately these are mainly related to spectral lines with small bandwidth, important for radio astronomy. However, geodetic VLBI retrieves its geometric precision by observing large bandwidths of spectra, which exceeds the bandwidth allocated to RAS. From the view of spectrum administration, although a radio telescope site might be affected by unwanted energy, it is not "interference" in terms of the Radio Regulation, because geodetic VLBI is operating out of the allocated RAS-bands. If unwanted energy from legalized transmitters reaches the radio telescope receiver and degrades the geodetic VLBI performance, it is difficult to reverse the situation by complaining about it. That is the reason why the observed spectral bands (channels) of geodetic VLBI measurements should enter into the Radio Regulation in order to enable an administrative leverage for the protection of geodetic radio telescope sites against interferences.

Another independent strategic approach for protection of geodetic radio telescope sites is their recognition as "critical infrastructure" due to the importance of Earth rotation monitoring for space activities.

2 Unwanted Energy from Ground vs. from Space

2.1 Unwanted Energy from Ground

The ITU-R is coordinating the global use of spectrum, but national administrations put the Radio Regulation into legal force for their territory (but are also free to deviate from the global consensus). Hence ground based communication services are regulated by the national administrations.

The potential ground-based interferers to geodetic VLBI are (among others) mobile telecommunication, radio relay, radar systems, WLAN, Wifi, consumer electronics, amateur radio, and home made local noise. The only way to achieve protection for the geodetic site would be a **radio quiet zone** (RQZ) or a **coordination zone** in which the other services are restricted to not interfere with the radio telescope operation (Figure 2). Such zones can be created by the national administration, which is also responsible for the auction of spectrum. The administration may apply restrictions in the surrounding area of geodetic radio telescope sites which have to be considered when spectrum is being licensed.

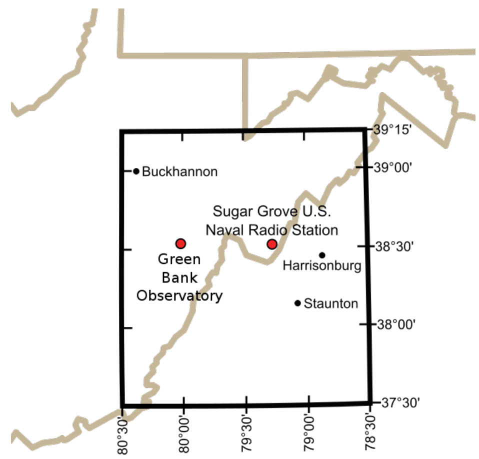

Fig. 2 Example of a Radio Quiet Zone (RQZ) around the Greenbank Observatory and the Naval Radio Station in the U.S.A.. The extension is about 195 km N-S and about 174 km E-W [1].

An RQZ is meant to be any recognized geographic area within which the usual spectrum management procedures are modified for the specific purpose of reducing or avoiding interference to radio telescopes, thereby maintaining the required standards for quality and availability of observational data [2].

2.2 Unwanted Energy from Space

The potential space-based interferers to geodetic VLBI are (among others) TV-satellite broadcast, GNSS, Earth exploration satellite systems, synthetic aperture radar systems, and provision of internet via satellite mega constellations. Space systems are orbiting the Earth, and as such they are not bound to one national administration. The regulating body in this case is the ITU-R with its limited legal power. Protection against unwanted energy from space can only be granted voluntarily by the space operators of such satellite systems.

Figure 3 gives a graphical impression of how dominant the population of satellites in the sky will become. Considering the overlap of satellite downlink spectra with the sensitivity of broadband receivers in geodetic VLBI, there are not many possibilities for keeping the downlink radiation away. Although radio telescopes are highly directional antennas, even if they are not pointing to a transmitting satellite, the radiation might be picked up by sidelobes or after reflection.

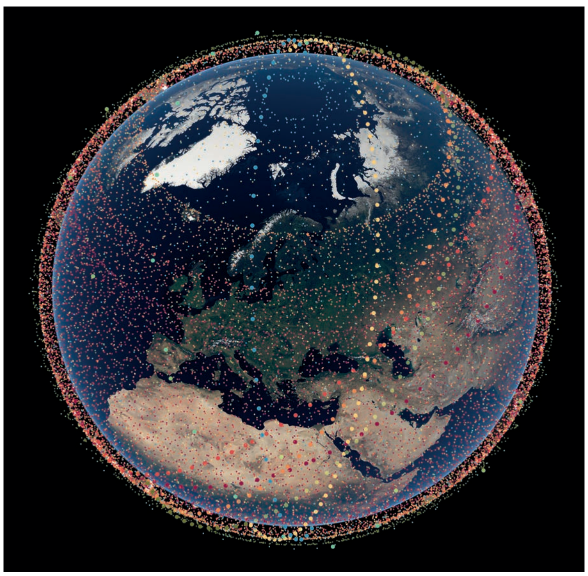

Fig. 3 Example of the satellite mega constellation Starlink Generation 2 with up to 30,000 satellites orbiting the Earth using the frequency range from 10.7–12.7 GHz for downlinks [3]. By the end of this decade (2020–2029), this number will have doubled, meaning that finding a satellite based transmitter in each square degree of the sky will make astronomical observations difficult.

Figure 4 illustrates different interference scenarios which may occur (even if the radio telescopes are located in an RQZ or a coordination zone): #1, #2, and #3 show cases in which either direct radiation or sidelobe radiation from the satellite may be caught by the sidelobe of the radio telescope receiver, and #4 illustrates the case in which the satellite downlink enters the line of sight of the radio telescope. The #4 scenario is the most detrimental and could be damaging to the receiver's low noise amplifier, which is typical for radar system radiation [4].

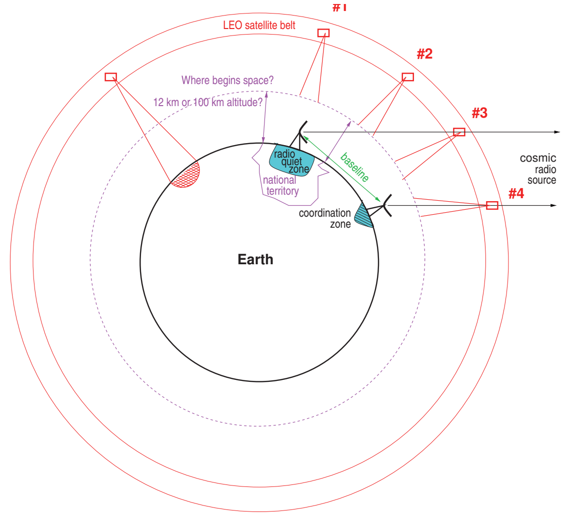

Fig. 4 Interference scenarios of a satellite downlink with a VLBI observation: The downlink from a satellite illuminates areas between 500–1,500 km in diameter.

To prevent geodetic radio telescopes from destructive direct satellite radiation, the satellite system operators could exclude radio telescope zones by steering the downlink beam away from the radio telescope or temporarily shutting the transmission off. For Starlink satellites with steerable downlink beams, successful tests were performed by integrating the actual pointing direction of the radio telescope into the satellite operation of the beam steering [5].

So even if a national administration is friendly to a geodetic VLBI site by providing a radio quiet zone or a coordination zone, the unwanted energy from space by satellite transmitters will remain a problem if the transmission bands coincide with the spectral range, 2–14 GHz, of the VLBI receiver. Steerable beams at satellites or off-switches combined with the knowledge of where the radio telescopes are pointing may enable the coexistence of both systems.

3 Ideas for Securing Undisturbed Geodetic VLBI Observations

In summary, there is no ideal geodetic VLBI world where undisturbed VLBI observations can be carried out. In the age of communication, the demands of industries for electromagnetic spectrum as a limited natural resource are increasing and expanding. The high demand challenges spectrum management to share more bandwidth of the spectrum, but also its usage in time. This multiple use requires regulation to balance the interests.

Geodetic VLBI works best in radio quiet zones or coordination zones around their radio telescope locations and ideally with a similar concept of a radio quiet sky for the undisturbed observational access to cosmic radio sources. Unfortunately, satellites are fast moving objects and a radio-quiet zone at the sky can only be realized by satellite operators through avoiding broadcasts towards radio telescope sites. For co-existence, new satellite operations modes could include active beam steering or a stop of broadcast resp. shutoff radar while passing a radio telescope site.

A different approach towards a radio quiet sky concerns the spectrum management; one path would be to limit the exploitation of the electromagnetic spectrum by industry and reserve certain spectral windows without transmissions, in analogy to natural parks to conserve ecosystems. Another path would be the assignment of bandwidth for the purpose of geodetic VLBI in the Radio Regulation, which never has been done. The Radio Astronomy Service would be awarded with additional entries in the RR for the observed channel spectra used for geodetic VLBI. Therefore, the IVS has to agree on a specific configuration of the observation channels, whose “fixed frequencies” can be brought into the World Radio Conference cycle. An adoption of such a proposal will be a longer process with the associated studies of the impact to the RR (at least six years).

In October 2023, the European Commission launched a questionnaire to the European Union legislative initiative on safety, resilience, and sustainability of space activities, called the “EU Space Law” (Figure 5, [6]). In this questionnaire the problems of radio astronomy were addressed by a few questions:

- “... 30. Do you agree that the increased number of satellites in orbit negatively impacts astronomy?
- 31. In your opinion and/or experience, what would be the most useful measures to protect dark and quiet skies?
- 32. What would be the impact of including measures that limit light and radio pollution in your space activities? ...”

The IVS participated in this questionnaire, answering these questions with the ideas laid out above.


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Targeted stakeholder consultation on EU legislative initiative on safety, resilience and sustainability of space activities ('EU Space Law')

Fields marked with * are mandatory.

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The European Commission is carrying out this targeted stakeholder consultation to help assess the current situation and problems and to substantiate with public feedback the analysis of the problems.

The survey aims at gathering views, opinions and input from policymakers and space experts (at European, international and Member States levels), representatives of the space industry (upstream sector - satellite operators, downstream sector, and users), NGOs, astronomers and citizens in relation to the policy initiative of the an EU Space Law.

The online questionnaire will be available until **2 November 2023.**

The survey consists of **two parts**:
1) Questions about the respondent.
2) Questions related to the current situation and the problem assessment.

Fig. 5 Questionnaire by the European Union for the “EU Space Law.”

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