How to Register a VGOS Radio Telescope at ITU and Why It Is Important

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Abstract VGOS radio telescopes enable observations in the range of 2–14 GHz and are much more receptive for unwanted radio frequency interference. Some spaceborne transmitters may cause detrimental radiation to VGOS receivers. The registration of new VGOS sites at ITU is important for obtaining administrative protection. This may help to avoid direct illumination by strong radars. This paper introduces the risk of damage and explains the registration procedure.

Keywords VGOS, spectrum management, RFI, SAR radar, ITU registration

1 The Problem: Satellite Signals are Strong

VGOS radio telescopes with wideband feeds are receptive to radiation at least in the spectral range between 2 and 14 GHz. In this range we find some very small spectral bands which are protected for radio astronomy use, but the majority is used by other (commercial and military) applications.

Radio frequency interference (RFI) is a threat to VLBI observations, because affected observations will not produce fringes in the correlation or will result in lower SNR and hence less accuracy.

If a detected RFI source is local, that means it is located at the observatory site, and it should be possible to identify and eliminate its origin (e.g., a WLAN device). If the RFI source is external, it can be either ground based (e.g., telecommunication transceiver) or space based (e.g., satellite transmitter). RFI can be picked up by the antenna sidelobes or by accidentally pointing directly at the RFI source.

Problematic RFI signals have much higher power levels than the expected quasar radiation for which the very sensitive wideband receivers are built. In general strong radio signals have to be avoided in the reception in order not to damage the receiver amplification chain, in particular, the low-noise amplifier (LNA), which is the first and most sensitive amplifier following the antenna feed. Wideband VGOS radio telesope systems are much more exposed to unwanted RFI radiation than the narrow band legacy S/X systems.

During recent years satellite based radars became popular in Earth Exploration Satellite Systems (EESS). Table 1 lists some satellite missions with strong transmitters. Synthetic Aperture Radars (SAR), which have some of the highest power transmitters, use microwaves to map the Earth, independent of cloud coverage. Applying interferometry to radar images of different epochs, areal deformations can be made visible.

In order to coordinate the use of the microwave spectrum among space agencies, the Space Frequency Coordination Group (SFCG) was founded. Its mission statement reads: "SFCG is the pre-eminent radio-frequency collegiate of Space Agencies and related national and international organizations through which global space systems spectrum resources are judiciously husbanded for the benefit of humanity." (Read more at https://www.sfcgonline.org/About/default.aspx).

At the conference SFCG-31 document SF31-9DR1 on the "Potential Damage to RAS Sites by EESS (Ac-

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Table 1 Overview of satellite missions with active sensors in the VGOS wideband frequency range of 2–14 GHz (excerpt from Table 4 in [2]).

Frequency Band	Band-width	Missions carrying spaceborne active transmitters			
[GHz]	[MHz]	SAR	Alti-meter	Scattero-meter	Precipi-tation radar
3.100–3.300	200	ALMAZ	•	•	•
5.250–5.570	320	Radarsat, ERS, Envisat, RISAT, Sentinel-1	Topex, Jason	ERS-2, MetOp	•
9.500–9.800	300	Cosmo-SkyMed, TerraSAR-X	•	•	•
13.250–13.750	500	•	Topex, Jason, ERS, Envisat	QuikSCAT, Envisat	TRMM

Table 2 Comparison of typical EESS power flux densities at the Earth's surface with RAS and VGOS damage thresholds (excerpt from Table 8 in [2] with information added for VGOS).

Parameter	Sensor type			
	SAR	Altimeter	Scattero-meter	Precipita-tion radar
Radiated power [W]	4400	20	4000	1013
Antenna gain [dB]	36.4	43.3	34	47.7
Orbital altitude [km]	225	1396	785	400
Incidence angle [deg]	21	0	32	0
PFD [dB/(W/m^2)]	−45.8	−77.2	−50.4	−45.3
RAS PFD damage level [dB/(W/m^2)]	−60	−60	−60	−60
Margin RAS	**–14.2**	**+17.2**	**–9.6**	**–14.7**
VGOS PFD damage level [dB/(W/m^2)]	−40	−40	−40	−40
Margin VGOS	**+5.8**	**+37.2**	**+10.2**	**+5.3**

tive)" [2] was presented by NASA, providing calculations of the power levels received from EESS transmitters vis-à-vis damaging power levels given in Report ITU-R RA.2188 [4]. The SFCG-31 report [2] compares the power flux density (PFD) levels of EESS with the damage levels for radio astronomy receiving systems (Table 2). The Radio Astronomy Services (RAS) damage level is determined by the most sensitive telescopes, typically 100 m in diameter.

Satellite radiation has the potential to damage the receiver LNAs at large radio telescopes, as seen by the negative RAS margins in three of the four cases in Table 2.

The VGOS radio telescope reflectors are typically 13.2 m in diameter and therefore less sensitive than a 100-m RAS telescope. With a VGOS antenna efficiency of about 80%—versus 50% of legacy systems—the PFD threshold for VGOS radio telescopes can be calculated to be −40 dB(W/m^2) instead of −60 dB(W/m^2) for 100-m radio telescopes, where an LNA damage threshold of 10 mW is assumed in both cases. The calculation of PFD VGOS damage level PFD^{dl}_{VGOS} for a 13.2-m radio telescope is:

$$PFD^{dl}_{VGOS} = \frac{P^{dl}_{LNA}}{A_e} = \frac{P^{dl}_{LNA}}{\eta_A \cdot \pi \cdot R^2} = \frac{0.01\,\mathrm{W}}{109\,\mathrm{m}^2} = 0.000091 = -40\,\mathrm{dB}(\mathrm{W/m}^2)$$

where

P^{dl}_{LNA} is the LNA input power that causes damage
A_e is the effective area of the radio telescope
η_A is the antenna efficiency ∼0.8
R is the radio telescope radius.

The VGOS threshold level of −40 dB(W/m^2) is fortunately above the EESS radiation level, i.e., the VGOS margins in the last line of Table 2 are all positive. But some of the margins are small. There will be a potential danger if future radar systems are equipped with stronger transmitters or flown at lower altitude.

These margins are estimated assuming the satellite and VGOS antennas point directly at each other. While such an occurrence is unlikely, the consequences of even a momentary mutual alignment of their beams would be serious if the satellite PFD exceeded the LNA damage threshold. It is not necessary for a VGOS antenna to track a satellite to cause a problem. Even momentary exposure when a satellite passes through a stationary VGOS beam or when a VGOS antenna points at a satellite as it slews from one source to another could damage the LNA. For example, a satellite at 500 km altitude will pass through the main beam of a stationary VGOS antenna in 0.1 to 1 second, depending on frequency. That time scale is long compared with typical LNA thermal time constants. As a result the LNA will suffer as much damage as if the exposure lasted much longer.

EESS have typical repetition periods of two days to two weeks. That means that the VGOS observatories are being observed again and again from space and hence exposed to radiation from satellites. In order to minimize the risk of losing VLBI observations or eventually receiving equipment, it is advised to register the VGOS radio telescope at the International Telecommunication Union (ITU).

The ITU-Regulation RA.2188 report [4] lists two options for avoiding LNA damage: (a) blanking satellite transmitters so they do not transmit toward RAS sites and (b) not allowing a VGOS radio telescope to be pointed at a satellite transmitter. The latter option is neither implemented yet at stations, where most often the survival position is the zenith position, nor in the VGOS scheduling process, which could check for satellites crossing the line of sight of the radio telescope. A third option is adding diode limiters at the LNA input to limit the voltage seen by the active components. Whether this is feasible for a specific LNA will depend on its characteristics.

Space agencies are using the ITU list of radio telescope sites for planning of their observation schedule and may respect or even get in contact with a radio telescope site, if a space maneuver will illuminate a radio telescope site. If a VGOS radio telescope site is not listed as sensitive receiving infrastructure at ITU, it might be difficult to claim losses due to RFI or to complain to the responsible space agency.

Fig. 1 Artist's view of a damaged frontend of a radio telescope being hit by too strong transmission power of a SAR transmitter.

2 A Partial Solution: Get Registered at ITU

The ITU is the United Nations specialized agency for information and communication technologies. It is allocating global radio spectra and satellite orbits and developing the technical standards that ensure that networks and technologies seamlessly interconnect. The administrations operating radio astronomy stations may register them with the Radiocommunication Bureau (RB) of ITU.

It is important to point out that at the ITU the (passive) radio astronomy service is recognized with an official status. There is no geodetic VLBI service known at ITU. Although the IVS programs observe quasars primarily for geodetic applications with geodetic observatories, from the perspective of the ITU it is a radio astronomy service.

ITU is used to dealing with dedicated portions of spectral ranges over the entire electromagnetic spectrum [1]. The VGOS frequency range from 2 to 14 GHz is full of such portions of spectral bands. Each band has allocated primary and secondary uses. Radio astronomy services have some allocated spectral bands as primary in which astronomers are observing spectral lines of atoms and molecules in the universe. Those allocated bands for RAS are protected and should not be interfered by other users, not even by out-of-band emissions of transmitters from adjacent bands. The RAS bands are usually different from those of the EESS.

Unfortunately, VGOS came up too late to claim the entire 2–14 GHz range for the exclusive use of VLBI. It is only possible to register a new site for the existing portions of bands allocated for RAS, which fall into the 2–14 GHz range.

As the VGOS range covers many RAS bands, VGOS radio telescopes may be registered as RAS sites. A registered RAS site should then be protected from strong signals according to RAS bands and other bands where footnotes in the regulations apply in favor of RAS.[1]

[1] Although protected, the trend of using the limited number of available bands is band-sharing. In regions where there is no suitable RAS observatory, the protected bands might be made avail-

Registration of radio astronomy stations (VGOS observatories) must take place through the telecommunications authority of the national administrations. The required characteristics of the radio astronomy station (kinematic and receiving parameters) are described in Annex 2 of Appendix 4 of the Radio Regulations (RR) [3]. Before starting the registration process the most recent version of the RR should be consulted, because parts of them are continuously updated according to the outcome of the World Radio Conferences (WRC).

The advantages of being registered are:

1. Several footnotes in the Radio Regulations provide protection to radio astronomy stations from unwanted emissions by satellites.
2. Examining a satellite system for compliance with footnotes, the Radiocommunication Bureau will consider only registered radio astronomy observatories.
3. Establishing a chronological priority for the registered station. It may claim protection from unwanted emissions of satellite systems filed for operation in adjacent or nearby bands at a later date.
4. Producing awareness of the national authorities about your protection-worthy RAS.

However, registering with ITU is far from a full solution, because it protects stations only in the RAS bands, but EESS generally transmit outside the RAS bands. Therefore the previously mentioned option (b) of not allowing a VGOS radio telescope to be pointed at a satellite transmitter should also be considered for VGOS network stations. This requires information on the geographical locations of the satellite beam ground tracks (or on satellite positions if the emission is at a constant nadir direction). This information is available at the space agencies which operate the satellites. If the satellite transmission cannot be stopped over a VGOS site, we propose that satellite operators study the feasibility of providing a 24h/7d dedicated beam alert system service which may interact directly with the antenna control unit of the VGOS radio telescope to avoid detrimental illuminations.

able to other users. Band-sharing is not only restricted to regions, but also in time. If an observatory does not observe, the protected bands might be used otherwise.

3 Summary

The ITU registration gives administrative protection. The following steps are necessary:

- Contact your national telecommunication administration.
- Supply to the national authority the information required for the ITU registration of the VGOS radio telescope according to the recent Radiocommunication Regulations.
- Check via the national telecommunication administration about the successful registration at ITU.

For protection against detrimental illuminations of VGOS radio telescopes by satellite radar systems, we propose to study the feasibility of a satellite beam monitoring system service that could be provided by the satellite operating space agencies.

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