Impact to the Radio Astronomy by the Interference caused by the Solar Power Satellite Systems

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Abstract

We have conducted a preliminary study to assess interference caused by a SPS to radio astronomy observations, and show that the SPS that is currently planned is highly unlikely to coexist with radio astronomy observations.

1. Introduction

Solar power satellite (SPS) systems generate electricity of about Giga Watts in space and to transmit the power to the ground by means of the microwave beam. Since the SPS systems may cause unknown effects not only to the radio services but bio-systems and/or ionosphere, several URSI commissions were incorporated toward the White Paper on SPS Systems[1], which was published in 2007.

One of concerns to radio astronomers would be the compatibility between very sensitive radio astronomy observations and the unwanted emission caused by the SPS transmitters. Thus we have conducted a preliminary study to assess interference caused by a SPS to radio astronomy observations.

2. Interference to Radio Astronomy Caused by A SPS

2.1. Radio Astronomy in the International Telecommunication Union

One of the most important tasks of the International Telecommunication Union (ITU) is to establish and update the Radio Regulations (RR).Since the RR has an international treaty status, the RR is regarded as a basis in frequency usage in signed governments. In Article 1, Section 1 of the Radio Regulations, radio astronomy is defined as *astronomy based on the reception of radio waves of cosmic origin*. The frequency bands allocated to the radio astronomy service are found in Article 5 of the Radio Regulations, which offer the greatest protection to radio astronomy are those for which the radio astronomy service has a primary allocation shared only with other passive (non-transmitting) services. Next in degree of protection are the bands for which radio astronomy has a primary allocation but shares this status with one or more active (transmitting) services. Less protection is afforded where bands are allocated to radio astronomy on a secondary basis. Article 29 of the Radio Regulations outlines general measures to be taken for protection of the radio astronomy service.

For many frequency bands, the protection is by footnote rather than by direct table listing. The footnotes are of several types. For an exclusive band allocated only to passive services, footnote **No. 5.340** of the Radio Regulations (Article 5) points out that all emissions are prohibited in the band. Other footnotes are used when radio astronomy has an allocation in only part of the band appearing in the table. A footnote of a different form is used for bands, or parts of bands, that are not allocated to radio astronomy but are nevertheless used for astrophysically important observations. This footnote, **No. 5.149**, urges administrations to take all practicable steps to protect radio astronomy when making frequency assignments to other services. Although such footnotes provide no legal protection, they have often proved valuable to radio astronomy when coordination with other services is required.

2.2. Interference Threshold Levels to Protect Radio Astronomy Observations

The radiation measured in radio astronomy has, in almost all cases, a Gaussian probability distribution in amplitude. Except in the case of narrow-band spectral line emissions, it has the same statistical characteristics as thermal noise radiation from the Earth, its atmosphere, or noise generated in a receiver itself. Moreover, the cosmic

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radio emissions are very weak. In radio astronomy observations the signal-to-noise ratio in the radio frequency (RF) and intermediate frequency (IF) parts of the receiver is typically in the range -20 dB to -60 dB, i.e. the power contributed by the source under study is a factor of 10^{-2} to 10^{-6} lower than the unwanted noise power from the atmosphere, the ground, and the receiver circuits. In most communication systems the corresponding signal-to-noise ratio is of the order of unity or greater. Because radio astronomy signals are so weak in comparison to those of other services, radio astronomy observations are highly vulnerable to radio interference and, except in the case of pulsars, cosmic signals generally have no characteristic modulation that would help to distinguish them from noise or from many forms of interfering signals. Such a situation can be easily understood by the fact that a special unit, Jansky (Jy) = 1×10^{-26} $W/m^2/Hz$, is used in radio astronomy

Figure 1 shows a diagram of threshold levels of interference harmful to radio astronomy observations. These values are defined in Recommendation ITU-R RA.769[2], established in the International Telecommunication Union. These threshold values have been used in frequency sharing and/or compatibility studies between any radio-transmitting service and radio astronomy.

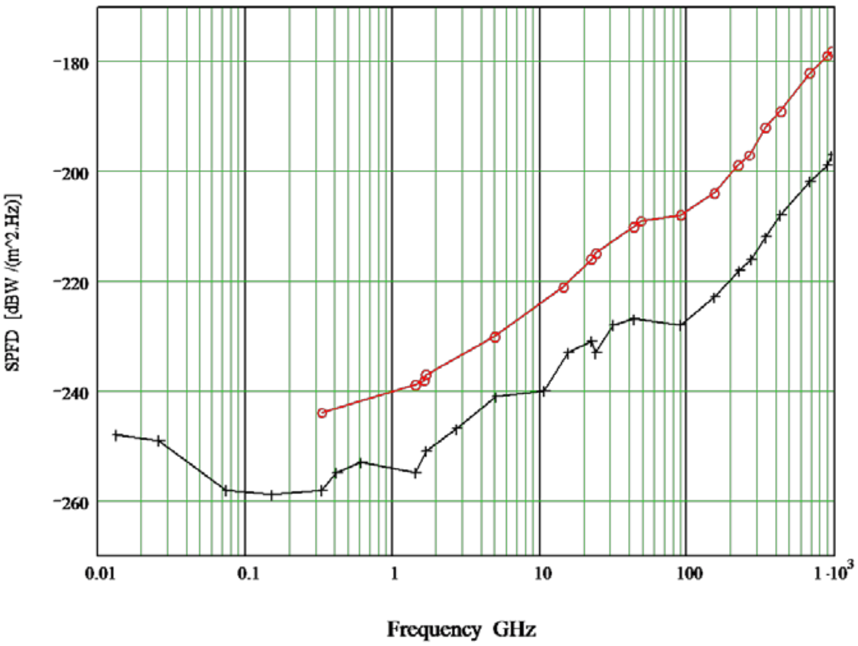

Figure 1. A Diagram of Threshold Values of Interference Harmful to Radio Astronomy Observations

2.3. Comparison with Emissions from A SPS

We made preliminary comparisons between the threshold levels of interference harmful to the radio astronomy observations shown in section 2.2 and received emission levels on the Earth's surface from a SPS, which was taken from Figure 2.2.1 of the URSI White Paper[1] (see Figure 2 below).

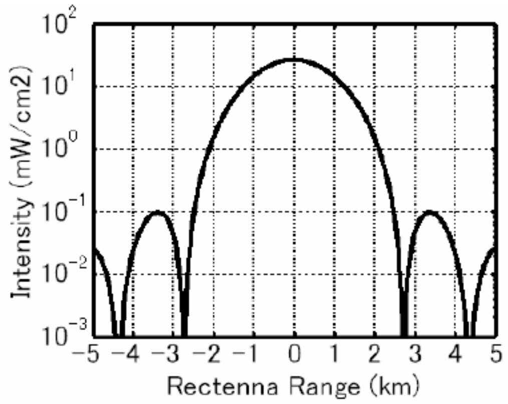

Fig. 2.2.1 Typical power density at a rectenna site
(1kmϕ TX antenna with 10dB Gaussian power distribution)

Figure 2. Estimated Received Emissions from a SPS on the Earth

In Figure 2, it can be seen that the peak level is about 30 mW/cm^2, and the first sidelobe level is around 0.1 mW/cm^2. If we assume a bandwidth of 1 MHz for the SPS transmission, these values are converted to spectral power flux densities of -35 dBW/m^2/Hz and -60 dBW/m^2/Hz, respectively. The threshold levels of interference harmful to radio astronomy observations, expressed in the spectral power flux density, are between -250 and -230 dBW/m^2/Hz in frequency range below 100 GHz, which are far below the estimated received emission levels from a SPS transmitter. The difference is as large as 190 dB for the first sidelobe.

In 2010 ITU adopted a new Report ITU-R RA.2188, “Power flux-density and e.i.r.p. levels potentially damaging to radio astronomy receivers”[3]. This Report shows that incident power flux density above -60 dB(W/m^2) = 10^{-7} mW/cm^2 are potentially damaging to a radio astronomy receiver at frequencies up to 90 GHz, while incident power flux-densities above –45 dB(W/m^2) = 3×10^{-6} mW/cm^2 are potentially damaging at frequencies above 90 GHz. Since the emission levels of the Earth’s surface from a SPS is much above the power flux density potentially damaging to radio astronomy receivers, it is concluded that a radio astronomy receiver would be damaged or burned out if the SPS emission was received by a radio telescope.

Appendix to Article 3 of the Radio Regulations defines permissible power levels for spurious emissions. According to this regulation, attenuation below the power supplied to the antenna transmission line must be 43+10log(P) or 70 dBc, whichever less stringent, where P denotes the peak power. For the case of SPS, P can be assumed to be 1 GW = 90 dBW. Since 43+10log(P)=133 for P=1GW, a minimum attenuation of 70 dBc is required for a SPS transmitter. Then estimated peak power on the Earth’s surface will be 3×10^{-6} mW/cm^2, which is still above the power flux density potentially damaging to radio astronomy receivers.

2.4. Permanent Sky Blockage by SPSs

SPSs may affect astronomical observations not only in radio waves but in the optical and infrared regions. An apparent size of a single SPS system in space (about 10 km×10 km) would be larger than the angular diameter of Jupiter (about 40 seconds of arc), which would be observed as “an artificial planet” that blocks a specific portion of the sky. It is obvious that the larger the number of SPSs in the sky the larger the sky blockage area. Such blocked area will become unobservable permanently.

3. Conclusion

In this preliminary study, we found the followings;

- Emission level of the SPS beam received on the Earth's surface would be much higher than the threshold levels of interference harmful to the radio astronomy observations by about 190 dB;
- Even if the SPS frequency does not coincide with the bands allocated to the radio astronomy observations, allowed spurious emission may damage the radio astronomy receivers; and
- The SPS constellation would block permanently some portions of the sky, where optical and infrared astronomical observations can never be conducted.

4. References

1. URSI, "White Paper on Solar Power Satellites", http://ursi-test.intec.ugent.be/?q=node/64 , June, 2007.

2. Recommendation ITU-R RA.769, "Protection criteria used for radio astronomical measurements", Geneva, March, 2005.

3. Report ITU-R RA.2188, "Power flux-density and e.i.r.p. levels potentially damaging to radio astronomy receivers", Geneva, October, 2010.