ECC PT1

ECC PT1 #68

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Date issued:	**[enter date]**
Source:	**CRAF, SKAO**
Subject:	**Compatibility studies for HIBS-RAS spurious emissions under WRC-23 AI1.4.**

Group membership required to read? (Y/N)

N

Summary:

RR 29.11 states that when assigning frequencies to stations in other bands, administrations are urged, as far as practicable, to take into consideration the need to avoid spurious emissions which could cause harmful interference to the radio astronomy service operating in accordance with these Regulations.

Under Agenda Item 1.4, CRAF identified the following HIBS frequency bands under study that may affect RAS:

- 694-960 MHz, 2nd harmonics could fall into the primary RAS bands 1 400 – 1 427 MHz, 1 610.6 – 1 613.8 MHz, and 1 660 – 1 670 MHz
- 1710 – 1785 MHz, intermodulation products may fall into the primary RAS bands 1 660 – 1 670 MHz
- 2500 – 2690 MHz, out of band emissions may fall into the primary RAS band 2 690 – 2 700 MHz

Preliminary studies show that large separation distances are required that might go beyond the national level for the case of CEPT countries.

The preliminary calculations are provided in Annex 1. It is also noted that the studies for RAS protection from second harmonics was requested by WP7D in its LS to WP5D during the last meeting in Sep 2020.

Proposal:

invites Group to support the inclusion of the proposed studies for RAS protection in the WP5D WORKING DOCUMENT TOWARDS SHARING AND COMPATIBILITY STUDIES OF HIBS UNDER WRC-23 AGENDA ITEM 1.4,

- Section A1.7: Compatibility studies between Radio Astronomy Service in the frequency bands 1610 – 1613 MHz and HIBS operating in the 694-960 MHz frequency *(Currently in square brackets)*.
- Addition of a new section A2.4 Compatibility studies between Radio Astronomy Service in the frequency band 1 660 – 1 670 MHz and HIBS operating in the 1 710 – 1 885 MHz frequency range

Background:

The large LoS of HIBS at 20 to 50 km altitude, combined with the large gain of RAS receivers pointing towards the sky creates a difficult scenario for compatibility between these two systems.

It is noted that the compatibility with respect to 2nd harmonics of IMT equipment into the RAS was previously studied in ECC Reports 309 and 325, and that Rec. ITU-R SM.329-12 Section 2.5 recognises the need to include harmonics in any test measurements of spurious emissions, as these can represent an important source of interference. Furthermore, Rec. ITU-R SM.329-12 points out that “special consideration of transmitter spurious domain emissions is required for protection of radio astronomy and other services” and “[urges] administrations […], as far as practical, to take into consideration the need to avoid spurious domain emissions which could cause interference to radio astronomy […]”.

It is noted that there exist a number of RAS facilities, which are located outside of CEPT countries, that are funded or co-funded by European research institutes and organisations. A prominent example would be SKA-MID, which is being built in South Africa. The separation distance needed to protect SKA-MID could be larger than the size of the SKAO radio quiet zone in South Africa.

ANNEX 1

1 INTRODUCTION

WRC-23 AI1.4 is considering the frequency bands 694 960 MHz, 1 710-1 885 MHz, and 2 500-2 690 MHz to be used by high-altitude IMT base stations (HIBS). Resolution 247 (WRC-19) does not recognize uplink and downlink frequencies within these bands, therefore the RAS bands that could be affected by the use of these frequencies by HIBS are:

- 1 400 – 1 427 MHz from 2nd harmonics of transmissions within 700 – 713 MHz
- 1 610.6 – 1 613.8 MHz from 2nd harmonics of transmissions within 805.3 – 806.9 MHz and from intermodulation products produced in the RAS receivers owing to high input power in the band 1710 – 1885 MHz
- 1 660 – 1 670 MHz from 2nd harmonics of transmissions within 830 – 835 MHz
- 2 690 – 2 700 MHz from adjacent transmissions within 2500-2690 MHz

The document [HIBS-CHARACTERISTICS] being developed by ITU-R WP5D identifies the channel arrangements currently used by IMT as the ones to be potentially used by HIBS. From the list of channel arrangements of Table 1 in [HIBS-CHARACTERISTICS], CRAF has identified that the 2nd harmonic of a HIBS operating under A3 (791 – 821 MHz for Base Station transmitter) could produce interference in the RAS primary band 1610.6 - 1613.8 MHz. While this document only considers interference into the 1 612 MHz RAS band, the use for the channel arrangement A6 (698 – 806 MHz in TDD mode) could produce a similar situation as the one studied in Section 2.2 but adding a potential interference into the passive band 1 400 – 1 427 MHz protected under RR No 5.340.

None of the channel arrangements in Table 1 of [HIBS-CHARACTERISTICS] indicates a risk for the RAS band 1 660 – 1 670 MHz from 2nd harmonics from HIBS, therefore this case is not considered here. However,owing to the high gain antennas and enormous sensitivity of RAS receivers, emissions from HIBS in the frequency range 1710 – 1 885 MHz could generate a high received power in 18 cm receivers that may lead to non-linear effects. Section 2.3 studies this situation which may lead to areas of the sky not observable by RAS stations.

2 PRELIMINARY COMPATIBILITY CALCULATIONS

Unfortunately, WP 5D has not yet finalised the technical parameters and deployment scenarios, which would be necessary for final compatibility studies. Therefore, here we can only do some preliminary studies based on existing technology and common sense. For HIBS, two operating altitudes were considered in the technical working groups for studies, 20 and 50 km. The antenna patterns are not known to us as of now, but a target footprint size of 100 km radius seems realistic for the case that the HIBS is pointing its antenna towards the Nadir. That means that for victim receivers outside of the footprint the effective HIBS antenna gain will be much lower, perhaps up to 20 dB. It is noted that this depends a lot on the chosen technology, for AAS sidelobe gain can vary a lot. A RAS telescope has very large antenna gain of 60 dBi and more for larger dishes of the 100-

m class, which means that a RAS Rx can pick up even very dim sources, if they are located in the main beam. On the other hand, the width of the main beam is very small in return, so that at separation from the boresight of about 19 deg and larger, an effective gain of 0 dBi can be assumed (see Recommendation ITU-R RA.517). This means, that for single entry studies one can identify four different cases, depending on whether the RAS station is in the HIBS footprint (within, full HIBS antenna gain applies) and whether the RAS antenna points towards the HIBS (within 19 deg) or not. It is noted that smaller RAS telescope antennas would have less main beam gain, but the beam sizes (and thus affected sky area) are larger.

2.1 ADJACENT CHANNEL COMPATIBILITY BETWEEN HIBS AND RAS AT 2 695 MHZ

Since this case is included as a placeholder section A4.9 of the [WORKING DOCUMENT TOWARDS SHARING AND COMPATIBILITY STUDIES OF HIBS UNDER WRC-23 AGENDA ITEM 1.4] being developed in ITU-R WP5D, CRAF will continue monitoring that section for appropriate consideration.

2.2 2^ND HARMONICS OF HIBS AT 800-MHZ INTO RAS BAND AT 1 612 MHZ

According to the channel arrangements for IMT at 800 MHz in some CEPT countries (under consideration for use by HIBS), downlinks in the frequency interval 805.3-806.9 MHz could create 2^nd harmonics in the RAS band 1610.6-1613.8 MHz, which is mainly used for spectroscopic observations of the OH molecule. The regulatory limit of such 2^nd harmonics caused by IMT devices is -30 dBm/MHz[1]. In the case of IMT base stations for LTE800 and previous generations, physical filters can very effectively suppress spurious emissions, in particular the harmonics. However, for AAS physical bandpass filters are often not applicable (as they would need to be attached to every antenna element, which is a cost factor). Therefore, it could happen that actual 2^nd harmonics are indeed close to the regulatory level. For reference, the calculations were also performed for lower 2^nd harmonic power levels, i.e., with -40 and -50 dBm/MHz.

For the path propagation losses, it suffices to work with line-of-sight (LoS) losses, as HIBS are visible out to 600 km and more, even for the lowest altitude of 20 km. At the low frequencies, which are considered here, only the free-space propagation plays a role, as atmospheric attenuation is very low. In Figure 1 and Figure 2, the received spectral powers are displayed for the two cases (HIBS within and outside RAS main-beam). In the region around the HIBS footprint radius (considered as 100 to 150 km distance) the received power would depend very much on the HIBS antenna model, therefore this part was left out of the calculation. The figures also show the RAS threshold levels according to Rec. ITU-R RA.769-2. For the first case, when the RAS station points towards the HIBS, the RAS thresholds are exceeded even for distances beyond 400 km. But also if located in the RAS sidelobes, a RAS station within a HIBS footprint would be subject to harmful interference, unless the 2^nd harmonics were restricted to about -50 or -60 dBm/MHz. **However, given the enormous distances over which the HIBS are in LoS, the chance to have any one HIBS close to the RAS main beam is not negligible and EPFD studies should be performed to fully assess the situation.**

[1] The working document [HIBS-CHARACTERISTICS] currently has two values in table 2, -13 dBm ad -30 dBm. CRAF has considered -30 dBm as the limit based on previous experience in IMT-RAS studies. Results in this document can be scaled by 17 dB for the case of spurious of -13 dBm.

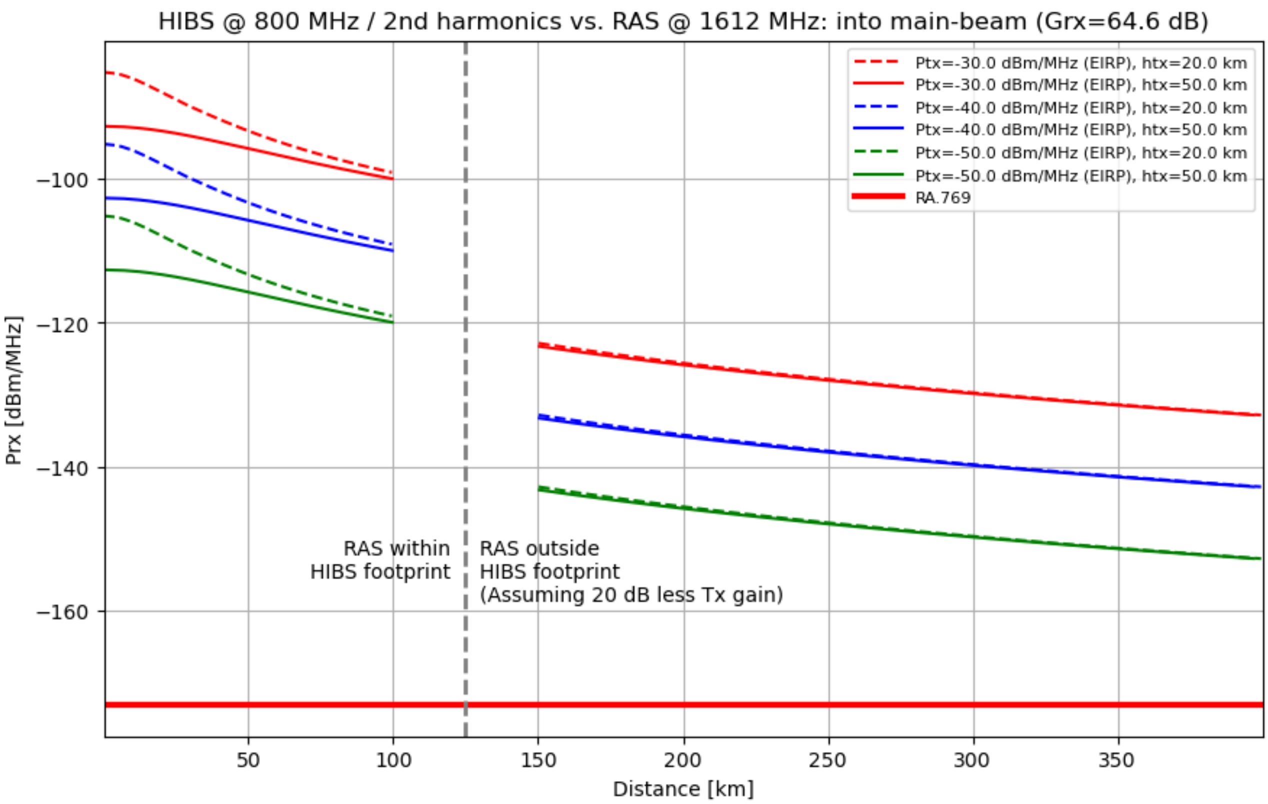

Figure 1: Received spectral power from HIBS 2nd harmonics at 800 MHz into the RAS band at 1612 MHz, assuming that the RAS telescope points towards the HIBS.

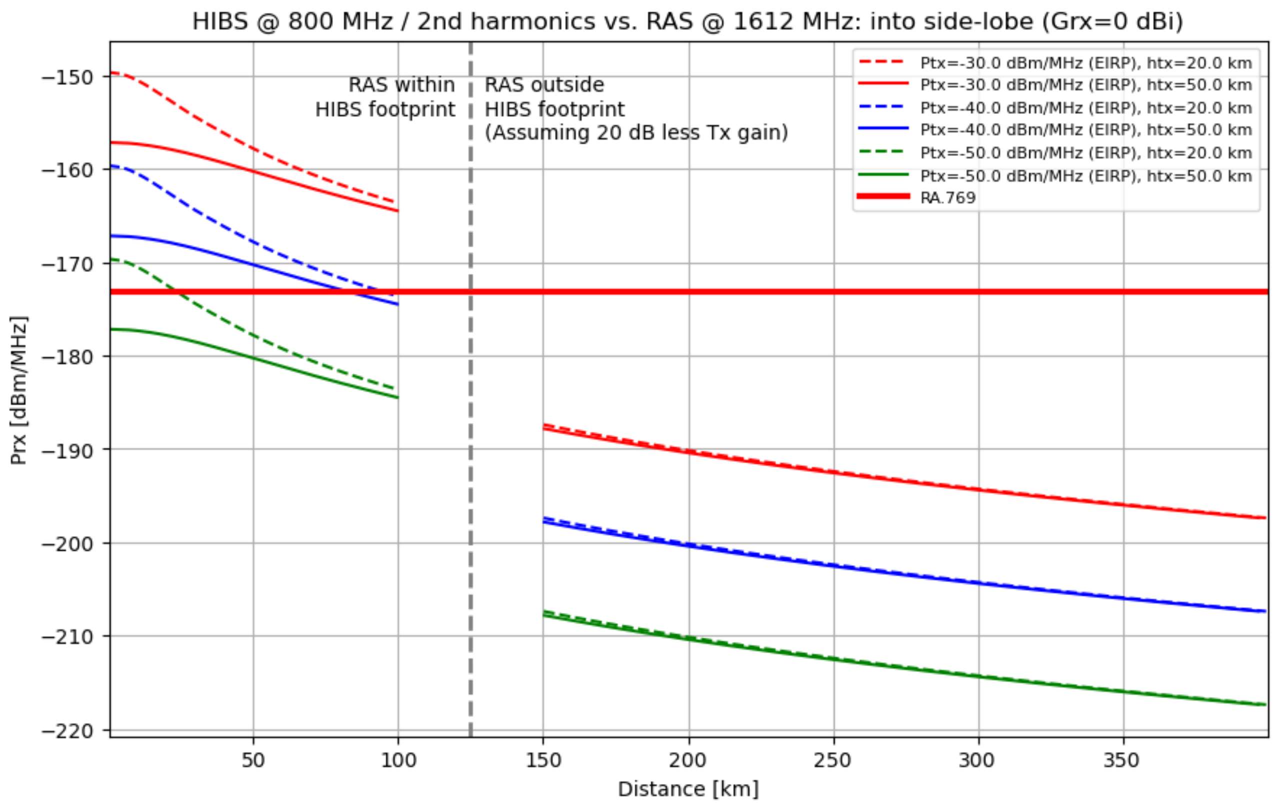

Figure 2: As Figure 1 but for the case that the HIBS is located in the RAS sidelobes.

2.3 POSSIBLE 18-CM RECEIVER SATURATION FROM IMT AT 1700-1900 MHZ

Radioastronomical receivers, especially the first-stage low-noise-amplifiers (LNA) are usually cryo-cooled to reach very low noise figures. The front-end parts are placed in dewars, which are evacuated with vacuum pumps and cooled to temperatures down to about 20 K. The resulting system temperatures can be as low as 15 K at some frequencies, and are mainly determined by non-Rx contributions, such as emission from the ground, the atmosphere, or the cosmic microwave background. While this increases the cost of RAS receivers significantly, it is worth the effort: improving the sensitivity by reducing the Rx noise leads to a substantially decreased radiometric noise in the recorded data. The only other means to achieve this would be to increase the antenna size (and thus antenna gain) – and for single dishes one has already reached the limits – or to integrate longer. The noise decreases however only with the square root of the integration time. Therefore, to lower the noise level of the data by a factor of two, one needs four times longer integration times. As cryo-cooled receivers often lead to system temperatures that are a factor of two or more lower than for an uncooled device, the same detections can be made in just a quarter or less of the time. Given that RAS telescopes are generally oversubscribed and expensive to operate, operating at the highest sensitivity level is very important for the efficient use of the radio astronomical spectrum.

Unfortunately, the increased sensitivity comes with a price, because the dynamic range of a sensitive receiver cannot be made arbitrarily high. RAS receivers will reach saturation at typical input power levels of −20 to −40 dBm. As modern RAS receivers cannot avoid featuring large input bandwidths, incident radiation from strong emitters outside of the protected RAS bands can also cause problems, even if their out-of-band or spurious emissions do not exceed the RAS thresholds (e.g., as defined in Rec. ITU-R RA.769). LNAs themselves are usually broadband and filters in front of the LNA would increase the noise figure significantly by virtue of their insertion loss, thus counteracting the effort to obtain the very low system noise required for high sensitivities. The maximum input power into the receiving systems should therefore be limited in order to protect the RAS from harmful interference that would degrade the operation of the station. The LNA, mixer, or the analogue-digital conversion in the back-end (or the Rx as a whole) would otherwise be driven into the non-linear regime, which may lead to intermodulation (IM) products, saturation (non-linear gain), or even blocking.

According to Rep. ITU-R RA.2188 (Section 3A), a RAS receiver could even get damaged, if the received power is in excess of 12 dBm.

A typical IMT base station at frequencies below 3 GHz will have an EIRP 40 to 60 dBm per channel (5-20 MHz). Given the high altitudes of the HIBS, it can be safely assumed that the transmitted power will rather be at the higher end of this range. For the calculations, it was assumed that only one channel is active, but in reality, the typical (or worst-case) utilization of the IMT band will obviously be higher. The results are displayed in Figure 3 and Figure 4. Also shown are the power levels at which the RAS Rx would go into the non-linear regime or even get damaged. Fortunately, the latter case is unlikely (unless the technical parameters of the HIBS deviate substantially from the assumptions made here). Only if a HIBS would be more or less above a RAS station and utilise all channels there could be a certain threat level. However, receiver saturation (and thus self-generated IMs in the RAS Rx) could occur frequently, if the RAS points towards the HIBS possibly creating areas of the sky not accessible to such receivers. In the case that several HIBS are visible by one RAS station – which seems likely, given the huge area that is in line-of-sight –, EPFD studies would need to be performed to fully investigate, whether the aggregate data loss would still be at an acceptable level for the RAS.

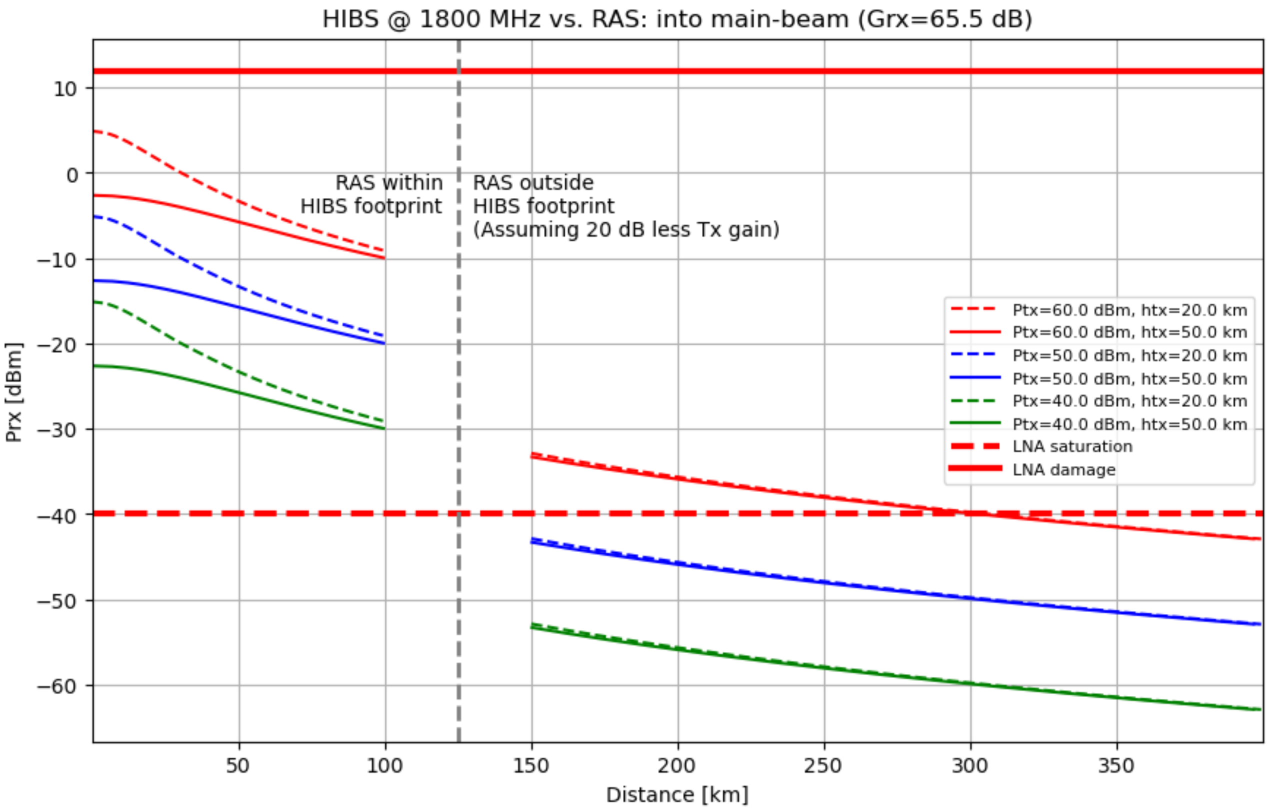

Figure 3: Received total power from on HIBS channel at 1800 MHz into the RAS 18-cm band, assuming that the RAS telescope points towards the HIBS.

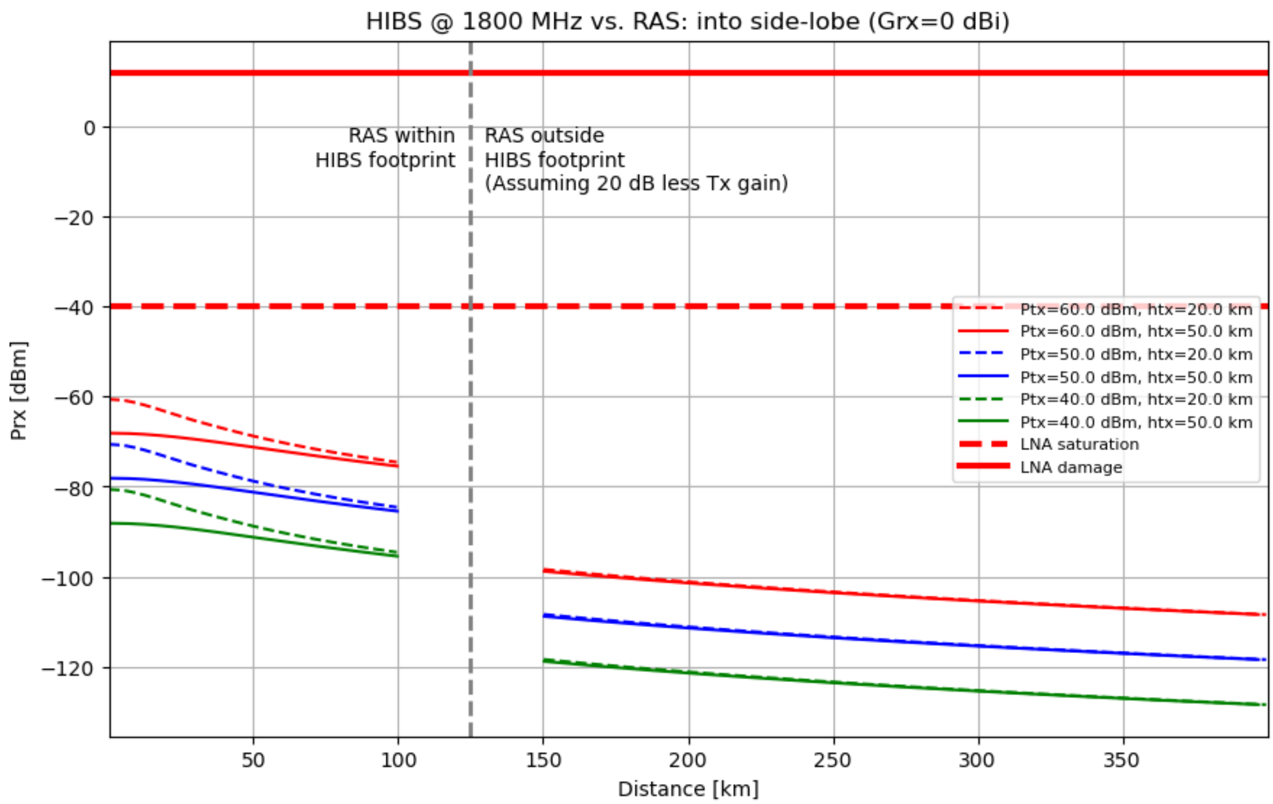

Figure 4: As Figure 3 but for the case that the HIBS is located in the RAS sidelobes.