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Recommendation ITU-R F.1612
(02/2003)

Interference evaluation of the fixed service using high altitude platform stations to protect the radio astronomy service from uplink transmission in high altitude platform station systems in the 31.3-31.8 GHz

F Series
Fixed service

International Telecommunication Union

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R F.1612*

Interference evaluation of the fixed service using high altitude platform stations to protect the radio astronomy service from uplink transmission in high altitude platform station systems in the 31.3-31.8 GHz band

(2003)

Scope

This Recommendation deals with the evaluation of interference arising from unwanted emissions from the uplink of high altitude platform station (HAPS) systems in the fixed service in the band 31.3-31.8 GHz to protect a radio astronomy (RAS) station. Annexes 1 to 3 provide typical parameters of the victim RAS station and interfering HAPS ground stations, propagation models for the evaluation and impact of the interference using the typical parameters.

The ITU Radiocommunication Assembly,

considering

a) that new technology utilizing high altitude platform stations (HAPS) in the stratosphere is being developed;

b) that it is necessary to protect appropriately the RAS, EESS (passive) and space research service (passive) in the band 31.3-31.8 GHz, taking into account the interference criteria given in the relevant ITU-R Recommendations,

recognizing

a) that the bands 27.9-28.2 GHz and 31.0-31.3 GHz may also be used for HAPS in the fixed service in certain countries on a non-harmful interference, non-protection basis,

recommends

1 that the methodology in Annexes 1, 2 and 3 should be used for the evaluation of interference by HAPS uplinks to the RAS in the frequency band 31.3-31.8 GHz;

2 that the location of HAPS airships and HAPS ground stations relative to the RAS station should be chosen to protect the RAS from unwanted emissions in the HAPS uplink in the 31.3-31.8 GHz band;

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* Radiocommunication Study Group 5 made editorial amendments to this Recommendation in December 2009 in accordance with Resolution ITU-R 1.

3 that in order to protect the RAS station from unwanted emissions via the HAPS uplink in the 31.3-31.8 GHz band, one or more spot beam cells around an RAS station should be excluded from the service area of the fixed service using HAPS;

4 that Recommendation ITU-R F.1569, which contains typical parameters describing the HAPS system, should be used for the evaluation of the impact of unwanted emissions on the RAS in the 31 GHz band.

NOTE 1 – The aggregate interference from fixed service, including HAPS, needs to be considered.

Annex 1

Typical parameters of the RAS and a model to be used for impact evaluation from HAPS ground station on the RAS station

1 Parameters of uplink transmission in HAPS system

The parameters regarding HAPS systems are based on Recommendation ITU-R F.1569 (altitude: 20-25 km, minimum operational elevation angle: 20°, and in rainy conditions). The footprint formed by a spot beam is referred to as a cell. A frequency reuse factor of four is adopted in this study, that is, the available frequency band of 300 MHz (31.0-31.3 GHz) is equally divided into four sub-bands of 75 MHz which are used simultaneously for uplink transmissions in multiple cells. An automatic power control scheme is adopted in the uplink, in which the power is increased or decreased by 6 dB, depending on weather conditions.

The level of out-of-band emissions in a HAPS uplink used in this study is –100 dB(W/MHz) under rainy conditions, assuming that automatic transmitting power control is being used in the uplink. The derivation of the out-of-band emission level is described in § 11 of Recommendation ITU-R F.1569.

2 Parameters of RAS

The parameters of RAS antennas used in this study are shown in Table 1. It is assumed that the RAS antenna is pointing at the azimuth of the HAPS ground station, at the minimum operational elevation for that particular radio telescope. The gain of the receiving antenna for the interference is calculated using Recommendation ITU-R SA.509 for the separation angle of more than 1° between the boresight direction of RAS antenna and the direction of arrival of the interference.

TABLE 1

Parameters of RAS antennas used in this study

	G_{max} (dBi)	Diameter (m)	Altitude (km)	Minimum operational elevation angle (degrees)
Nobeyama (Japan)	81.2	45	1.35	15
Taeduk (Korea)	70.9	13.7	0.12	15
Delingha (China)	70.9	13.7	3.2	5

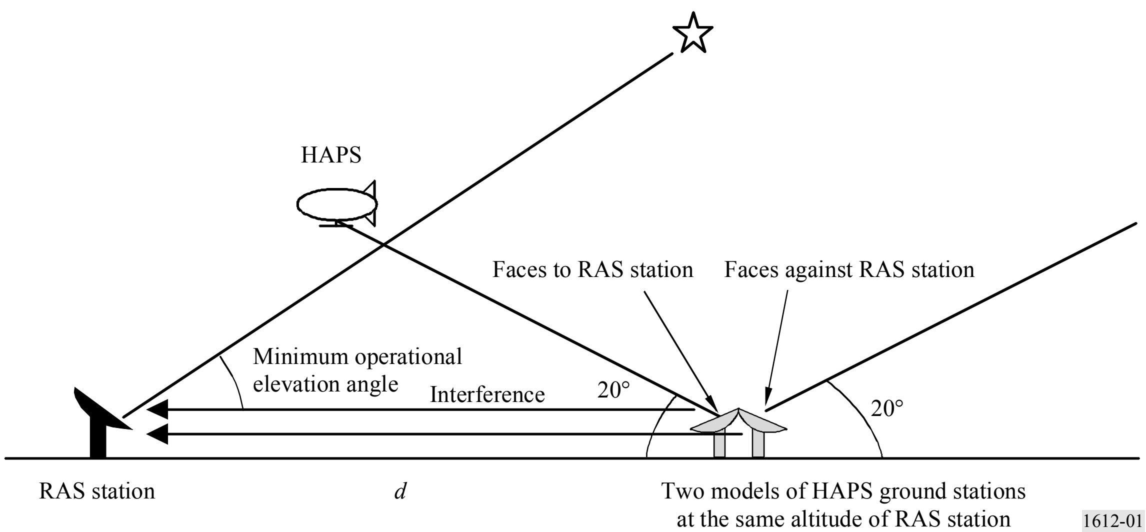
3 Interference evaluation model

3.1 Single entry

Figure 1 shows the interference evaluation model for one HAPS ground station and one RAS station. It is assumed that HAPS ground station is located in the same plane as the RAS station. Two situations are considered regarding the antenna boresight direction of HAPS ground station. One is that the antenna of HAPS ground station faces to the RAS station in azimuth (worst case in the single entry scenario) and the other is that the antenna of HAPS ground station is directed at an azimuth 180° away from the direction of the RAS station. It is assumed that the RAS antenna is being operated with the minimum operational elevation angle in both cases.

FIGURE 1

Interference from a HAPS ground station to a RAS station (single entry case)



3.2 Aggregate interference from multiple HAPS stations

As shown in Fig. 2, the following models and assumptions are used for the evaluation of aggregate interference:

– four HAPS ground stations are located in the centre of each service cell and all the antennas point to the corresponding HAPS airship (total bandwidth of 300 MHz (31.0-31.3 GHz), frequency reuse of four times and signal bandwidth of 20 MHz are assumed);

– the aggregate interference is obtained by summing a parameter defined as the "received interference pfd at RAS station" plus "receiving RAS station gain for the interference" for all HAPS ground stations (= 367 cell × 4 stations × 3 HAPS service area);

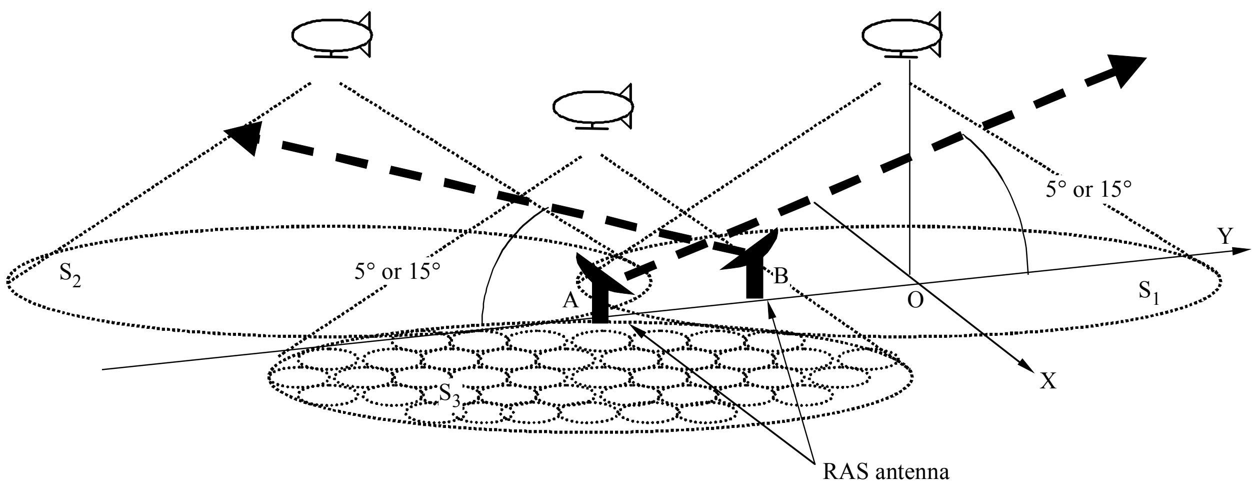
– the out-of-band emission power of −100 dB(W/MHz) is assumed from each HAPS ground station;

– the RAS antenna is located at between the boundary, A, of the three HAPS service areas and the nadir point O;

– RAS antenna located at point B directs A or O in azimuth. It is assumed that the RAS antenna is at the lowest elevation angle at which observations are made using that instrument (5° or 15°).

FIGURE 2

Model example for aggregate interference evaluation



A: boundary of three HAPS service areas
B: location of RAS antenna on segment AO
O: nadir point of HAPS
S_1: main area
S_2 S_3: sub area

RAS antenna located at point B directs A or O in azimuth.

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Annex 2

Propagation model and protection criteria of RAS

1 Propagation model

According to Recommendation ITU-R P.452, § 4.2, the propagation loss between stations on the surface of the Earth not exceeded for time percentage, p% is given by:

$$L_{b0}(p) = 92.5 + 20\log f + 20\log d + E_s(p) + A_g \quad \text{dB} \qquad (1)$$

where:

f: frequency (GHz) (31.3 is used in this study)

d: path length (km)

$E_s(p)$: correction for multipath and focusing effects

$$E_s(p) = 2.6(1 - e^{-d/10})\log(p/50) \quad \text{dB} \qquad (2)$$

A_g: total gaseous absorption (dB)

$$A_g = [\gamma_0 + \gamma_w(\rho)]\,d \quad \text{dB} \qquad (3)$$

where:

$\gamma_0, \gamma_w(\rho)$: specific attenuation due to dry air and water vapour, respectively, and are found from the equations in Recommendation ITU-R P.676

ρ: water vapour density

$$\rho = 7.5 + 2.5\omega \quad \text{g/m}^3 \qquad (4)$$

ω: fraction of the total path over water.

In this study, the factor of gaseous absorption A_g is assumed to be 0 in order to consider the worst case of interference.

2 Protection criteria of RAS

Recommendation ITU-R RA.769 provides the threshold spectral pfd to protect the RAS (calculated for an antenna gain of 0 dBi). This methodology gives pfd levels of –168 dB(W/(m^2 · MHz)) in the band 31.3-31.8 GHz. In order to take the effect of the receiving antenna gain into account, the value of "interference pfd received at RAS antenna" plus "receiving RAS antenna gain for the interference" is adopted as the protection criteria of RAS and the required separation distance is obtained by the need to meet the Recommendation ITU-R RA.769 criterion –168 dB(W/(m^2 · MHz)).

Annex 3

Impact of HAPS ground station on RAS station

1 Interference evaluation

1.1 Single entry

Under the conditions described in Annexes 1 and 2, the impact (received pfd + RAS antenna gain) of one HAPS ground station is calculated as function of the distance between the RAS station and HAPS ground station. Recommendation ITU-R F.1245 is used for the antenna radiation pattern of HAPS ground station. The results for Nobeyama (Japan), Taeduk (Korea) and Delingha (China) are shown in Figs. 3 and 4 for time percentage of 0.001%, 1% and 10%. The results obtained by using free space propagation model are also shown for the reference. Required separation distance is obtained by the intersecting point of the obtained curve and the protection criterion of RAS: -168 dB(W/(m^2 · MHz)).

Table 2 summarizes the required separation distances for several values of time percentage. The required separation distances, when the RAS antenna and HAPS ground station direct face-to-face in azimuth (denoted by forward), are 0.9 km for Nobeyama and Taeduk and 3.94 km for Delingha even when the free space propagation model and the time percentage of 1% are assumed. Separation distances when the antenna of HAPS ground station is directed 180° away from the direction to RAS station are also shown as references (denoted by backward).

The required guardband is calculated by using the example IF filter and equation (3) described in § 11 in Annex 1 of Recommendation ITU-R F.1569. The thermal noise level at the input of RF module is used as the minimum level to determine f_{pmt}. The width of the required guardband is 10 MHz for 20.2 MHz IF filter bandwidth (-3 dB). This guardband depends on the signal bandwidth and the attenuation characteristics of the IF band-pass filter.

1.2 Aggregate interference

In the case of the aggregate interference under the condition described in § 3.2 in Annex 1, it is assumed that there are no HAPS transmissions in the cell including the RAS station. Figures 4a) to 4d) show the total weighted value of "received pfd" plus "RAS antenna gain", where the RAS antenna is pointed at the point A or O. Furthermore, the minimum operational elevation is 15° or 5° and "Y coordinate of RAS" shows the distance of RAS antenna from the nadir point O. The terms "main area" and "sub area" are defined in Fig. 2. As shown in these Figures, the aggregate value of "received pfd" plus "RAS antenna gain" does not exceed the permissible interference criterion of RAS of -168 dB(W/(m^2 · MHz)) except for the case of Fig. 4d).

Figure 4d) which is a certain special case for an antenna elevation 5°, shows that the total "received pfd" plus "RAS antenna gain" exceeds the protection criterion. Such a result occurs since both RAS antenna and HAPS ground station antenna direct face-to-face with short separation distance.

TABLE 2

Required separation distances between HAPS ground station and RAS station for the case of single entry

			Required separation from a HAPS ground station (km)		
	Direction(1)	**Time percentage *p* (%)**	**0.001**	**1**	**10**
Nobeyama, Taeduk	Forward	Line-of-sight (including aggregate)	0.99	0.90	0.88
	Backward	Line-of-sight (including aggregate)	0.31	0.30	0.30
Delingha	Forward	Line-of-sight (including aggregate)	6.38	3.94	3.56
	Backward	Line-of-sight (including aggregate)	1.36	1.21	1.17

(1) Forward: the antenna of HAPS ground station is faced to the RAS station.
Backward: the antenna of HAPS ground station is against the RAS station.

FIGURE 3

Received pfd plus RAS antenna gain at RAS station over line-of-sight where RAS station and HAPS ground station direct face-to-face

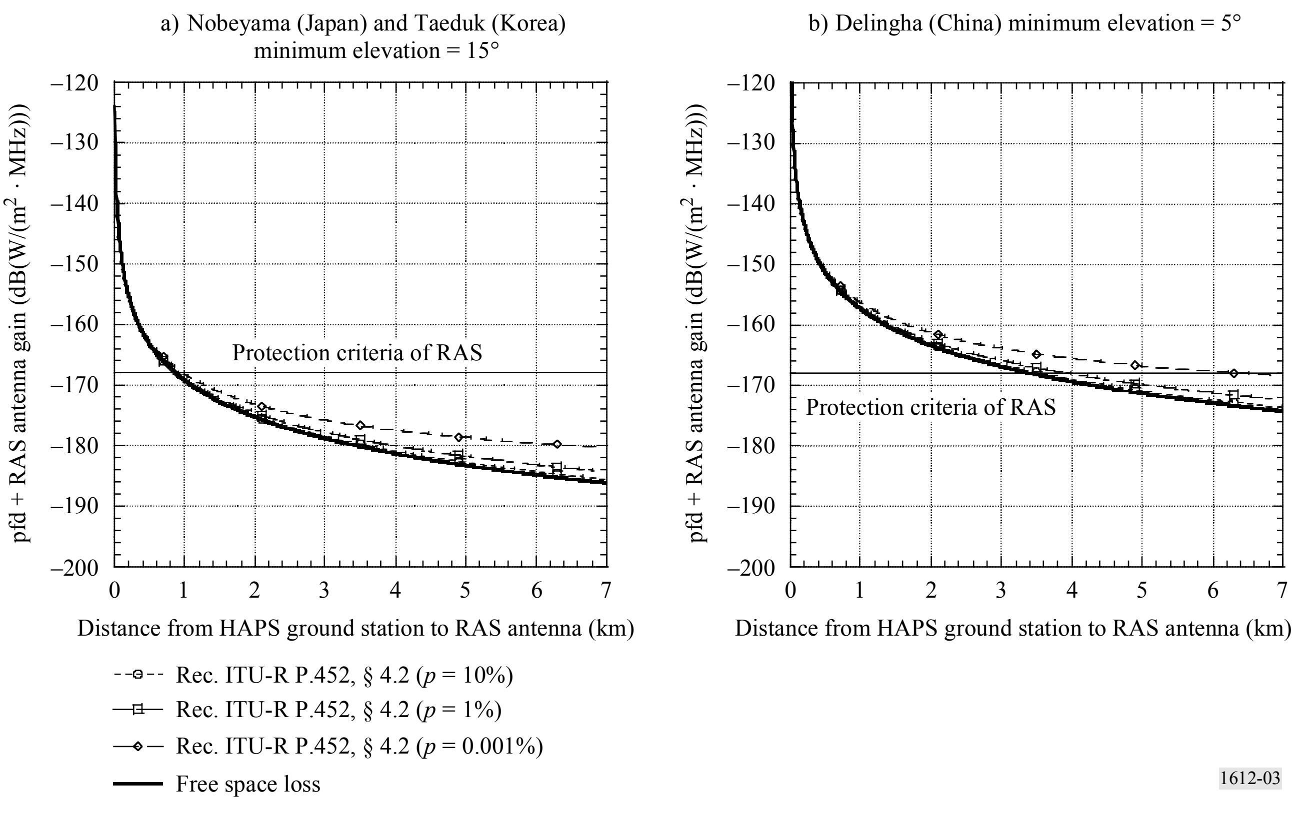


FIGURE 4

pfd plus RAS antenna gain in the case of aggregate interference

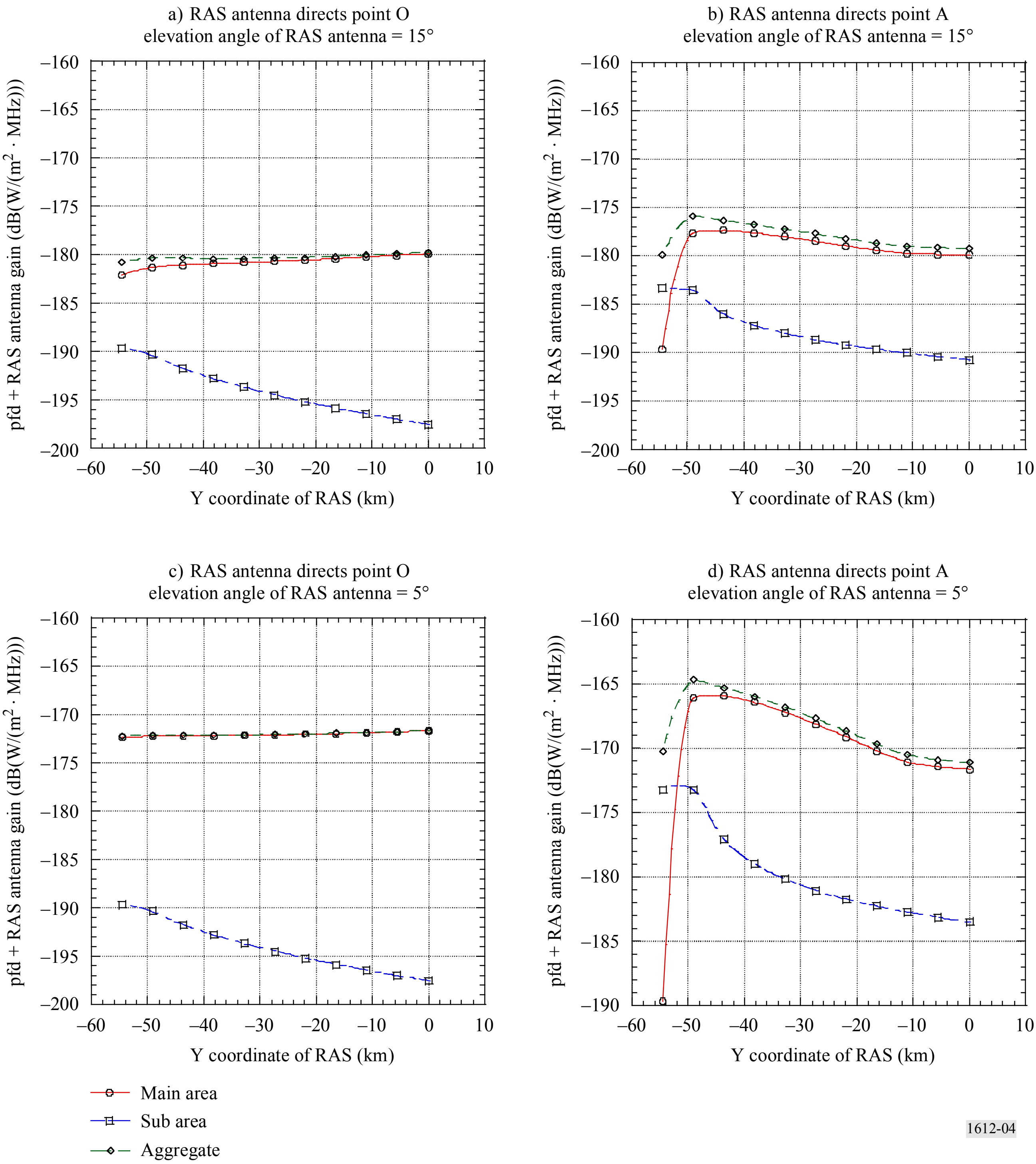
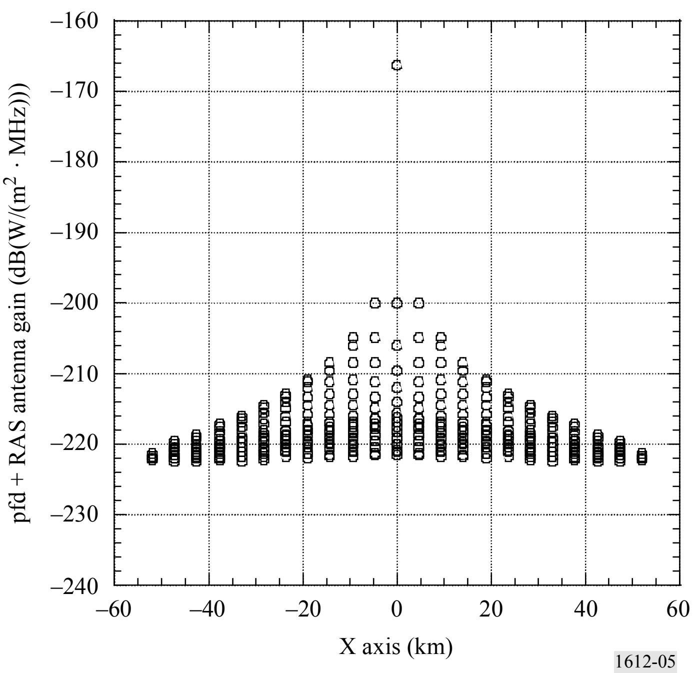


Figure 5 shows plots of interference level of "received pfd" plus "RAS antenna gain" from the HAPS ground station in each spot. The interference of the HAPS ground stations in the neighbouring cell at the boresight direction of RAS antenna is the largest one, which is –166.1 dB(W/(m^2 · MHz)). If such HAPS ground stations (or cells) causing such high levels of unwanted emissions are prohibited from operating, the aggregate interference will not then exceed the protection criterion. It must be pointed out however that in aggregate interference cases, the total unwanted emission power received at the radio telescope depends on the mode of operation of the RAS station and the design of HAPS network and that general conclusions cannot be obtained.

FIGURE 5

Plots of received pfd plus RAS antenna gain for each HAPS ground station in the case of Fig. 3d) where the value of Y coordinate distance is –49.1 km

(all interference values are projected to X axis, where X axis is defined in Fig. 2)



2 Summary

Study results indicate that HAPS systems should be deployed under the following conditions to protect a radio astronomy station:

– HAPS airships should not be located in the vicinity of a RAS station in order to avoid the situation where many HAPS ground stations are pointing in azimuth towards the RAS station;

– the fixed service using HAPS should not operate within an area equivalent to one or more spot beam cells around a RAS station.

Table 3 provides results for the required separation distances between HAPS ground stations and RAS stations for the single entry case of interference case, including the worst-case condition where a HAPS ground station antenna is pointing towards a RAS station in azimuth. Results given in § 1.1 of this Annex were obtained using Recommendation ITU-R F.1245 for the antenna radiation pattern of HAPS ground station. Recommendation ITU-R F.699 should be used to determine the separation distance between a single HAPS ground station and a RAS station. Using Recommendation ITU-R F.699, the side-lobe level increases by 6 dB, then the required separation distance between a HAPS ground station and a RAS station is increased twice.

TABLE 3

Required separation distances between a HAPS ground station and a RAS station for the single entry case using antenna pattern given in Recommendation ITU-R F.699
(Time percentage: 1%)

RAS antenna elevation angle (degrees)	**Required separation distance (km)**		
	HAPS ground station antenna elevation angle 20°		**HAPS ground station antenna elevation angle 90°**
	Forward	**Backward**	**Forward/Backward**
1	60.3	21.4	21.4
5	7.9	2.4	2.4
10	3.0	1.0	1.0
15	1.8	0.6	0.6

NOTE 1 – Forward: the antenna of the HAPS ground station is facing directly towards the RAS station in azimuth.

Backward: the antenna of the HAPS ground station is facing directly away from the RAS station in azimuth.