RECOMMENDATION ITU-R F.1819

Protection of the radio astronomy service in the 48.94-49.04 GHz band from unwanted emissions from HAPS in the 47.2-47.5 GHz and 47.9-48.2 GHz bands*

(2007)

Scope

This Recommendation provides a minimum separation distance between a radio astronomy station and the nadir of a HAPS platform in order to protect radio astronomy stations operating in the band 48.94-49.04 GHz from unwanted emissions of high altitude platform stations (HAPS) operating in the 47.2-47.5 GHz and 47.9-48.2 GHz bands.

Abbreviations

HAPS	High altitude platform stationsRAS radio astronomy service
UAC	Urban area coverage
SAC	Suburban area coverage
RAC	Rural area coverage

The ITU Radiocommunication Assembly,

considering

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

b) that WRC-97 made provisions for the operation of HAPS within the fixed service in the bands 47.2-47.5 GHz and 47.9-48.2 GHz;

c) that Recommendation ITU-R F.1500 contains the characteristics of systems in the fixed service using HAPS operating in the 47.2-47.5 GHz and 47.9-48.2 GHz bands;

d) that it is necessary to protect the radio astronomy service (RAS) operating in the 48.94-49.04 GHz band;

e) that Resolution 122 (Rev.WRC-03) requested frequency sharing studies between the radio astronomy service and HAPS systems using the above-mentioned bands,

recommends

1 that, to protect radio astronomy stations operating in the band 48.94-49.04 GHz from unwanted emissions of HAPS operating in the 47.2-47.5 GHz and 47.9-48.2 GHz bands, the separation distance between the radio astronomy station and the nadir of a HAPS platform should exceed 50 km (see Annex 1).

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[*] This Recommendation should be brought to the attention of Radiocommunication Study Group 7.

Annex 1

Methodology to determine the minimum separation between a RAS antenna and the nadir of a HAPS platform

1 Introduction

This Recommendation presents the results of compatibility studies between high altitude platform stations (HAPS) providing fixed wireless access (FWA) services in the 47.2-47.5 GHz and 47.9-48.2 GHz bands and the radio astronomy service (RAS) in the 48.94-49.04 GHz band (RR 5.555B) which is only used for spectral line RA observations. Based on the results of the study a minimum separation distance is proposed to protect RAS.

2 System characteristics

2.1 The HAPS system

The parameters used in this analysis are given in Recommendation ITU-R F.1500.

2.2 Threshold levels of interference detrimental to the radio astronomy service

The proposed threshold spectral power flux-density (spfd) level to protect an RAS station with a 0 dBi side-lobe antenna gain is -209 dB(W/(m^2 · Hz)) or -149 dB(W/(m^2 · MHz)). It is necessary to consider the actual RAS antenna gain G in order to determine whether the interference exceeds the detrimental threshold level.

RAS antennas typically have extremely high antenna gain, of the order of 70-80 dBi. In the model antenna response in Recommendation ITU-R SA.509, the side-lobe level at an angle of 5° from the main beam is 15 dBi. The 0 dBi side-lobe level occurs at an angle of 19.05° from the main beam axis. Because of the narrowness of the main beam, interference to a radio astronomy antenna is almost always received through the antenna side-lobes, so it is assumed here that the HAPS platform will not come closer than 5° to the RAS antenna main beam, so that the main beam response to interference is not considered in this study. Clearly it would be desirable to position the HAPS platform no closer than 20° from the antenna main beam, but that is not always practical. Hence in this study the interference criterion is taken to be -164 dB(W/(m^2 · Hz)) to allow for the side-lobe gain of the RAS antenna of 15 dBi.

2.3 Interference mitigation techniques

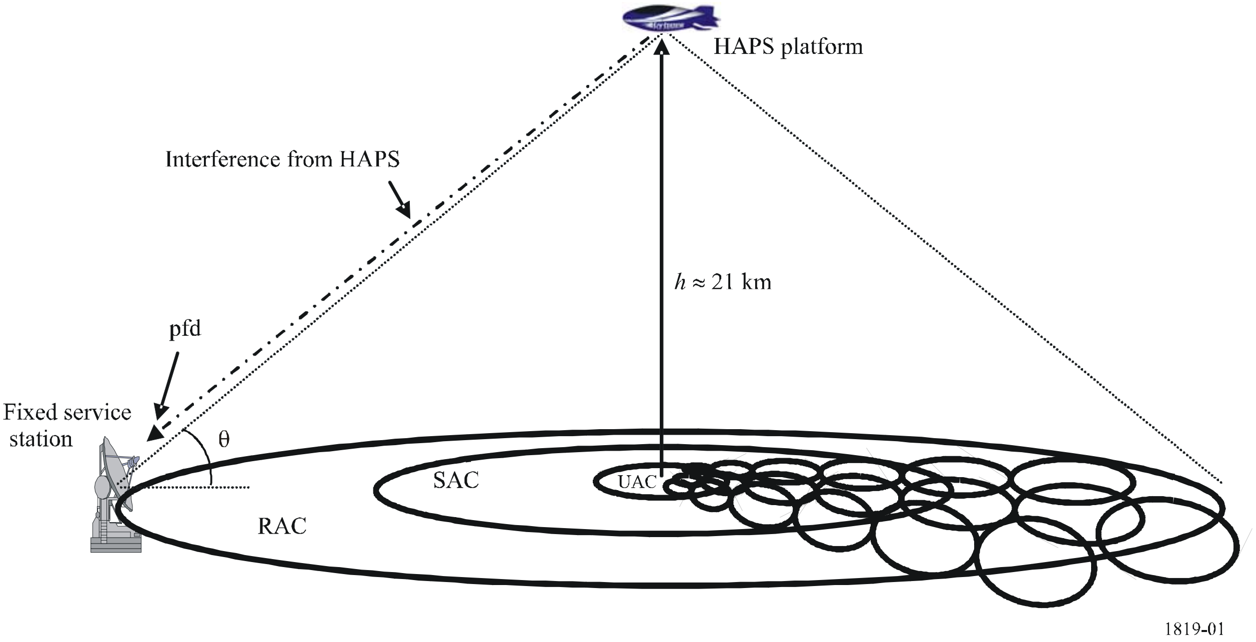
Each HAPS platform antenna contains a 12-section Chebyshev waveguide passband filter with a stop-band rejection ratio of better than 70 dB for unwanted emissions in frequencies greater than four 3 dB bandwidths from the passband. To further mitigate potential interference to the RAS at 49 GHz, it also has an integrated 5-section Chebyshev stop-band (notch) filter with a -25 dB notch depth within the 100 MHz stop-band. This provides a total stop-band rejection of more than 95 dB for the protection of the 49 GHz RAS band.

2.4 Interference scenario

The interference scenario assumed is shown in Fig. 1. In this scenario, the ground radio astronomy station that receives the interference signal emitted by a HAPS platform is located either at or beyond the edge of the HAPS coverage. The aggregate interference signal from all the transmitters on board the HAPS platform is computed to provide an upper limit to the power flux-density (pfd).

FIGURE 1

Interference from HAPS platform to RAS station



UAC, SAC and RAC describe respectively the urban, suburban and rural area coverage by HAPS.

2.5 Basic transmission loss

The basic transmission loss L_b from a single HAPS platform station antenna to an RAS station, according to Recommendation ITU-R P.619, can be expressed as:

$$L_b = 92.5 + 20\log f + 20\log d + A_g + A_D - G_S \quad \text{dB} \tag{1}$$

where:

f: frequency (GHz)
d: path length (km)
A_g: attenuation due to atmospheric gases (dB)
A_D: attenuation (dB) due to beam spreading
G_S: gain (dB) due to scintillation.

For atmospheric attenuation, Recommendation ITU-R F.1501 will be used. For the interference analysis, only the minimum attenuation formula is of interest, hence the formula for the attenuation A_H at the high-latitude regions (above 45°) at 47.2 GHz is selected to provide a worst-case analysis.

$$\begin{aligned} A_H\ (h, \theta) &= 46.70/[1 + 0.6872\,\theta + 0.03637\,\theta^2 - 0.001105\,\theta^3 + 0.8087 \times 10^{-5}\,\theta^4 \\ &\quad + h\,(0.2472 + 0.1819\,\theta) + h^2\,(0.04858 + 0.03221\,\theta)] \end{aligned} \tag{2}$$

The formula is valid for $0 \le h \le 3$ km and $0 \le \theta \le 90°$, where θ (degrees) is the elevation angle of the ground station with respect to the HAPS platform, and h (km) is the altitude of the ground station above sea level. For actual elevation angles below 0°, the attenuation for 0° should be used.

In the interest of a worst-case analysis, the attenuation due to beam spreading is ignored in this study.

The scintillation gain, G_S, is a function of frequency, earth station antenna diameter, elevation angle, and local climate and can be calculated from the predicted intensity of tropospheric scintillation. The receiving antenna aperture plays a role in smoothing the effect of the index of refraction fluctuation; the larger the antenna aperture in relation to the first Fresnel zone, the smaller is the receiver aperture averaging factor, which is always less than 1. The typical RAS antenna has an aperture averaging factor from 0.1 to 0.7 along the main beam axis. For off-axis reception, the averaging factor should approach 1.

Since the minimum elevation angle for a HAPS platform will be greater than 5°, there is currently no guideline as to how to estimate the scintillation gain at 49 GHz. However, as a guide, Recommendation ITU-R P.618, equation (25), is used to estimate the standard deviation of the scintillation amplitude:

$$\sigma(f,\theta,D) = \sigma_{reference}(f_0,\theta_0,D_0)\cdot\left(\frac{f}{f_0}\right)^{7/12}\cdot\left(\frac{\sin(\theta_0)}{\sin(\theta)}\right)^{1.2}\cdot\frac{G(D)}{G(D_0)} \qquad (3)$$

where $\sigma_{reference}(f_0, \theta_0, D_0)$ is a reference standard deviation of the scintillation amplitude at frequency f_0, elevation angle θ_0, and the aperture diameter D_0, $G(D)$ is the aperture averaging gain factor due to scintillation, and f, θ, and D are the frequency, the elevation angle, and the antenna aperture of the RAS antenna in question.

Recommendation ITU-R P.452, § 4.4, also provides an equation for the computation of the transmission loss between the stations on the surface of the Earth due to tropospheric scatter not exceeded for time percentage *p*%. However, the tropospheric scatter loss is only applicable to trans-horizon paths (ITU-R P.452, § 4.4, Note 2), which in the case of a HAPS platform is more than 500 km from nadir. Hence as long as the computed minimum separation distance is less than that, the troposcatter loss can be ignored. The same is true for other trans-horizon losses such as ducting and diffraction losses.

2.6 Study results

To compute the aggregate interference level from a HAPS platform, an array gain factor must be calculated first in order to obtain the effective transmitting antenna gain G_t to provide the total transmitting power level before all losses as given by equation (1). The array gain factor is computed assuming that the HAPS antennas are arranged as a hexagonal lattice on a hemispherical surface, bearing in mind the fact the antenna array would not cover the entire hemisphere even with a minimum elevation angle of zero, so this computation corresponds to the upper bound of the spfd limit. A further simplifying assumption is to replace all other RAC antennas by lower gain SAC antennas, except the one that is pointing directly toward the interfered ground receiver. Unlike the co-channel interference scenarios, all HAPS platform antennas contribute to the unwanted emission at the RAS frequencies of 48.94-49.04 GHz. The actual interference power is computed by multiplying the single antenna gain (not in dBi) by the array gain factor.

FIGURE 2

Array gain factor vs. total number of HAPS beams

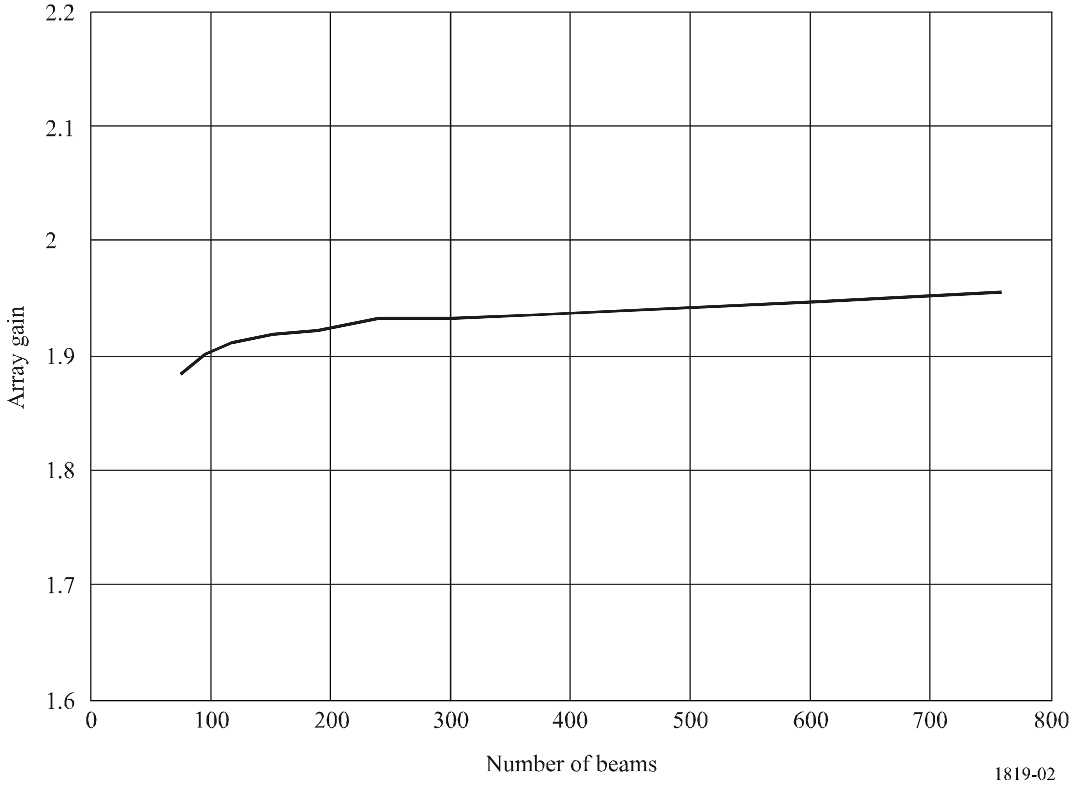


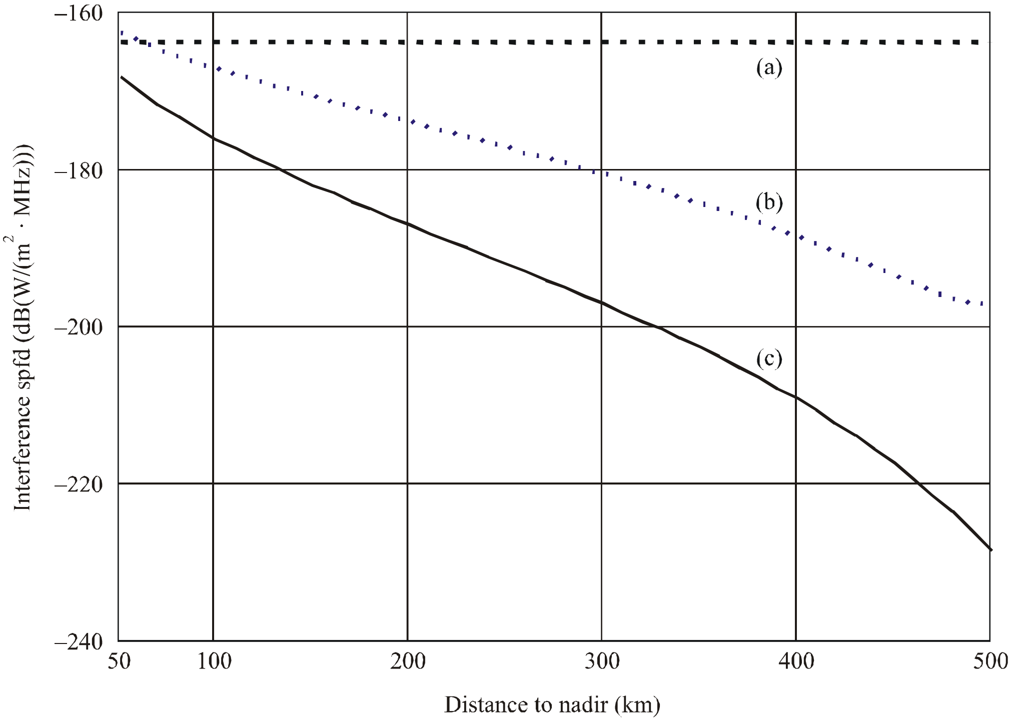
Figure 2 shows that the computed array gain factor is close to 2 almost irrespective of the number of HAPS beams. Hence the interference power level before all losses can be estimated by pretending that there is only a single HAPS antenna pointing directly at the RAS station antenna and by multiplying the resulting power level by the array gain factor. Since the array gain factor is always less than 2, 2 will be taken to be the array gain factor for this calculation.

Figure 3 below shows the estimated upper bound for the interference spfd that an RAS station at a distance between 50 km and 500 km from the nadir of the HAPS platform is expected to experience. A transmitting bandwidth of 11 MHz and a combined cable/feeder loss of 5 dB are assumed, and the total stop-band attenuation of 95 dB is used to obtain the final results. The computed spfd is in the range of −176.3 dB(W/(m^2 · MHz)) and −236.6 dB(W/(m^2 · MHz)) for distances of 50 km and 500 km, respectively, as represented by the solid curve.

To get some idea of the effect of troposcatter scintillation, the long-term measurement data obtained at Isfjord Radio, Spitzbergen during the summer of 1982 at 3.2° elevation is extrapolated to 49 GHz and to other elevation angles using equation (3) in Recommendation ITU-R F.1501. Note that equation (3) is not recommended for use when elevation angles are less than 4°, nor for frequencies in excess of 20 GHz. So its use is not entirely appropriate and is only to obtain a rough estimate. Spitzbergen measurement data shows that scintillation amplitude gain exceeded 12 dB for no more than 0.001% of the time. The dashed curve represents the addition of the extrapolated troposphere scintillation gain to account for the interference enhancement due to troposphere scatter of the radio wave at 49 GHz, whereas the solid curve is the interference level when the scintillation gain is zero. The RAS antenna aperture averaging gain factor $G(D)$, which is always less than 1, is ignored in this study in order to obtain a worse-case estimate. The interfering spfd level when this is included ranges from −172.0 dB(W/(m^2 · MHz)) to −212.5 dB(W/(m^2 · MHz)). The more pronounced increase of the interfering pfd reflects the large enhancement of the radio signal at low elevation angles. The spfd bound stays below the RAS spfd protection threshold of −164 dB(W/(m^2 · MHz)), when no troposphere scintillation gain has been included. With scintillation gain, the minimum separation distance is about 51 km. However, if the HAPS platform can stay more than 5° from the main beam axis of the RAS antenna, the minimum separation distance most likely would be negligible even with scintillation. The spfd decreases sharply when the distance becomes greater than 200 km, signifying a rapid increase in atmospheric attenuation. The elevation angle that corresponds to the distance of 200 km from nadir is about 5°. The above computation is based on the assumption that the interfered fixed service ground station is at sea level. Fixed service ground station at higher than sea level will receive higher interference levels because of the reduced atmospheric attenuation.

FIGURE 3

Received spfd by RAS antenna vs. distance to nadir



Curve (a): Protection threshold for RAS
Curve (b): Interference level with scintillation gain
Curve (c): Interference level when the scintillation gain is zero

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3 Minimum separation distance of RAS antenna and nadir of HAPS platform station for protection of radio astronomy service

It is proposed that, for the purpose of protecting radio astronomy observations in the 48.94-49.04 GHz band from a HAPS platform operating in the frequency bands 47.2-47.5 GHz and 47.9-48.2 GHz, the separation distance between an RAS antenna and the nadir of a HAPS platform should exceed 50 km.