# RECOMMENDATION ITU-R F.1764

## Methodology to evaluate interference from fixed service systems using high altitude platform stations to fixed wireless systems* in the bands above 3 GHz

(Question ITU-R 212/9)

(2006)

**Scope**

This Recommendation provides a methodology for interference evaluation that could be used for sharing studies between fixed service systems using high altitude platform stations (HAPS) and conventional fixed wireless systems in the frequency bands above 3 GHz in response to the technical study invited by Resolution 734 (Rev.WRC-03). Interference situations from HAPS airships and ground stations to the radio-relay stations are analysed.

The ITU Radiocommunication Assembly,

*considering*

a) that new technology utilizing high altitude platform stations (HAPS) in the stratosphere has been developed to provide high-capacity services;

b) that some administrations intend to operate the systems using HAPS in the bands allocated exclusively by the Table of Frequency Allocations or by footnotes for terrestrial radiocommunication such as the fixed services,

*recognizing*

a) 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 (see Resolution 122 (Rev.WRC-03));

b) that since the 47 GHz bands are more susceptible to rain attenuation, at WRC-2000 several countries in Region 3 and one country in Region 1 expressed a need for a lower frequency band for HAPS and Nos. 5.537A and 5.543A of the Radio Regulations (RR) were adopted;

c) that WRC-03 modified RR Nos. 5.537A and 5.543A to add several countries and also permitted the use of HAPS in the fixed service within 300 MHz of spectrum in the band 27.5-28.35 GHz and in the band 31.0-31.3 GHz in Region 2 countries on a non-harmful interference, non-protection basis to other stations of services operating in accordance with the Table of Frequency Allocations of RR Article 5 by Resolution 145 (WRC-03);

d) that Resolution 734 (Rev.WRC-03) invites ITU-R to conduct regulatory and technical studies to determine the feasibility of use by HAPS and encourages administrations to contribute actively to the sharing studies in the frequency bands above 3 GHz allocated exclusively for terrestrial radiocommunication,

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* The term "fixed wireless system" used in this Recommendation means point-to-point radio-relay systems. Therefore, the term "radio-relay station" is also used.

*recommends*

**1** that the methodology described in Annex 1 can be used, in response to the technical study stated in *recognizing* d), to evaluate interference from HAPS systems to fixed wireless systems in the bands above 3 GHz.

# Annex 1

## Methodology for interference evaluation from fixed service systems using HAPS to fixed wireless systems in the bands above 3 GHz

### 1 Introduction

This Annex provides a methodology for interference evaluation to be used for sharing studies between fixed service systems using HAPS and fixed wireless systems in the frequency bands above 3 GHz. Interference situations from HAPS airships and ground stations to the radio-relay stations are considered.

It also provides the example of interference evaluation at 6 GHz[1]. This frequency is assumed only to show an example of the interference evaluation.

### 2 Calculation methodology of interference from fixed service systems using HAPS to fixed wireless systems

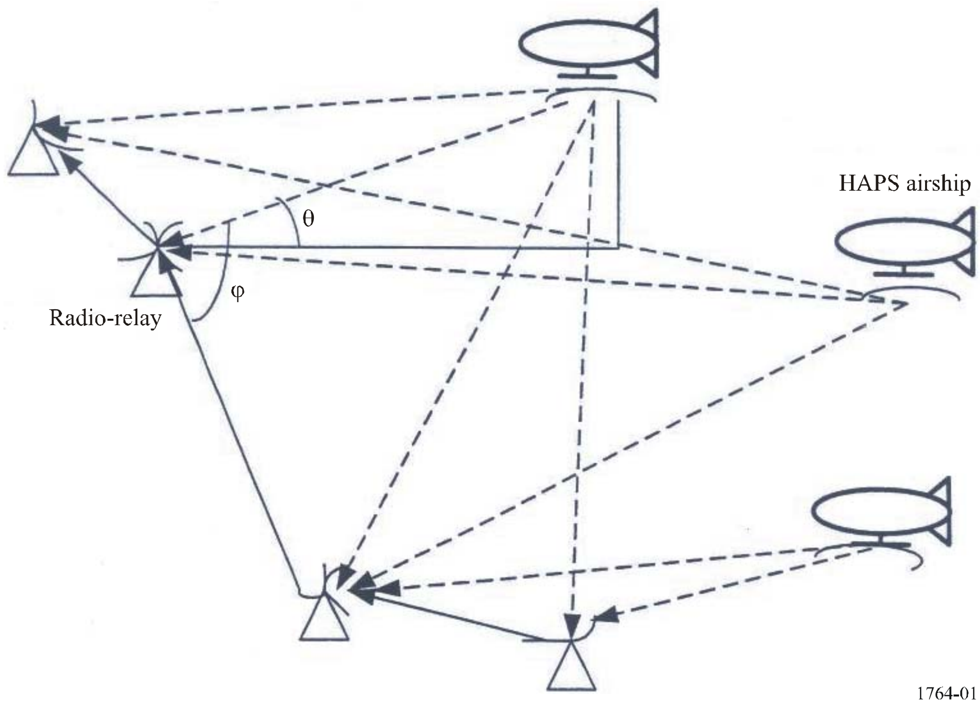
#### 2.1 Interference from HAPS airships to radio-relay stations

Figure 1 shows the interference situation from HAPS airships to radio-relay stations.

[1] It is recognized that the frequency 6 GHz is not in a band allocated exclusively for terrestrial radiocommunication. It was chosen for this analysis to facilitate the development of the methodology because of the prevalence of available technical data for the terrestrial system.

FIGURE 1

**Interference environment from HAPS airships to radio-relay stations**




### 2.1.1 For analogue radio-relay stations

The baseband interference of an analogue radio-relay station from a HAPS airship can be obtained by equation (1):

$$I_A = F(\theta) + G(\varphi) + N_{br} + 10\log\left(\frac{\lambda^2}{4\pi}\right) - L_{fr} \tag{1}$$

where:

- $F(\theta)$: power flux-density (pfd) of HAPS airship according to the angle of arrival above the horizontal plane, θ (dB(W/(m$^2$ · 4 kHz)))
- $G(\varphi)$: antenna gain of radio-relay station to the direction of HAPS airship, φ (dBi)
- $N_{br}$: baseband thermal noise-to-receiver thermal noise ratio (dB(pW0p · 4 kHz))
- $\lambda$: wavelength of the carrier (m)
- $L_{fr}$: feeder loss of radio-relay station (dB).

Generally, the pfd level on the Earth's surface, $F(\theta)$ can be defined in the form as follows:

$$F(\theta) = \begin{cases} pfd_{low} & \text{for } 0^\circ \le \theta \le 5^\circ \\ pfd_{low} + 0.05(pfd_{high} - pfd_{low})(\theta - 5) & \text{for } 5^\circ \le \theta \le 25^\circ \\ pfd_{high} & \text{for } 25^\circ \le \theta \le 90^\circ \end{cases} \tag{2}$$

where:

- $pfd_{low}$: allowable level for low angle of arrival dB(W/(m$^2$ · 4 kHz))
- $pfd_{high}$: allowable level for high angle of arrival dB(W/(m$^2$ · 4 kHz)).

Therefore, the baseband interference of an analogue radio-relay station by multiple inputs from visible airships can be calculated using equation (3):

$$I_{A\text{-}T} = 10 \log\left\{ \sum_i \left( 10^{\frac{F(\theta_i)}{10}} \, 10^{\frac{G(\varphi_i)}{10}} \right) \right\} + N_{br} + 10 \log\left( \frac{\lambda^2}{4\pi} \right) - L_{fr} \qquad (3)$$

where $i$ represents the effect by $i$-th HAPS airship which is visible at the radio-relay station.

### 2.1.2 For digital radio-relay stations

Currently most fixed service systems employ digital modulation. In the case of digital point-to-point (P-P) and point-to-multipoint (P-MP) FS systems, it is appropriate to evaluate interference in terms of fractional degradation of performance values of routes, $FDP_{route}$, as defined in Recommendation ITU-R F.1107, taking into account that the interference level is time-invariant.

For digital P-P fixed service systems with $n$ hops operating at frequencies where multipath fading generally predominates and acknowledging that, in general, the performance objectives for multi-hop P-P fixed service systems are specified on a route basis as follows:

$$FDP_{route} = 100 \frac{\sum_{k=1}^{n} (I_k)}{n \times N_T} \quad \% \qquad (4)$$

where:

$N_T$: receiver thermal noise

$I_k$: aggregate interference falling into the $k$-th receiver from visible HAPS airships.

The aggregate interference received at a digital radio-relay station can be determined by summing the contributions from each visible HAPS airships. Each contribution can be determined as follows:

$$I_D = F(\theta) + G(\varphi) + 10 \log\left( \frac{\lambda^2}{4\pi} \right) - L_{fr} \qquad (5)$$

where:

$F(\theta)$: pfd of HAPS airship according to the angle of arrival above the horizontal plane, $\theta$ (dB(W/(m$^2$ · MHz)))

$G(\varphi)$: antenna gain of radio-relay station to the direction of HAPS airship, $\varphi$ (dBi)

$\lambda$: wavelength of the carrier (m)

$L_{fr}$: feeder loss of radio-relay station (dB).

## 2.2 Interference from HAPS ground stations to a radio-relay station

Figure 2 shows the interference situation from HAPS ground stations to a radio-relay station.

The interference power from a HAPS ground station to a radio-relay station is obtained by equation (6):

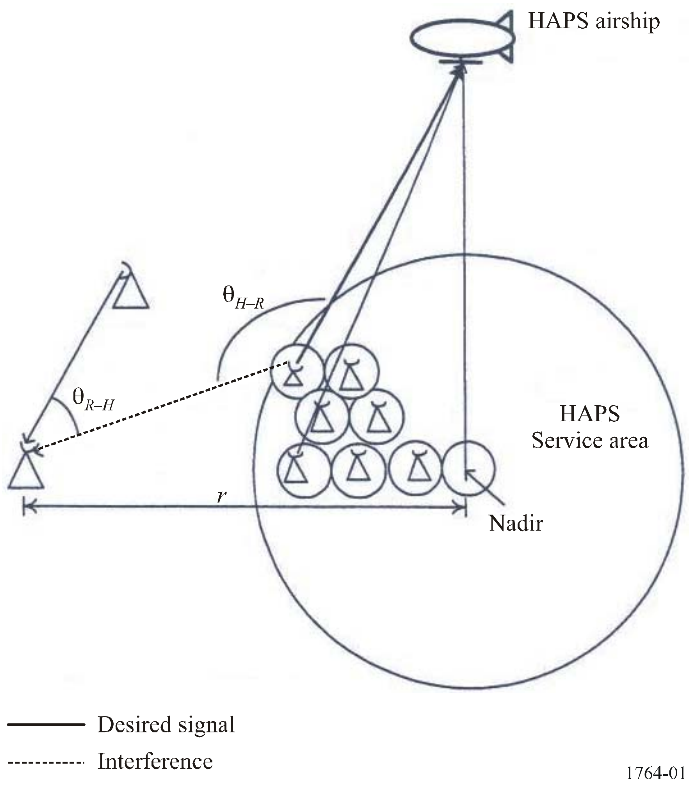
$$I_G = P_{HG} - L_{fh} + G(\theta_{H-R}) - L_b(p) + G(\theta_{R-H}) - L_{fr} \qquad (6)$$

where:

- $P_{HG}$: transmission power density from HAPS ground station (dB(W/MHz))
- $L_{fh}$: feeder loss of the HAPS ground station (dB)
- $G(\theta_{H-R})$: transmitting antenna gain of HAPS ground station at the angle, $\theta_{H-R}$ between the direction of main beam of HAPS ground station and the direction of the interfered radio-relay station (dBi)
- $L_b(p)$: basic transmission loss not exceeded for time percentage, $p$(%) given in Recommendation ITU-R P.452
- $G(\theta_{R-H})$: receiving antenna gain of radio-relay station at the angle $\theta_{R-H}$ between the direction of main beam of radio-relay station and the direction of the interfering HAPS ground station (dBi)
- $L_{fr}$: feeder loss of the radio-relay station (dB).

FIGURE 2

**Interference environment from HAPS ground stations to a radio-relay station**




The interference power at a radio-relay station from multiple inputs of HAPS ground stations can be obtained using equation (7) taking into account the mechanism shown in Fig. 3.

In equation (7), it is assumed that the atmosphere absorption can be ignored on the line-of-sight propagation path below 10 GHz. And the propagation model used is based on Recommendation ITU-R P.452 with the percentage of time, $p$ being 50%:

$$I_{G\text{-}T} = P_{HG} - L_{fh} - 92.5 - 20 \log f$$

$$+10 \log\left\{ \sum_i \sum_j \left(\sqrt{x_{ij}^2 + y_{ij}^2}\right)^{-2} 10^{\frac{G(\theta_{R-H})}{10}} 10^{\frac{G(\theta_{H-R})}{10}} \right\} - L_{fr} \qquad (7)$$

where:

$f$: frequency (GHz)

$$x_{ij} = \begin{cases} r + id & (j = \text{even}) \\ r + \dfrac{(2i-1)}{2} d & (j = \text{odd}) \end{cases}$$ : $x$ position of HAPS ground station

$y_{ij} =$ $jd \sin 60°$: $y$ position of HAPS ground station

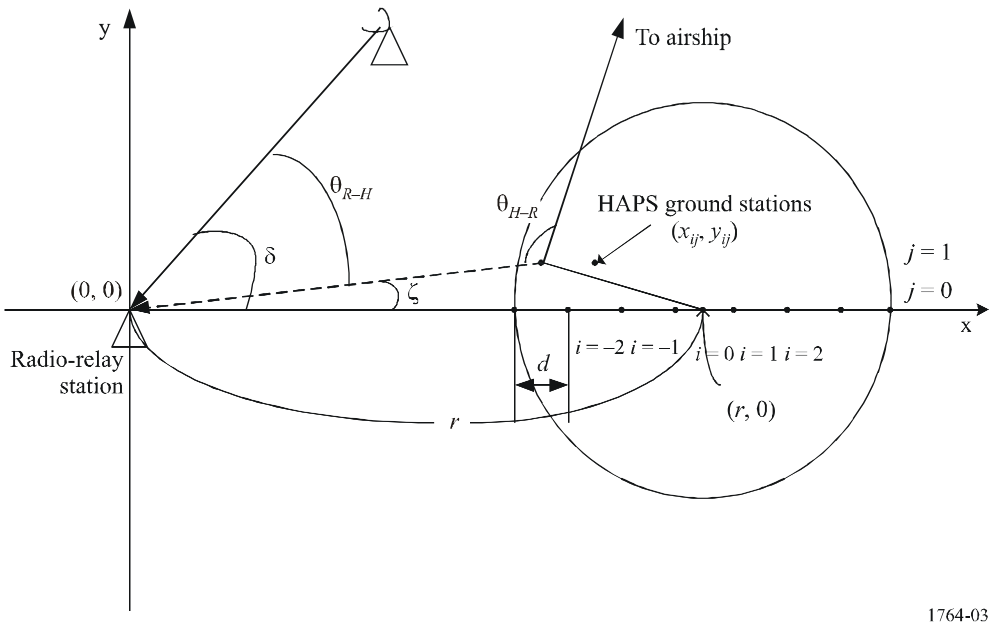
$r$: distance between radio-relay station and nadir of HAPS airship

$d$: distance between HAPS ground stations

$i, j$: cell location on $x$ axis and $y$ axis, respectively.

FIGURE 3

**Mechanism for calculating interference from HAPS ground stations to a radio-relay station**




Once the interference level at a radio-relay station has been assessed, the $I/N$ ratio can be assessed as follows:

$$I/N = I_{G\text{-}T} - \{10 \log(k\ T\ B) + NF\} \quad \text{dB} \qquad (8)$$

where:

$k$: Boltzmann's constant = $1.38 \times 10^{-23}$ (J/K)

$T$: temperature (K)

$B$: bandwidth (Hz)

$NF$: noise figure of radio-relay station (dB).

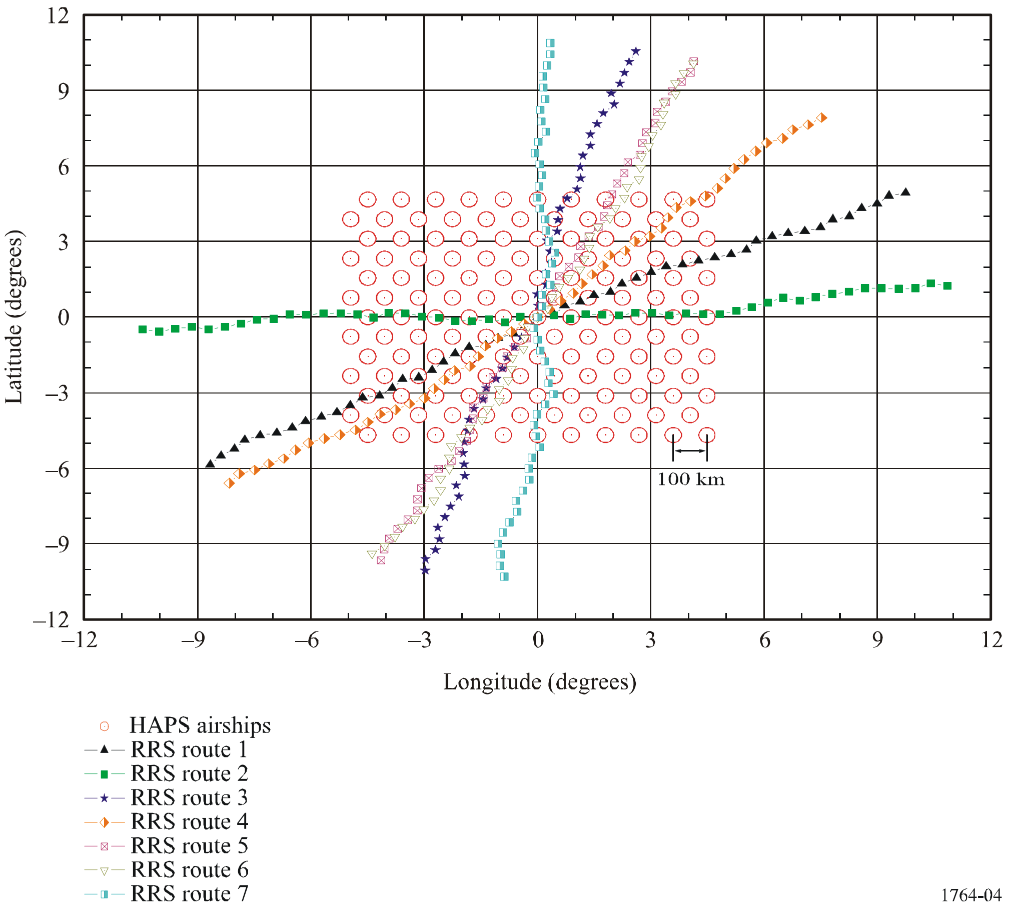
## 3 Example of interference evaluation from HAPS systems to fixed wireless systems

### 3.1 Interference from HAPS airships to radio-relay stations

Figure 4 shows the assumed distribution model of HAPS airships and radio-relay stations for interference evaluation.

FIGURE 4

**Distribution model of radio-relay stations and HAPS airships**




HAPS airships at a fixed point of an altitude of 20 km can cover the service area of 110 km in diameter on the ground (elevation angle: 20°), so that the location of HAPS airship nadir can be distributed uniformly with 100 km interval considering the overlap between service areas, as shown in Fig. 4. It is assumed that HAPS airships are uniformly distributed in the area of $1\,000 \times 1\,000$ km$^2$.

Interfered routes of a fixed wireless system composed of 50 hops are assumed to be distributed aligning the centres of the routes with the centre of airship distribution.

Table 1 shows the system parameters of a fixed wireless system and HAPS airship used in the calculation. The frequency of 6 GHz is chosen just to show an example of interference evaluation. For the interference evaluation in this Annex, all coordinates take into account the curvature of the Earth.

TABLE 1

**Common parameters of a fixed wireless system and HAPS airship**

| Parameters | | Values |
|---|---|---|
| Frequency | | 6 GHz |
| Fixed wireless system | Number of hops per route | 50 |
| | Distance between hops | 50 km |
| | Number of routes | 600 |
| HAPS airship | Number of airships | 126 |
| | Altitude | 20 km |

### 3.1.1 For analogue radio-relay stations

Table 2 shows the system parameters of analogue radio-relay system and HAPS airship used in the calculation. The system parameters of fixed wireless systems for frequency sharing are based on Recommendation ITU-R F.758.

TABLE 2

**System parameters of an analogue fixed wireless system and HAPS airship**

| Parameters | | Specifications |
|---|---|---|
| Fixed wireless system | Antenna radiation pattern | Recommendation ITU-R F.699 |
| | Maximum antenna gain | 45 dB |
| | Feeder loss | 4 dB |
| | Receiver noise figure | 8 dB |
| | Elevation angle between radio-relay station | Gaussian distribution |
| HAPS airship | $pfd_{low}$ | –156 $\simeq$ 152 (dB(W/(m$^2$ · 4 kHz))) |
| | $pfd_{high}$ | –148 $\simeq$ 142 (dB(W/(m$^2$ · 4 kHz))) |

The maximum allowable value of interference is assumed to be 1000 pW0p psophometrically-weighted 1 min mean power for more than 20% of any month for analogue fixed wireless systems, as described in Recommendation ITU-R SF.357.

The estimated interference distributions from HAPS airships to analogue radio-relay stations are shown in Figs. 5 and 6, with the variables of $pfd_{low}$ and $pfd_{high}$.

In Fig. 5, when the pfd level of HAPS airship is assumed to be –152/–142 (dB(W/(m$^2$ · 4 kHz))), the radio-relay stations would experience interference less than 1000 pW0p in about 84% of the routes. As $pfd_{low}$ decreases, experienced interference also decreases. For example, when $pfd_{low}$ is decreased by 4 dB, i.e. $pfd_{low}$ is –156(dB(W/(m$^2$ · 4 kHz))), the radio-relay stations in 100% of the routes would experience interference less than the assumed interference criterion of 1 000 pW0p.

FIGURE 5

**Interference distribution with *pfd_low* from HAPS airships**

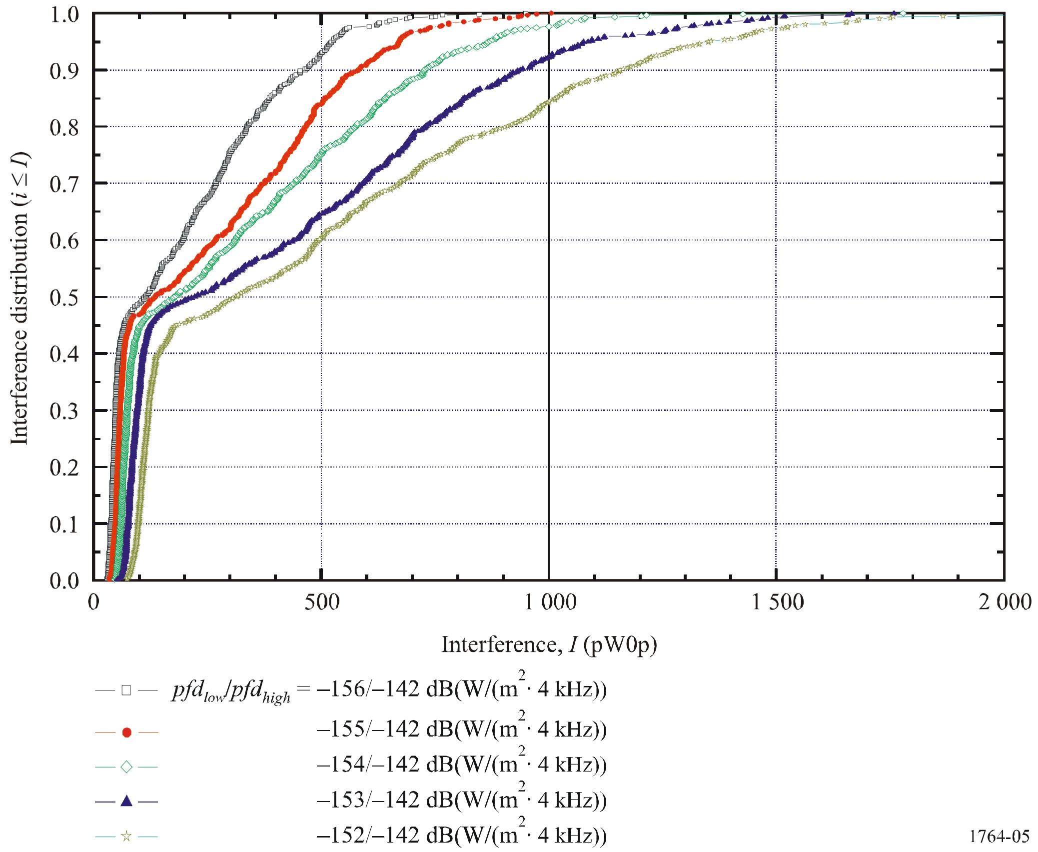



Figure 6 shows the interference distribution with the changes of $pfd_{high}$, when $pfd_{low}$ is –152 (dB(W/(m$^2$ · 4 kHz))). Even though $pfd_{high}$ is decreased by 6 dB from –142 (dB(W/(m$^2$ · 4 kHz))), the maximal difference of the interference distribution less than 1 000 pW is only about 5%.

### 3.1.2 For digital radio-relay stations

Table 3 shows the system parameters of a digital fixed wireless system and HAPS airship used in the calculation. The system parameters of a fixed wireless system for frequency sharing are also based on Recommendation ITU-R F.758.

For bands where the fading is controlled by multipath, Recommendation ITU-R F.758 states that, in principle, the interference level relative to receiver thermal noise should not exceed –10 dB (or –6 dB). In the case of digital FS systems, these values correspond to an FDP of 10% (or 25%), respectively. Assuming the required protection level of 10%, the estimated interference distributions from HAPS airships to digital radio-relay stations are shown in Figs. 7 and 8, with the variables of $pfd_{low}$ and $pfd_{high}$.

FIGURE 6

**Interference distribution with *pfd*$_{high}$ from HAPS airships**

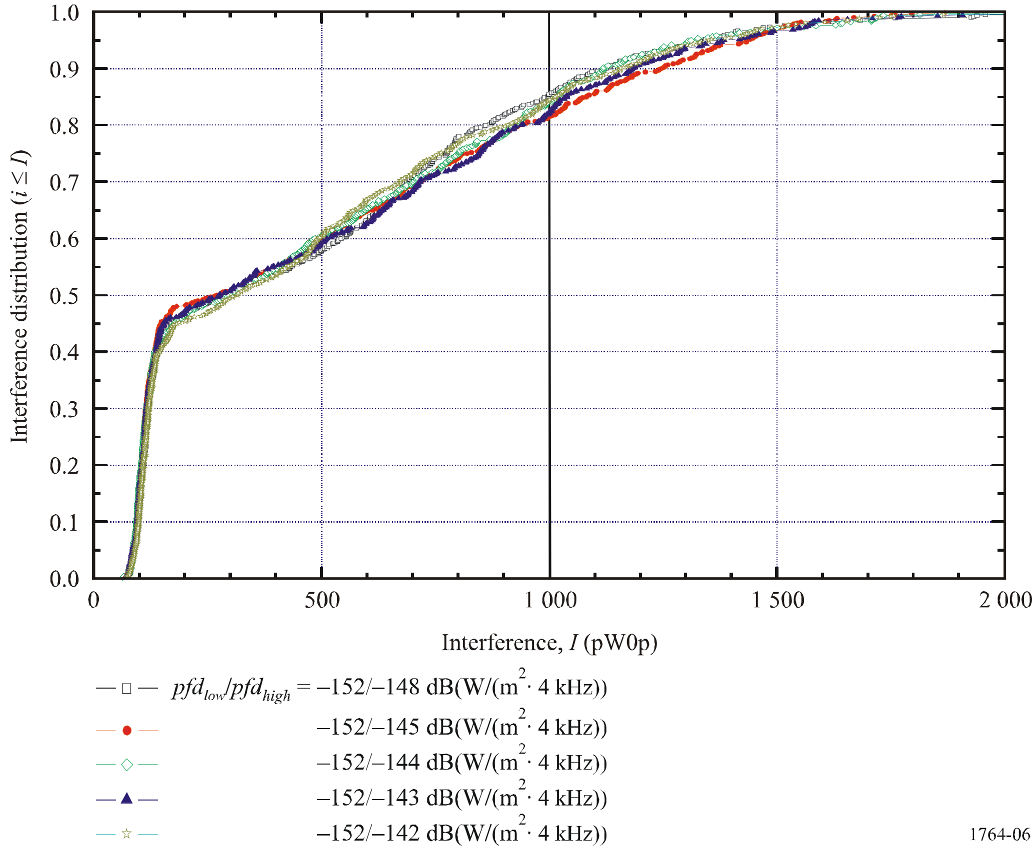



TABLE 3

**System parameters of a digital fixed wireless system and HAPS airship**

| **Parameters** | | **Specifications** |
|---|---|---|
| Fixed wireless system | Antenna radiation pattern | Recommendation ITU-R F.1245 |
| | Maximum antenna gain | 45 dB |
| | Feeder loss | 5.5 dB |
| | Receiver noise figure | 4 dB |
| | Elevation angle between radio-relay station | Gaussian distribution |
| HAPS airship | $pfd_{low}$ | –146 ≃ 140 (dB(W/(m$^2$ · MHz))) |
| | $pfd_{high}$ | –127 ≃ 118 (dB(W/(m$^2$ · MHz))) |

In Fig. 7, when the pfd level of HAPS airship is assumed to be –140/–118 (dB(W/(m$^2$ · MHz))), the FDP of radio-relay stations would be less than 10% in about 58% of the routes. As $pfd_{low}$ decreases, experienced interference also decreases. For example, when $pfd_{low}$ is decreased by 6 dB, i.e. $pfd_{low}$ is –146 (dB(W/(m$^2$ · MHz))), the FDP of radio-relay stations in 100% of the routes would be less than the assumed interference criterion of 10%.

FIGURE 7

**FDP distribution with *pfd*$_{low}$ from HAPS airships**

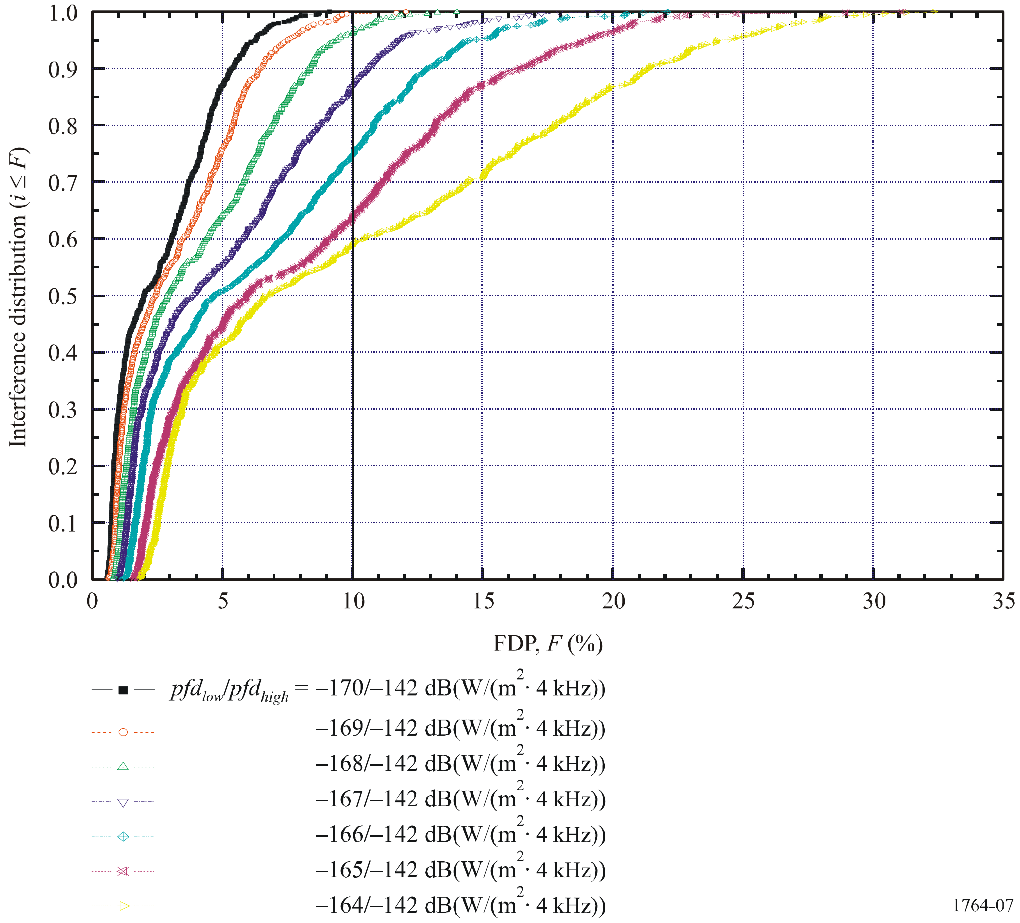



Figure 8 shows the interference distribution with the changes of $pfd_{high}$, when $pfd_{low}$ is –145 (dB(W/(m$^2$ · MHz))). Even though $pfd_{high}$ is decreased by 6 dB from –121 (dB(W/(m$^2$ · MHz))), the maximal difference of the interference distribution less than 10% is only about 5%.

### 3.2 Interference from HAPS ground stations to a radio-relay station

Table 4 shows the system parameters of a fixed wireless system and a HAPS system used in the calculation.

FIGURE 8

**FDP distribution with $pfd_{high}$ from HAPS airships**

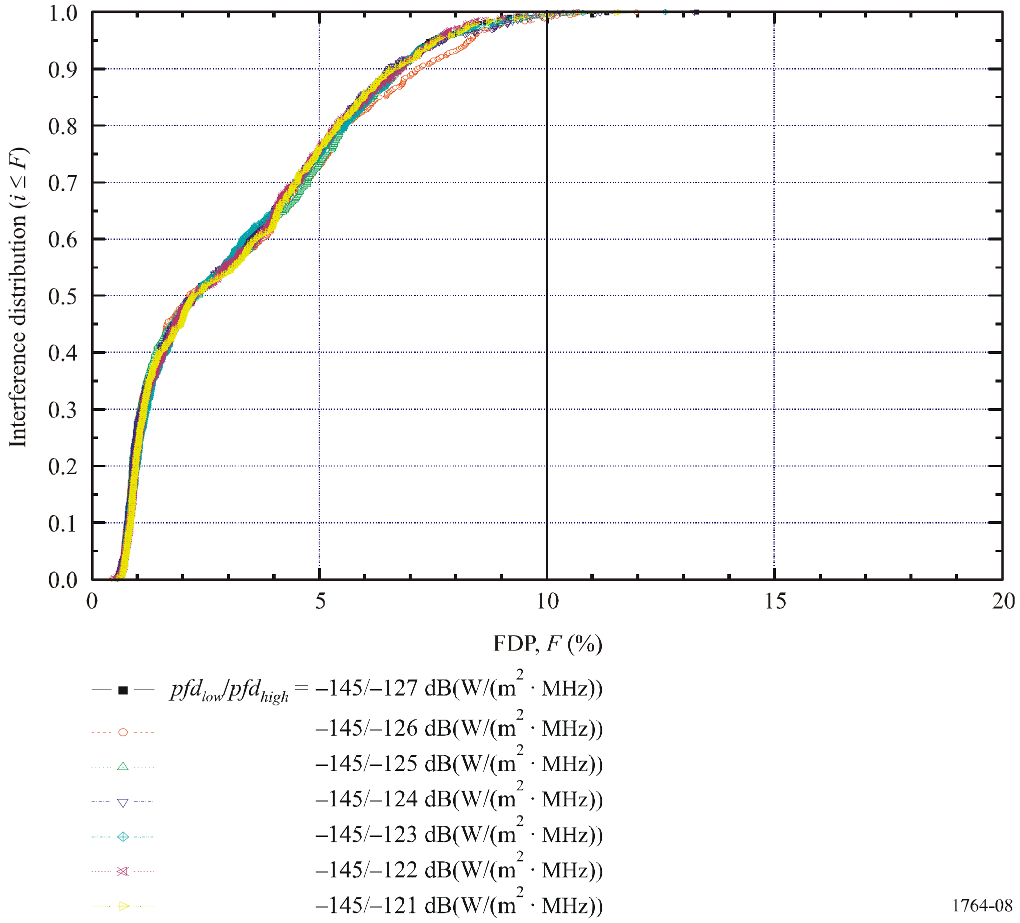



TABLE 4

**System parameters of a fixed wireless system and a HAPS system**

| **Parameters** | | **Values** |
|---|---|---|
| Frequency | | 6 GHz |
| Fixed wireless system | Antenna radiation pattern | Recommendation ITU-R F.1245 |
| | Maximum antenna gain | 45 dBi |
| | Noise figure | 4 dB |
| | Feeder loss | 5.5 dB |
| HAPS system | Diameter of service coverage | 110 km |
| | Altitude of airship | 20 km |
| | Antenna radiation pattern of ground station | Recommendation ITU-R F.1245 |
| | Maximum antenna gain of ground station | 45 dBi |
| | Number of ground stations | 367 (uniform distribution) |
| | Distance between ground stations | 5.5 km |

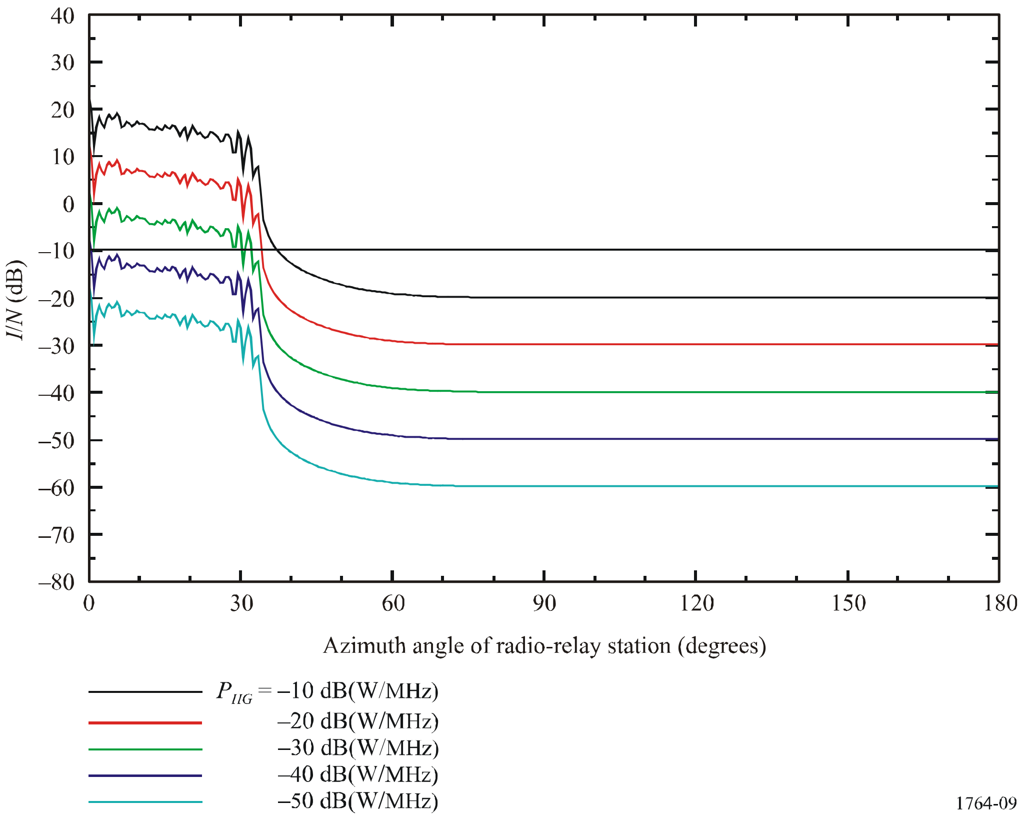
Assuming that $T$ is 293 $K$, $B$ is 1 MHz, and $NF$ is 6 dB, noise power $N$ is –137.93 (dB(W/MHz)). If $I/N$ = 10% is assumed as a criterion, permissible interference power, $I_{G\text{-}T}$ should be less than –147.93 (dB(W/MHz)).

Since $I_{G\text{-}T}$ depends on the transmitting power of HAPS ground station, the angle between signal paths, and the distance between radio-relay station and HAPS nadir, the $I/N$ with these parameters can be calculated by equation (8).

Figure 9 shows the values of $I/N$ with the transmitting power, $P_{HG}$ at every azimuth angle, δ when the distance, $r$ is 100 km. From this figure, it turns out that the interference power is naturally affected by the transmitting power per HAPS ground station, and when $P_{HG}$ is –50 (dB(W/MHz)), $I/N$ does not exceed –10 dB at all of the azimuth angles.

FIGURE 9

***I/N* with the transmitting power, $P_{HG}$**




Figures 10 and 11 show the separation distance between the radio-relay station and the nadir of HAPS airship. The maximum separation distance is required at the azimuth angle, δ of 0°. And when the radius of HAPS coverage is 55 km and the transmitting power per HAPS ground station, $P_{HG}$ is –50 (dB(W/MHz)), the separation distance required for sharing between radio-relay stations and HAPS ground stations is from 56 km to 73 km.

FIGURE 10

**Separation distance between a radio-relay station and the nadir of a HAPS airship with the transmitting power of HAPS ground stations**

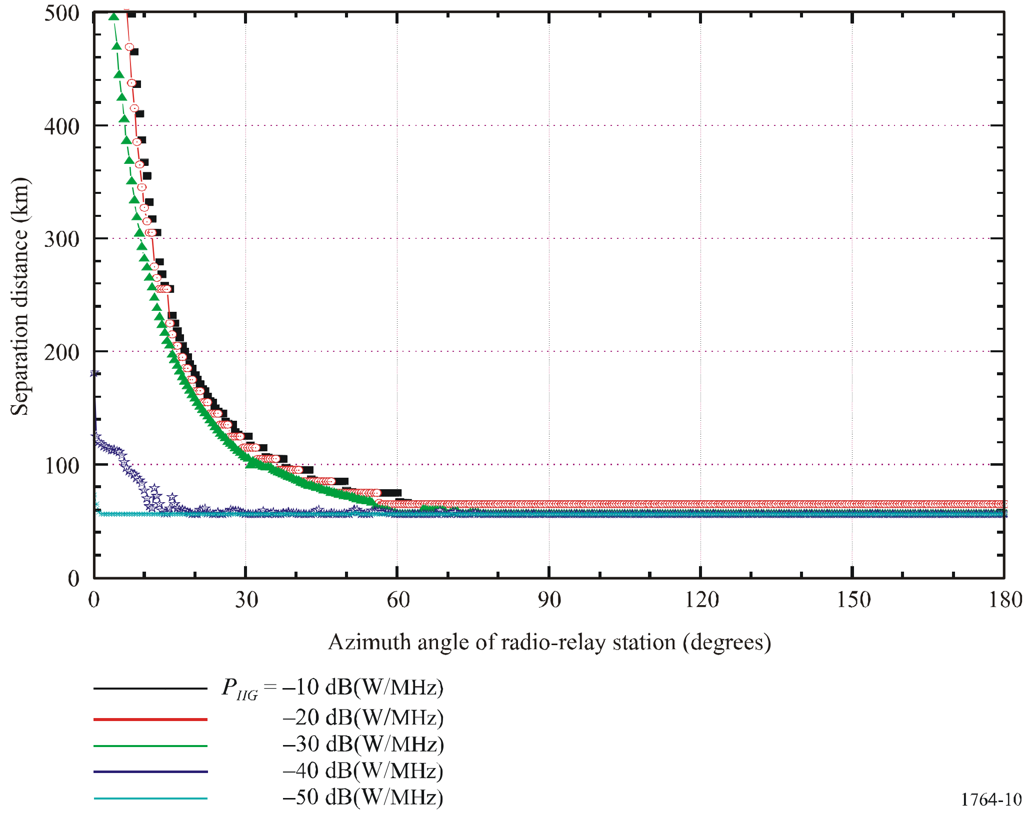
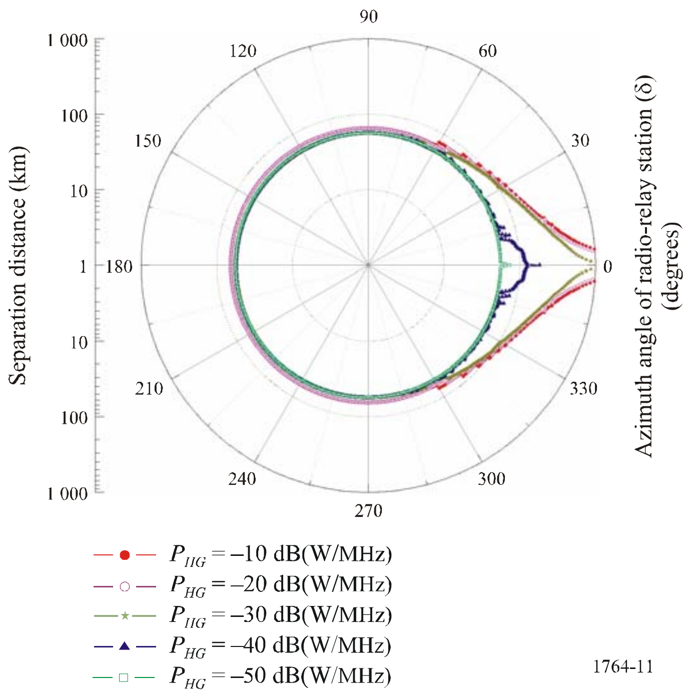



FIGURE 11

**Separation distance between a radio-relay station and the nadir of a HAPS airship (Polar graph)**



## 4 Summary

This Annex shows a method to evaluate interference from a HAPS system to a fixed wireless system and the example of interference evaluation at 6 GHz. The frequency is assumed only to show an example of the interference evaluation.

The interference from HAPS airships to radio-relay stations is evaluated with the variables of pfd level of a HAPS airship on the Earth's surface.

And interference from HAPS ground stations to a radio-relay station is evaluated in terms of $I/N$ and the separation distance required for the sharing as a function of the azimuth angle is calculated.