International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R F.1764-1
(05/2011)

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

Electronic Publication
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RECOMMENDATION ITU-R F.1764-1

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

(2006-2011)

Scope

This Recommendation provides a methodology for interference evaluation that could be used for sharing studies between user links in fixed service (FS) systems using high altitude platform stations (HAPS) and conventional fixed wireless systems in the frequency bands above 3 GHz. Interference situations from HAPS airships and ground stations to the fixed wireless stations are analysed. In this Recommendation, HAPS gateway links are not considered.

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;

c) that information on architectures, including user and gateway links, of systems using high altitude platform stations in the band 5 850-7 075 MHz can be found in Recommendation ITU-R F.1891;

d) that HAPS user links may operate in the bands 47.2-47.5 GHz and 47.9-48.2 GHz;

e) that in some countries HAPS user links may operate in the band 27.9-28.2 GHz and 31.0-31.3 GHz on a non-harmful interference, non-protection basis,

recommends

1 that the methodology described in Annex 1 may be used to evaluate interference from user links in fixed service systems using high altitude platform stations to fixed wireless systems in the bands above 3 GHz.

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

Annex 1

Methodology for interference evaluation from user links in fixed service systems using high altitude platform stations 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 user links in 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 fixed wireless stations are considered.

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

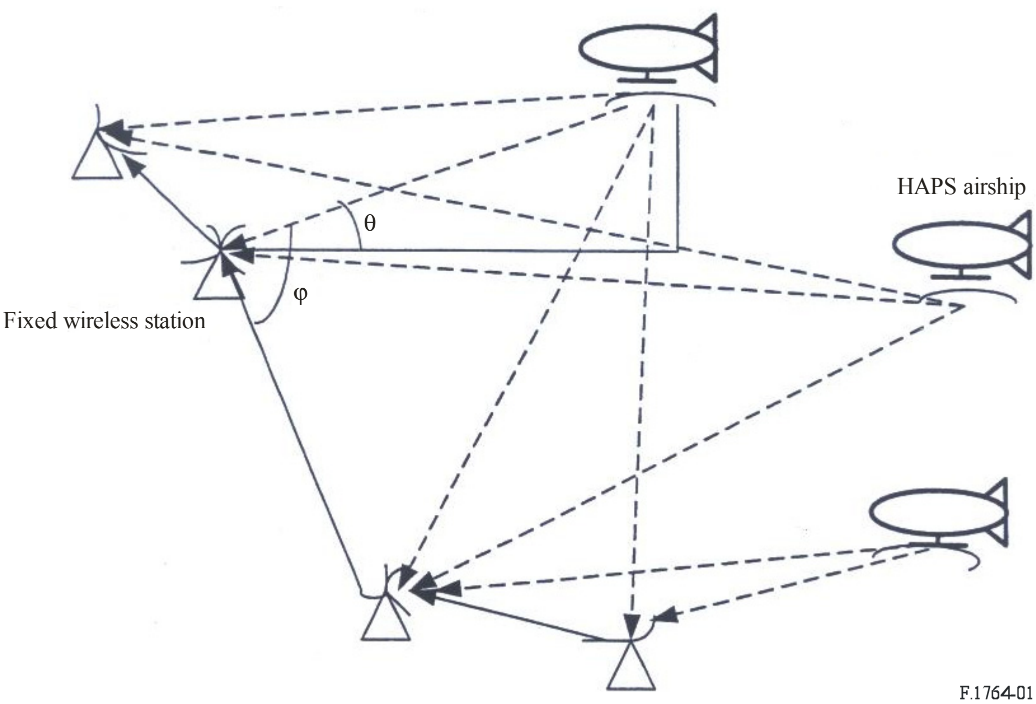
2 Calculation methodology of interference from fixed service systems using HAPS to fixed wireless systems

2.1 Interference from HAPS airships to fixed wireless stations

Figure 1 shows the interference situation from HAPS airships to fixed wireless stations.

FIGURE 1

Interference environment from HAPS airships to fixed wireless 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.

Currently most FS 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, assuming 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 FS systems are specified on a route basis as follows:

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

where:

N_T: receiver thermal noise

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

NOTE 1 – This model reflects a multi-hop fixed wireless station system for baseline interference studies, reflecting the period when microwave systems provided long-haul high-capacity traffic. However, with the development of metropolitan, national and international fibre optic networks, such systems are rapidly being replaced with back-haul systems carrying a diverse variety of traffic and connecting to the fibre network. Hence, most modern deployments contain mainly short links. Therefore, any analysis based upon 50-hop end-to-end degradation of performance caused by interference may no longer be applicable. Instead, each hop would need to be protected individually.

The aggregate interference received at a digital fixed wireless station can be determined by summing the contributions from all visible HAPS airships. Each contribution can be determined as follows:

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

where:

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

$G(\varphi)$: antenna gain of fixed wireless station to the direction of HAPS airship, φ (dBi)

λ: wavelength of the carrier (m)

L_{fr}: feeder loss of fixed wireless station (dB).

2.2 Interference from HAPS ground stations to a fixed wireless station

Figure 2 shows the interference situation from HAPS ground stations to a fixed wireless station.

The interference power from a HAPS ground station to a fixed wireless station is obtained by equation (3):

$$I_G = P_{HG} - L_{fh} + G(\theta_{H-R}) - L_b(p) + G(\theta_{R-H}) - L_{fr} \tag{3}$$

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, θ_{H-R} between the direction of main beam of HAPS ground station and the direction of the interfered fixed wireless station (dBi)

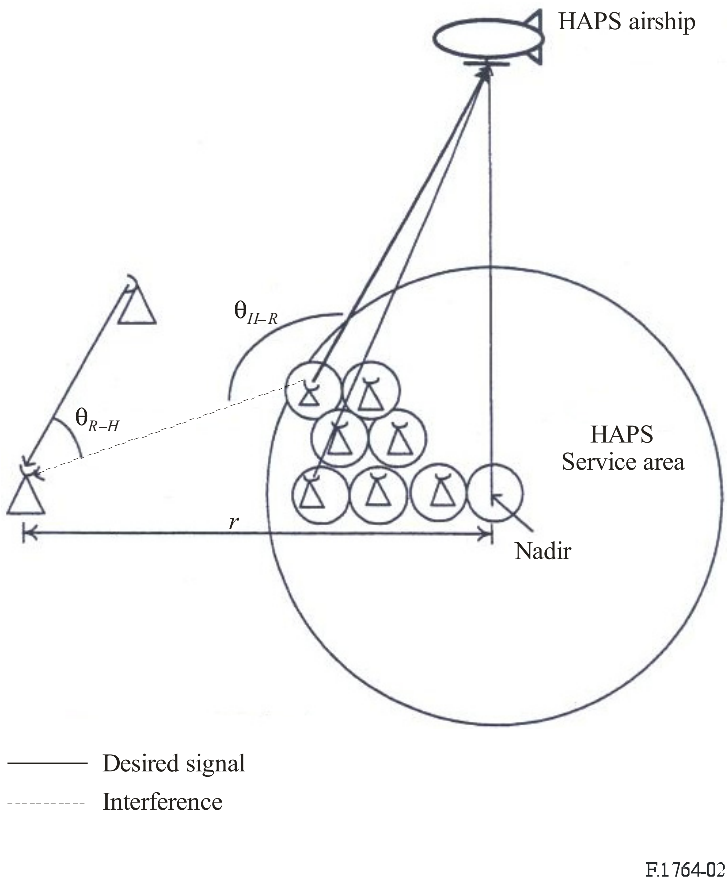
$L_b(p)$: basic transmission loss not exceeded for time percentage, p(%) given in Recommendation ITU-R P.452

$G(\theta_{R-H})$: receiving antenna gain of fixed wireless station at the angle θ_{R-H} between the direction of main beam of fixed wireless station and the direction of the interfering HAPS ground station (dBi)

L_{fr}: feeder loss of the fixed wireless station (dB).

FIGURE 2

Interference environment from HAPS ground stations to a fixed wireless station



The interference power at a fixed wireless station from multiple inputs of HAPS ground stations can be obtained using equation (4) taking into account the mechanism shown in Fig. 3.

In equation (4), 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%:

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

$$+10 \log\left\{ \sum_i \sum_j \left(\sqrt{x_{ij}^2 + y_{ij}^2}\right)^{-2} 10^{\frac{G(\theta_{R-H})}{10}} 10^{\frac{G(\theta_{H-R})}{10}} \right\} - L_{fr} \tag{4}$$

where:

f: frequency (GHz)

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

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

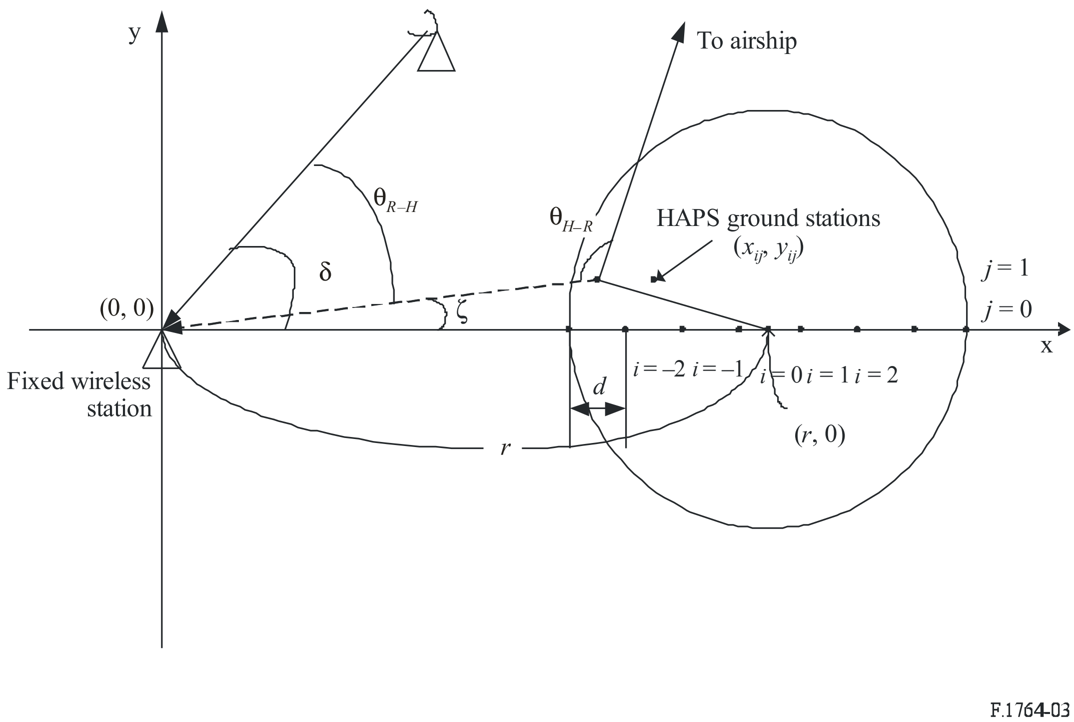
r: distance between fixed wireless station and nadir of HAPS airship

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 fixed wireless station



Once the interference level at a fixed wireless station has been assessed, the I/N ratio can be assessed as follows:

$$I/N = I_{G\text{-}T} - \{10 \log(k\,T\,B) + NF\} \qquad \text{dB} \qquad (5)$$

where:

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

T: temperature (K)

B: bandwidth (Hz)

NF: noise figure of fixed wireless station (dB).

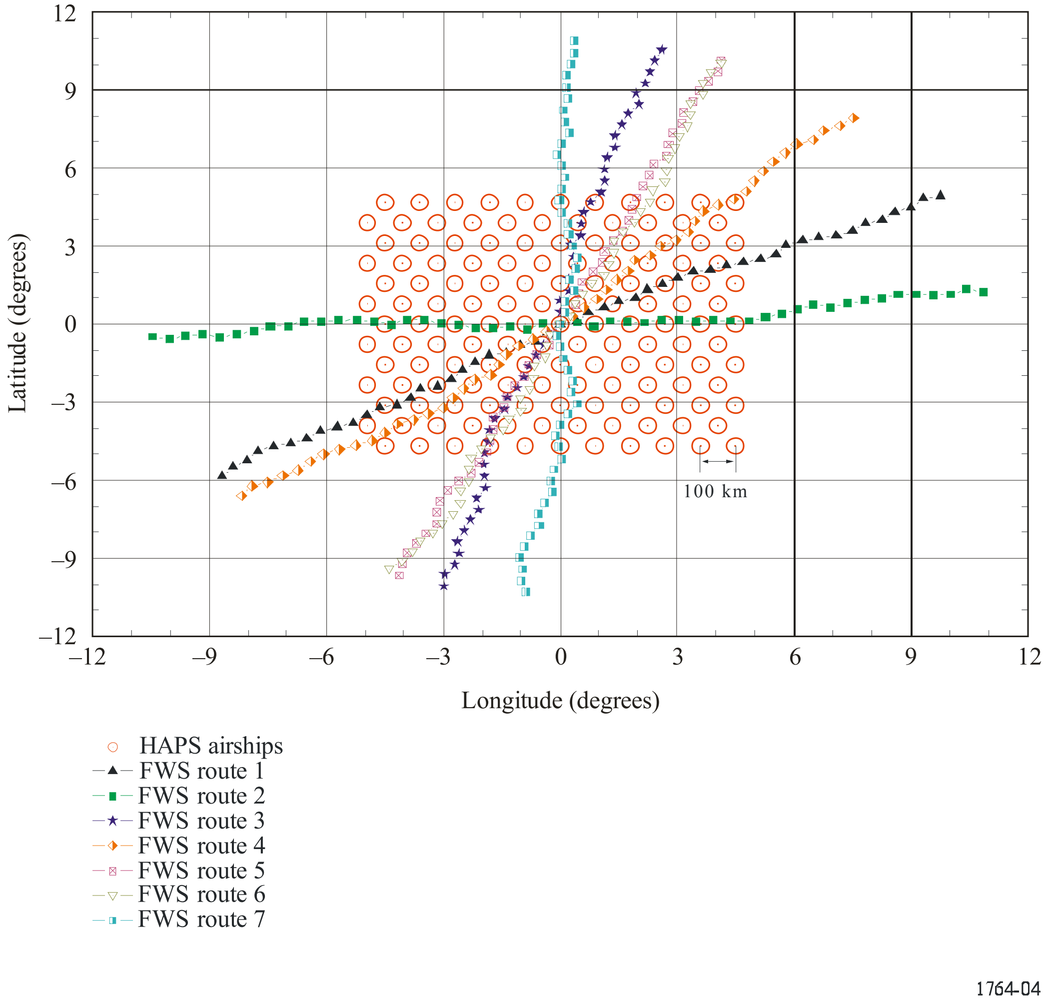
3 Example of interference evaluation from HAPS systems to fixed wireless systems

3.1 Interference from HAPS airships to fixed wireless stations

Figure 4 shows the assumed distribution model of HAPS airships and fixed wireless stations for interference evaluation.

FIGURE 4

Distribution model of fixed wireless stations and HAPS airships



HAPS airships at a fixed point of an altitude of 20 km can cover a 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 an area of 1 000 × 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

Table 2 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. However, since this usage would be superimposed on already existing links which have been coordinated with other systems, the allowance of 10% may already be used up. In order not to increase this interference, it may be required to limit interference to below 1 to 2%. Nevertheless, for illustrating the methodology, assuming the required protection level is 10%, the estimated interference distributions from HAPS airships to digital fixed wireless stations are shown in Figs 5 and 6, with the variables of pfd_{low} and pfd_{high}.

TABLE 2

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 dBi
	Feeder loss	5.5 dB
	Receiver noise figure	4 dB
	Elevation angle between fixed wireless station	Gaussian distribution
HAPS airship	pfd_{low}	$-146 \simeq -140$ (dB(W/(m^2 · MHz)))
	pfd_{high}	$-127 \simeq -118$ (dB(W/(m^2 · MHz)))

In Fig. 5, when the pfd level of HAPS airship is assumed to be –140/–118 (dB(W/(m² · MHz))), the FDP of fixed wireless 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/(m² · MHz))), the FDP of fixed wireless stations in 100% of the routes would be less than the assumed interference criterion of 10%.

FIGURE 5

FDP distribution with *pfd_{low}* from HAPS airships

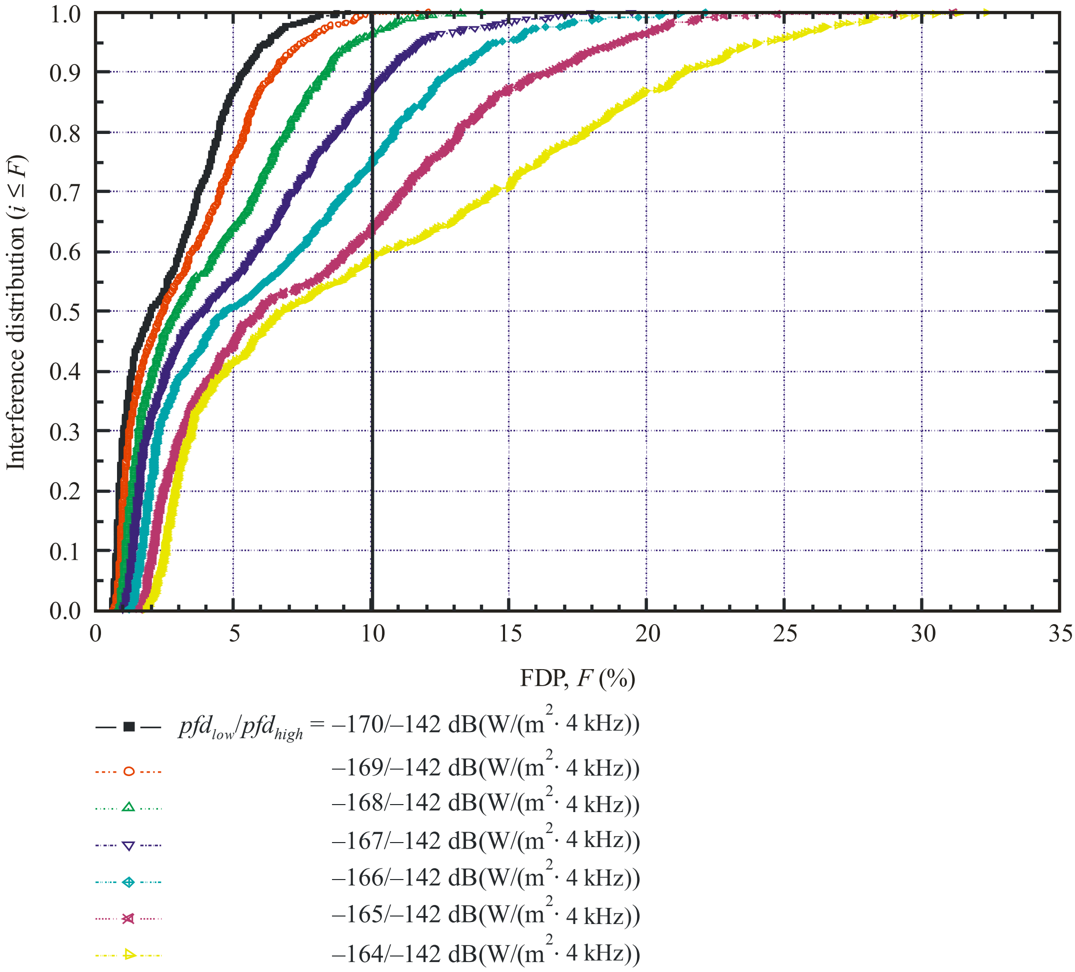


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Figure 6 shows the interference distribution with the changes of pfd_{high}, when pfd_{low} is –145 (dB(W/(m² · MHz))). Even though pfd_{high} is decreased by 6 dB from –121 (dB(W/(m² · MHz))), the maximal difference of the interference distribution less than 10% is only about 5%.

3.2 Interference from HAPS ground stations to a fixed wireless station

Table 3 shows the system parameters of a fixed wireless system and a HAPS system used in the calculation.

FIGURE 6

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

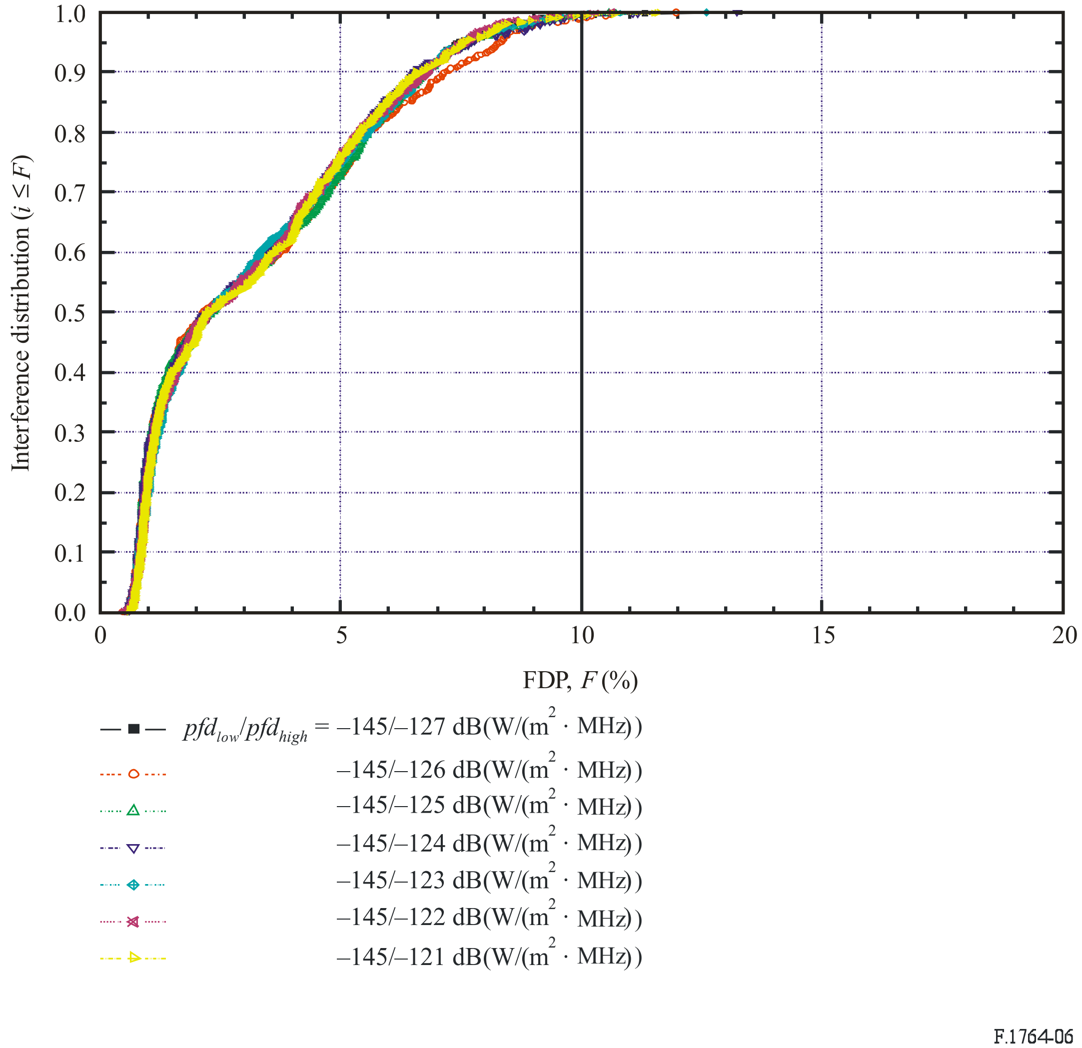


TABLE 3

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

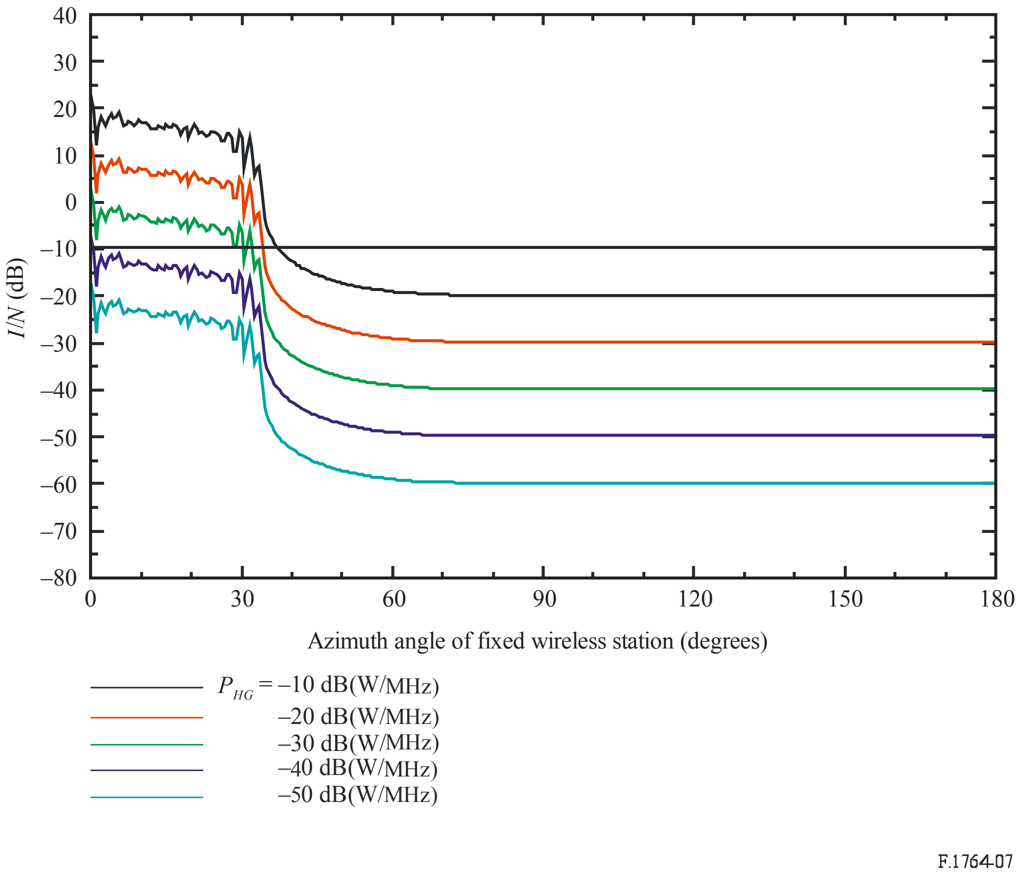
Assuming that T is 293 K, B is 1 MHz, and NF is 6 dB, noise power N is –137.93 (dB(W/MHz)). If I/N = 10% is assumed as a criterion, permissible interference power, I_{G-T} should be less than –147.93 (dB(W/MHz)).

Since I_{G-T} depends on the transmitting power of HAPS ground station, the angle between signal paths, and the distance between fixed wireless 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 7

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



Figures 8 and 9 show the separation distance between the fixed wireless 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 fixed wireless stations and HAPS ground stations is from 56 km to 73 km.

FIGURE 8

Separation distance between a fixed wireless station and the nadir of a HAPS airship with the transmitting power of HAPS ground stations

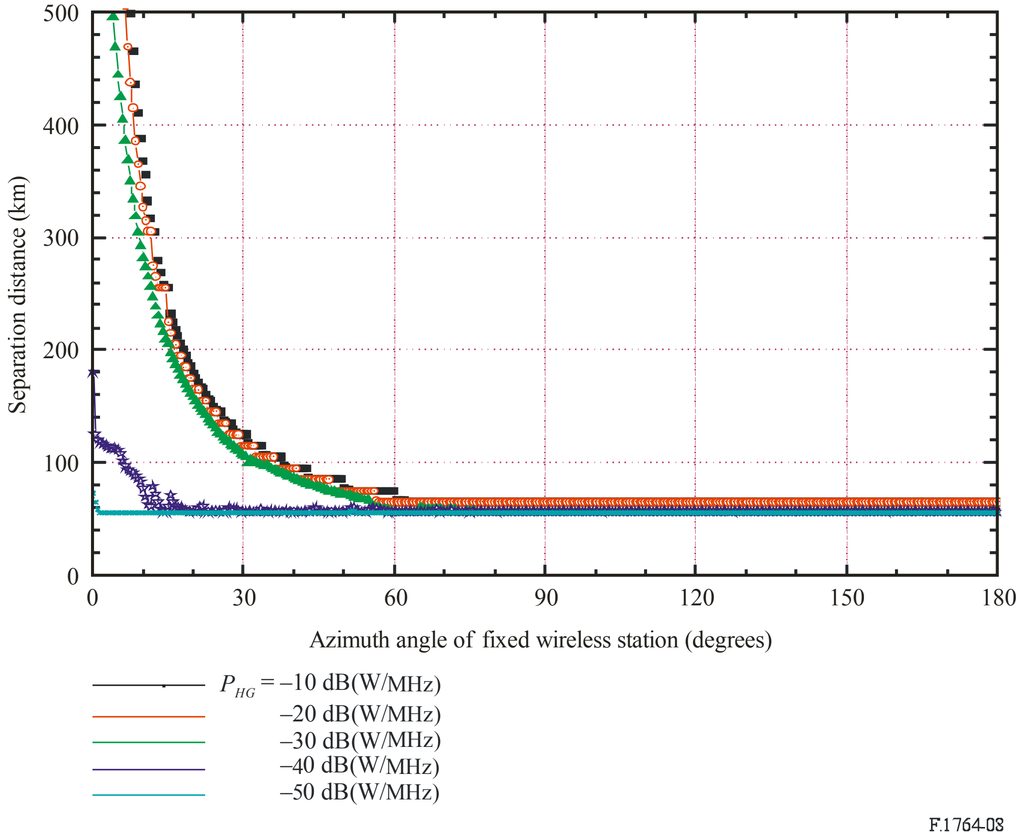
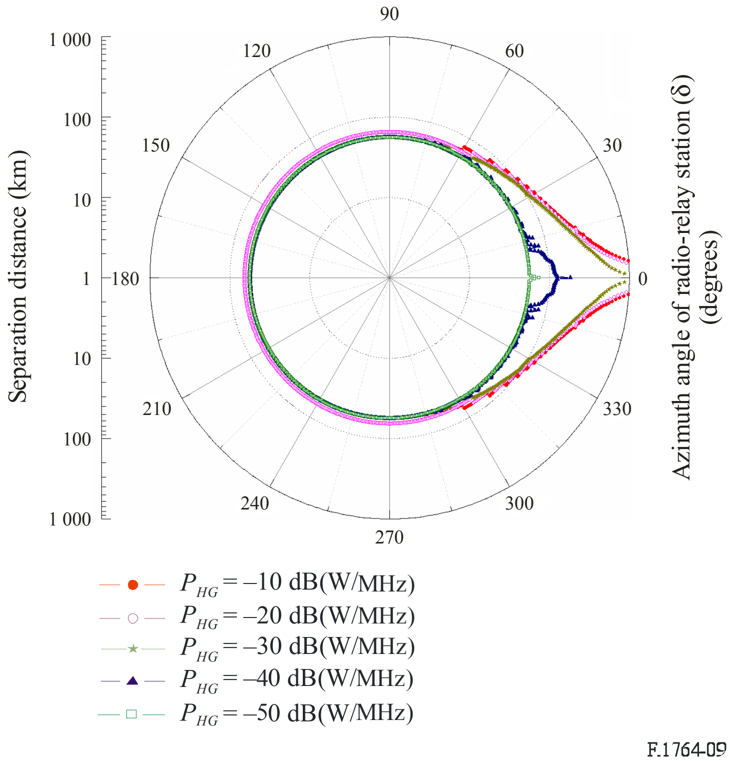


FIGURE 9

Separation distance between a fixed wireless station and the nadir of a HAPS airship (Polar graph)



4 Summary

This Annex shows a method to evaluate interference from a HAPS system user links 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 fixed wireless stations is evaluated with the variables of pfd level of a HAPS airship on the Earth's surface. The model uses an end-to-end fractional degradation of performance of 10% compiled over 50 hops. However, with each hop needing to be protected individually the protection criteria should be based on an *I*/*N* protection of each victim receiver. Furthermore, it is necessary to adopt an appropriate criterion, given that the HAPS service will be superimposed on an already crowded band.

Interference from HAPS ground stations to a fixed wireless station is to be evaluated in terms of *I*/*N* and the separation distance required for the sharing as a function of the azimuth angle is calculated.