



Recommendation ITU-R F.1608
(02/2003)

**Frequency sharing between systems in the
fixed service using high altitude platform
stations and conventional systems
in the fixed service in the bands
47.2-47.5 and 47.9-48.2 GHz**

F Series
Fixed service

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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.1608*

Frequency sharing between systems in the fixed service using high altitude platform stations and conventional systems in the fixed service in the bands 47.2-47.5 and 47.9-48.2 GHz

(2003)

Scope

This Recommendation deals with frequency sharing between conventional fixed service (FS) systems and systems using high altitude platform stations (HAPS) in the bands 47.2-47.5 and 47.9-48.2 GHz. Based on the analysis utilizing HAPS system parameters described in Recommendation ITU-R F.1500, the Annexes provide a methodology for the sharing study as well as a guidance for the sharing feasibility between HAPS and FS systems according to their deployed area coverage.

The ITU Radiocommunication Assembly,

considering

- a) that systems utilizing one or more high altitude platform stations (HAPS) located at fixed points in the stratosphere may possess desirable attributes for high-speed broadband digital communications, including interactive video and other applications, with significant potential for frequency reuse and capable of providing service to a high density of users;
- b) that such systems would be able to provide coverage to metropolitan regions with high elevation angles, and to outlying rural areas or neighbouring countries with low elevation angles;
- c) that broadband digital services provided by such systems in the fixed service are intended to provide widespread communications information infrastructures promoting the global information infrastructure;
- d) that the radio spectrum above 30 GHz is allocated to a variety of radio services and that many different systems are already using or planning to use these allocations;
- e) that there is an increasing demand for access to these allocations;
- f) that the allocation to the fixed service in the bands 47.2-47.5 GHz and 47.9-48.2 GHz is designated for use by HAPS;
- g) that administrations are urged to facilitate coordination between HAPS in the fixed service operating in the bands 47.2-47.5 GHz and 47.9-48.2 GHz and other co-primary services in their territory and adjacent territories;
- h) that because of the visible range of HAPS frequency sharing between HAPS networks and other conventional fixed service systems may present difficulties on a co-area, co-frequency basis,

recommends

1 that the characteristics of systems in the fixed service using HAPS given in Recommendation ITU-R F.1500 may be used in analysing sharing possibilities between HAPS systems in the fixed service and other conventional systems in the fixed service in the bands 47.2-47.5 GHz and 47.9-48.2 GHz;

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

2 that in analysing the sharing possibilities between systems in the fixed service using HAPS and other conventional systems in the fixed service, such as is done in Annex 2, the methodology described in Annex 1 may be used;

3 that, for the sharing possibility between HAPS systems and conventional FS systems, the following results of the analysis in Annex 2 may be taken into account:

- in those areas where a ubiquitous HAPS service is envisioned, such as the urban and suburban coverage areas, co-area frequency sharing with conventional fixed service systems will be difficult. For the typical HAPS system described in Recommendation ITU-R F.1500, with symmetric service areas around the HAPS nadir point, the limit of ubiquitous service is likely to be at the outer edge of the suburban coverage area, at about 80 km from nadir;
- in those areas where a ubiquitous HAPS service is not envisioned, such as the rural coverage area, sharing with other fixed service systems could be feasible provided there is sufficient angular discrimination between conventional systems in the fixed service and HAPS systems operating in the fixed service. Such angular discrimination may only be possible if the conventional fixed service systems are located outside the visible range of the HAPS platform;
- in those areas where the HAPS coverage is limited to only the urban area coverage (UAC) or to both the UAC and the suburban area coverage (SAC), sharing with conventional fixed service systems will only be possible if they are deployed beyond the visible range of the HAPS platform;

4 that further studies could identify additional operational scenarios and mitigation techniques that could facilitate frequency sharing.

Annex 1

The methodology to be used in the analysis of frequency sharing between systems in the fixed service using HAPS and conventional fixed service systems

1 Introduction

This Annex provides the basis for methodology for the investigation of the interference scenarios and sharing possibilities between fixed service systems using HAPS and conventional fixed service systems.

To be specific, the frequency bands identified for the fixed service systems using HAPS are 47.2-47.5 GHz and 47.9-48.2 GHz. These bands are part of the band 47.2-50.2 GHz which is also allocated to the fixed-satellite (Earth-to-space) and mobile services.

There are some fixed service applications in the 47.2-47.5 GHz and 47.9-48.2 GHz bands; Recommendation ITU-R F.758 discusses the considerations necessary in the development of sharing criteria. The bands are not currently in use by the mobile service and no parameters are

available on which to base typical interference analysis. It should be noted, however, that the high density of small user terminals envisaged for use by the HAPS-based network (HAPN) is expected to render sharing with mobile service systems very difficult.

2 Technical characteristics

The technical characteristics for a typical HAPN operating in the bands 47.2-47.5 GHz and 47.9-48.2 GHz are given in Recommendation ITU-R F.1500. This text gives information on both the technical parameters of the equipment and on the gains and directivity of antennas mounted on a HAPS.

Technical characteristics for terrestrial fixed service systems operating in the band 47.2-50.2 GHz are given in Recommendation ITU-R F.758. Reference antenna patterns are given in Recommendation ITU-R F.699.

The propagation characteristics for free space path loss, atmospheric gaseous absorption, and hydrometeor attenuation and scattering are given in various Recommendations in the ITU-R P-Series.

3 Sharing study methodology

Recommendation ITU-R F.1500 indicates that a typical HAPN may offer up to 2 100 cells, with a 7-times frequency reuse factor, within a service diameter of 468 km. In addition there may be up to 40 gateway stations within a diameter of 181 km. Dependent on the bandwidth assigned to an individual HAPN, there may be up to 330 000 simultaneous user terminals in operation from a subscriber base of more than 5 million. Each of these user terminals will have an antenna directed towards the HAPS. The 2 100 beams from the HAPS will extend across the whole of the coverage area, with frequency reuse.

Conventional fixed service usage of the band may be either for wide bandwidth links between well-defined fixed locations, or for high-density fixed links where the location and orientation of each link may not be specified in advance. For both of these types of conventional application the link length will be limited by both terrain and screening and by atmospheric and hydrometeor absorption.

Due to the multiplicity of potential links, the methodology for undertaking sharing studies will have to be based on determining the potential interference between a pair of stations, including the appropriate antenna directivity characteristics, and calculating for many such cases using a random selection of station locations within the coverage areas and subject to appropriate frequency reuse, bandwidth, etc. considerations.

Some preliminary studies of this kind have been undertaken, with 720 million cases in the simulations. These have indicated that co-channel sharing between terrestrial fixed stations and HAPN user terminals will be very difficult, and that necessary geographical separation between a HAPN coverage and a conventional fixed service station depends on the gain, and thus on the orientation of the fixed link. For such adjacent area coverages simulation using unobstructed plane Earth paths will not be adequate and the method should include Earth curvature and the probability of screening from terrain or surface features.

Similarly for interference simulation for the HAPS terminals, adjacent area sharing depends on the location and direction of the fixed links, but in this case there is a smaller probability of diffraction screening due to the oblique paths.

Annex 2

Frequency sharing between the conventional fixed service and HAPS systems

1 HAPS in the fixed service

Recommendation ITU-R F.1500 contains details of the preferred characteristics of a typical HAPS system in the fixed service. These characteristics are given in Tables 1 to 4:

TABLE 1
HAPS coverage zones

Coverage area	Elevation angles (degrees)	Ground range (km) (HAPS at 21 km)
UAC	90-30	0-36
SAC	30-15	36-76.5
RAC	15-5	76.5-203

RAC: rural area coverage

TABLE 2
Platform station transmitter parameters

Coverage area	Transmitter power (dBW)	Antenna gain (dBi)
UAC	1.3	30
SAC	1.3	30
RAC	3.5	41

TABLE 3
User terminal transmitter parameters

Coverage area	Transmitter power (dBW)	Antenna gain (dBi)
UAC	-8.2	23
SAC	-7	38
RAC	-1.5	38

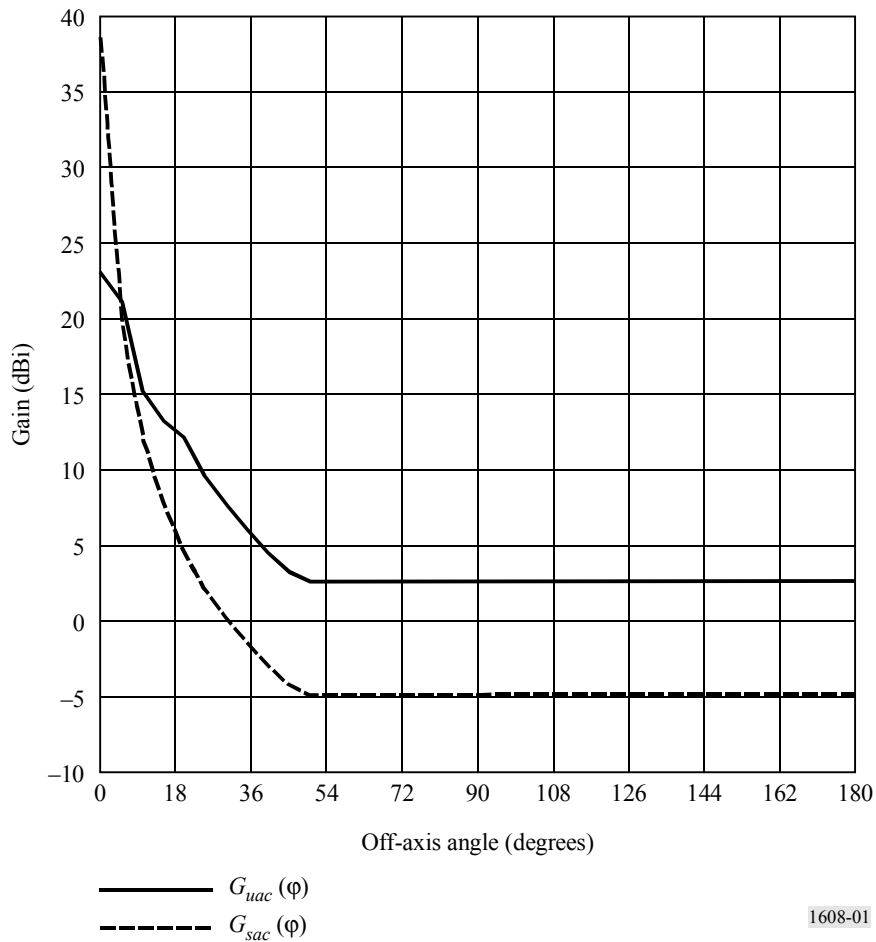
TABLE 4

Interference criteria for HAPS systems

	User terminal	HAPS
Interference criteria (dB(W/MHz))	-149	-151.6

FIGURE 1

**Antenna reference radiation pattern envelopes for HAPS user terminals
(based on Recommendation ITU-R F.699)**



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2 Overview of other fixed service systems in the bands 47.2-47.5 GHz and 47.9-48.2 GHz

Table 5 gives parameters of conventional fixed service systems in the 47 GHz band as provided in Recommendation ITU-R F.758.

System 1 will be used as the interference source (because it has the highest spectral e.i.r.p.), and System 3 as the victim (because it is the system most sensitive to interference).

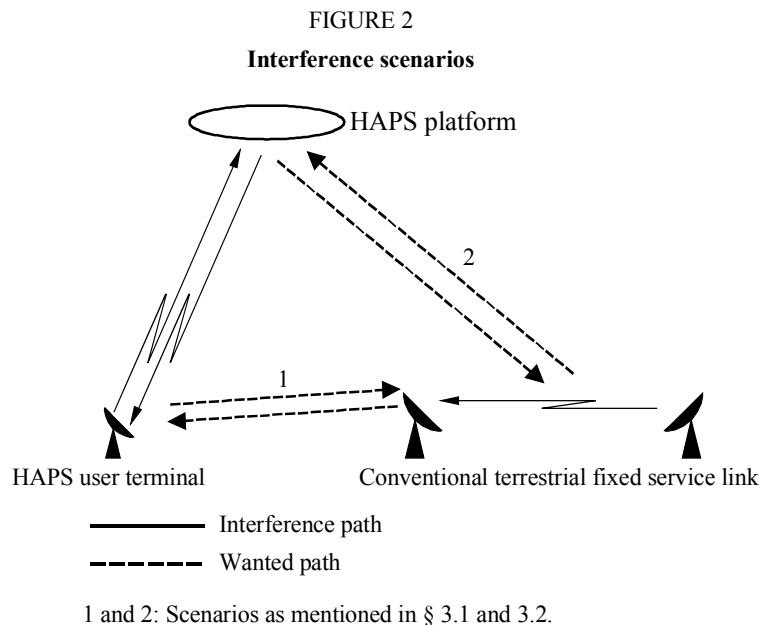
TABLE 5

Terrestrial service fixe system radio characteristics

System	1	2	3	4
Modulation	2-FSK	4-QAM	16-QAM	256-QAM
Capacity (Mbit/s)	1.544	44.736	90	310
Channel bandwidth (MHz)	5	50	50	50
Maximum antenna gain (dBi)	46	46	46	46
Maximum transmitter power (dBW)	-11	-12	-2	-2
Maximum e.i.r.p. (dB(W/MHz))	28	17	27	27
Receiver bandwidth (MHz)	2	50	50	50
Receiver noise figure (dB)	11	13	5	5
Receiver thermal noise (dB(W/MHz))	-133	-133	-137	-137
Interference criteria (dB(W/MHz))	-143	-143	-147	-147

3 Interference analysis

The interference analysis is based on the scenarios identified in Fig. 2.



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3.1 Interference between HAPS user terminals and conventional systems in the fixed service (Scenario 1)

This section examines the following interference scenarios:

- interference from conventional systems in the fixed service into HAPS user terminals;

- interference from HAPS user terminals into conventional systems in the fixed service.

The analysis is based on single and multiple interference sources. A separation distance is determined between the HAPS user terminals and conventional systems in the fixed service such that the relevant interference criterion is not exceeded.

The results of previous studies indicate that co-area frequency sharing will be difficult especially in areas where a ubiquitous HAPS service is envisioned and is only likely to be possible in special situations where carefully selected antenna locations and path geometries are favourable. Hence, the separation distances in this study are calculated on the basis that the conventional systems in the fixed service are located outside the HAPS coverage area.

3.1.1 Interference analysis based on a single interference source

Table 6 gives the calculated values of the separation distance for the single interference analysis. It is assumed that the HAPS user terminal and the conventional systems in the fixed service are located at a height of 10 m.

TABLE 6

Separation distances for interference between HAPS user terminals and conventional fixed service systems

Interference scenario	RAC	SAC	UAC
	Separation distance (km)		
Fixed service into HAPS user terminal	26.5	26.5	29.5
HAPS user terminal into fixed service	28	28	31

3.1.2 Interference analysis based on multiple sources

The multiple interference analysis is based on a Monte-Carlo approach, taking actual United Kingdom terrain data into account.

The aggregate interference at the receiver was calculated for each of 1 000 000 trials, where each trial corresponds to a random distribution of interfering transmitters. The path loss from each transmitter to the receiver was calculated using Recommendation ITU-R P.452.

A cumulative distribution function (CDF) of interference at the receiver was then generated. This CDF does not correspond to the time for which interference may be experienced, but rather to the likelihood, given the random location of terminals.

3.1.3 Interference from conventional systems in the fixed service into HAPS user terminals

For the case of interference from conventional systems in the fixed service into a HAPS user terminal the parameters shown in Table 7 have been assumed. Sites in Cambridgeshire, United Kingdom, at Breckland and Great Bardfield, were chosen. Breckland is made up of low-lying/flat terrain while Great Bardfield is made up of very hilly/rough terrain. The separation distance

between the HAPS user terminal and the area populated with interfering transmitters was set to 30 km (approximately equal to separation distance derived from the single interference analysis in § 3.1.1).

TABLE 7

**Parameters used to assess aggregate interference from conventional systems
in the fixed service into a HAPS user terminal**

Terrestrial fixed service system transmitters	
Density	0.02 sites/km ²
Location	10 km radius around TL660900 (Breckland) or TL675300 (Great Bardfield)
HAPS user terminal receiver	
Location	Madingley, Cambridge (TL388595)

The results of the simulations are illustrated in Figs 3 and 4.

FIGURE 3

**CDF of interference for aggregate interference from conventional systems
in the fixed service into HAPS user terminal located at the edge of a UAC
(based on fixed service systems located at Breckland)**

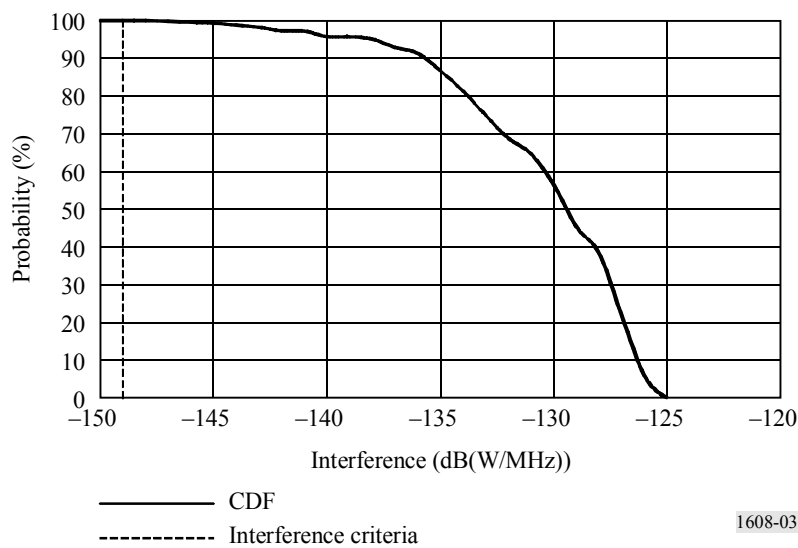
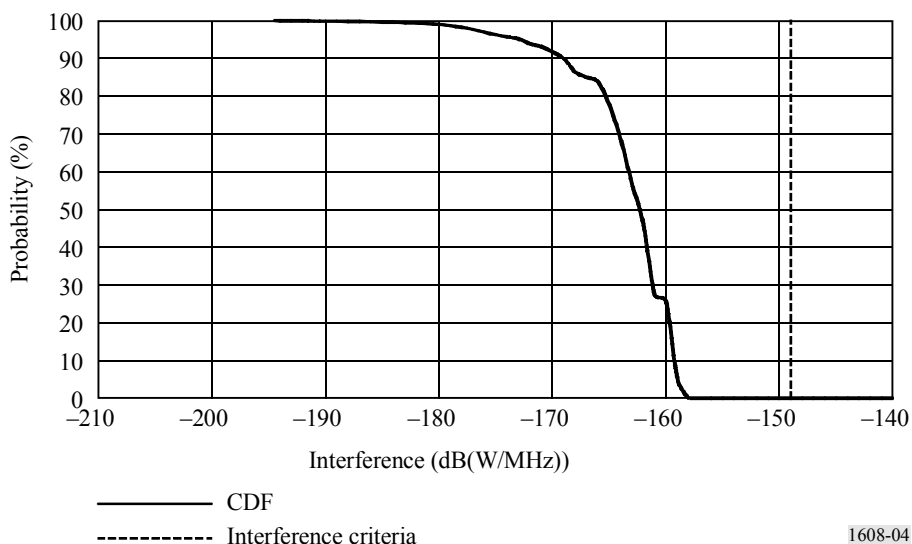


FIGURE 4
Interference CDF for aggregate interference from conventional systems in the fixed service into a HAPS user terminal located at the edge of a UAC (based on fixed service systems located at Great Bardfield)



It can be seen from Figs 3 and 4 that the difference in the terrain accounts for a substantial difference (about 40 dB) in the interference received at the HAPS user terminal. In addition, the interference criterion of the HAPS user terminal is satisfied for the case where the systems in the fixed service are located around Great Bardfield, which has a hilly/rough terrain.

Therefore, terrain will have a substantial impact on interference between HAPS user terminals and conventional systems in the fixed service.

3.1.4 Interference from HAPS user terminals into conventional systems in the fixed service

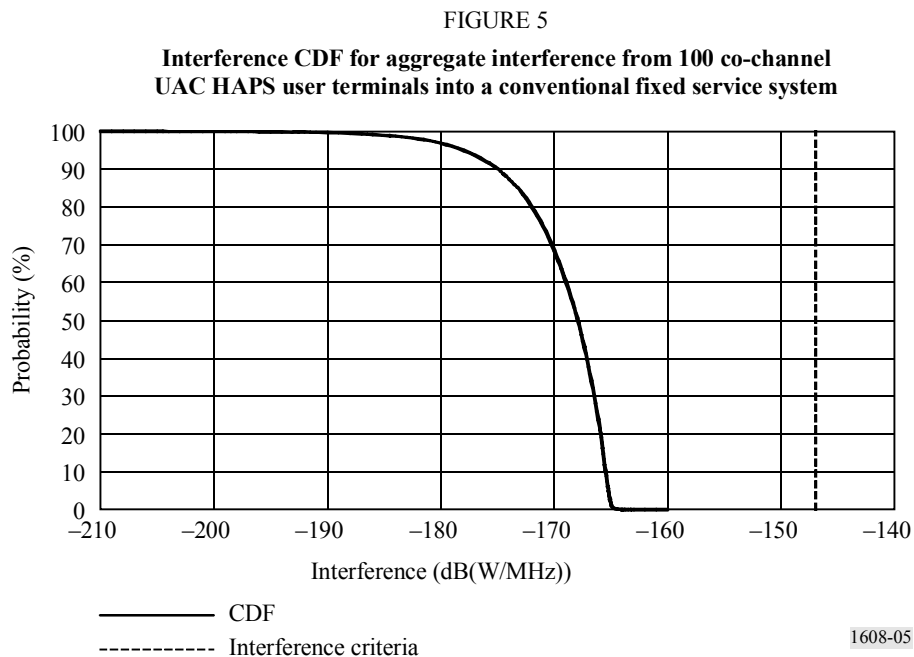
For the case of interference from HAPS user terminals into conventional systems in the fixed service, the parameters shown in Table 8 have been assumed. The analysis is based on 100 co-channel HAPS user terminals distributed around an area with a low-lying/small hill terrain. The distance between the fixed service system and the HAPS coverage area is taken to be 30 km (approximately equal to the separation distances derived in the case single interferer analysis in § 3.1.1).

TABLE 8

Parameters used to assess aggregate interference from HAPS user terminals located in a UAC into conventional systems in the fixed service

HAPS user terminal transmitters	
Density	0.024 sites/km ² (100 co-channel user terminals within the UAC)
Location	36 km radius around SK000000 (UAC around Birmingham)
Fixed service receivers	
Location	Leicester (SK660000)
Azimuth angle	270° (towards the HAPS coverage area)

The result of the simulation is illustrated in Fig. 5.



It can be seen from Fig. 5 that the interference level is well below the long-term interference criterion for the terrestrial fixed service system (-147 dB(W/MHz), see Table 5). This is due to the nature of the terrain between the conventional fixed service systems and the HAPS coverage area.

Hence, interference between HAPS user terminals and the conventional fixed service should be acceptable as long as the conventional fixed service systems are located outside the HAPS coverage regions. The results also indicate that terrain will have a significant impact and must be taken into account. The separation distances derived in § 3.1.1 are valid. But the impact of terrain must be taken into account when considering realistic scenarios such as the aggregate interference case.

3.2 Interference between HAPSs and conventional fixed service systems (Scenario 2)

The following were considered:

- interference from conventional systems in the fixed service into a HAPS;
- interference from a HAPS into conventional systems in the fixed service.

3.2.1 Interference from conventional systems in the fixed service into a HAPS

3.2.1.1 Fixed service systems located outside the HAPS coverage area

The CDF, as shown in Fig. 6, was derived from a statistical analysis based on a random distribution of conventional fixed service transmitters located outside a HAPS coverage area.

FIGURE 6
Interference CDF for aggregate interference from other fixed service systems deployed outside a HAPS coverage area

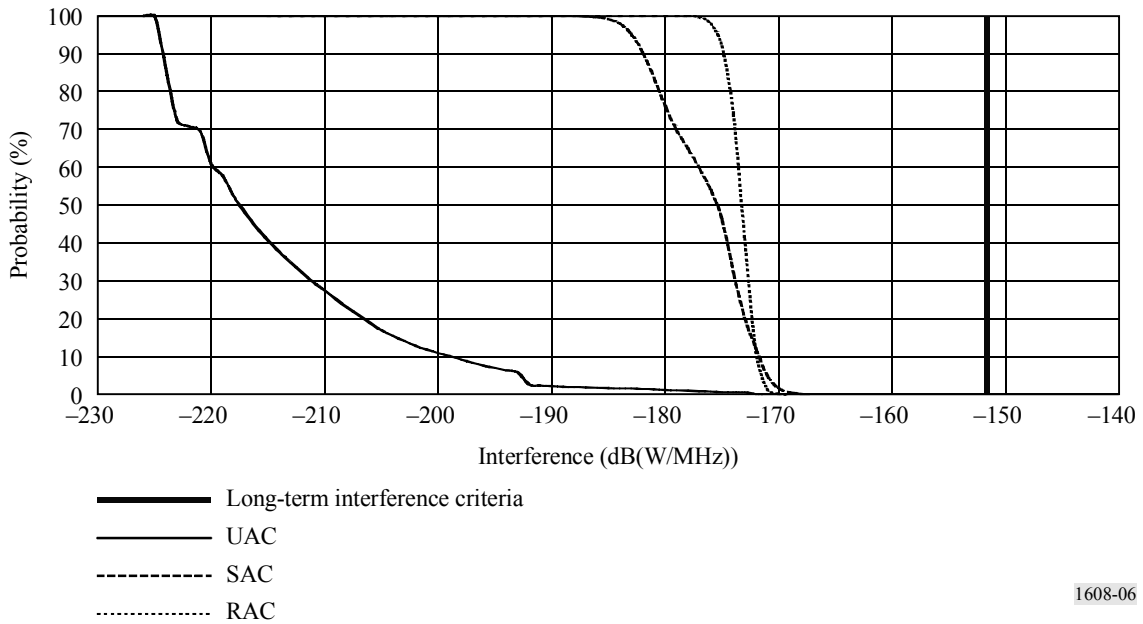


Figure 6 indicates that the aggregate interference from other systems in the fixed service into a HAPS will be significantly below the interference criterion of the HAPS, bearing in mind that the other fixed service systems were located at a distance equal to the separation distance determined in § 3.1.1.

3.2.1.2 Fixed service systems deployed inside a HAPS coverage area

Figure 7 shows the CDFs for aggregate interference from other systems in the fixed service, for the case where the fixed systems are located within the HAPS coverage area.

FIGURE 7
Interference CDFs for aggregate interference from conventional systems in the fixed service into a HAPS

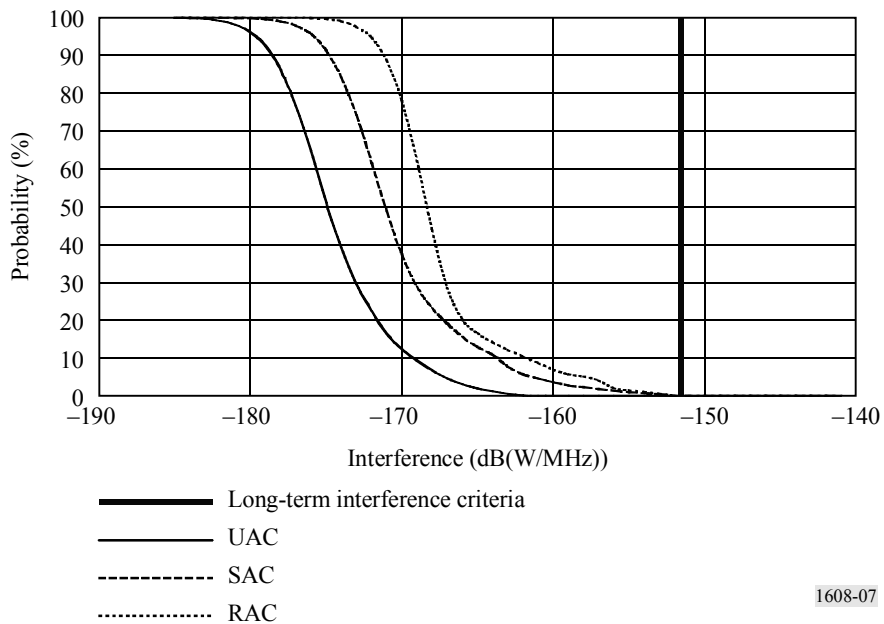


Figure 7 illustrates that the interference criterion is exceeded for approximately 0.25% of the total number (1 000 000) of random distribution trials for the UAC and SAC case but not exceeded at all for the RAC case.

Therefore, interference from the conventional fixed service into HAPS will be acceptable where the systems in the fixed service are located in a HAPS RAC. For conventional fixed service systems located in a HAPS UAC or SAC, there is a 0.25% chance that the interference criterion at the HAPS will be exceeded.

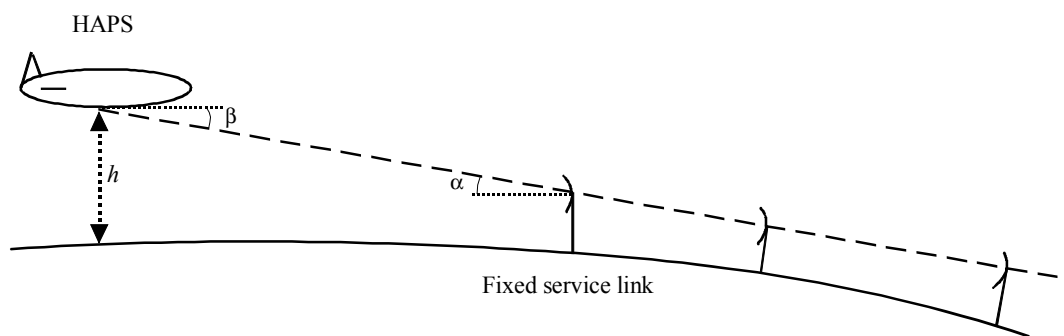
3.2.2 Interference from a HAPS into a conventional fixed service system

In general, HAPSs will communicate with different user terminals over a period of time and these terminals can be anywhere within the HAPS coverage area. These two factors were taken into account during the analysis.

It may be noted that § 2.1 of Annex 1 to Recommendation ITU-R F.1500 indicates that coverage in the RAC is not anticipated at 47 GHz due to atmospheric and rain attenuation. However, in the case where the coverage area of the HAPS extends to user terminals in the RAC at 5° elevation, the interference received at the conventional fixed service system varies from -144 dB(W/MHz) to -120 dB(W/MHz), depending on the location of the fixed service system relative to the HAPS.

The Earth's curvature also has an impact on the interference analysis. The off-boresight angle, α , from the conventional fixed service system towards the HAPS becomes smaller as the distance of the conventional fixed service system from the nadir of the platform increases. This is illustrated in Fig. 8. The reduction in the off-boresight angle results in an increase in antenna gain towards the HAPS. In cases where the HAPS coverage extends to 5°, there is a strong possibility of main beam coupling between the platform and the conventional fixed system. Under these conditions, the conventional fixed service systems would have to be deployed outside the visible range of the platform. This could mean a separation distance of at least 500 km if the HAPS coverage area extends to user terminals at 5°, i.e. user terminals deployed in an RAC.

FIGURE 8
Impact of the Earth's curvature



Therefore, interference from HAPS into conventional systems in the fixed service will exceed the interference criterion as long as the conventional systems in the fixed service are deployed within the visible range of the HAPS.

4 Mitigation techniques

4.1 Introduction

This section explores mitigation techniques that could be employed by HAPS systems in the fixed service to facilitate frequency sharing with conventional systems in the fixed service. The following are considered:

- improved radiation patterns;
- increasing the minimum elevation angle of the HAPS user terminals;
- dynamic channel assignment (DCA);
- environmental screening;
- automatic transmit power control (ATPC).

4.2 Improvement of radiation patterns

Improving the side-lobe performance of the antenna radiation patterns of HAPS user terminals would result in a reduction in the separation distance. In cases where the HAPS user terminals and the conventional systems in the fixed service operate on a co-coverage basis, a 10 dB relaxation in the side lobes of a HAPS user terminal antenna results in a 40% reduction in required separation distance. However, this reduction is not sufficient to facilitate frequency sharing on a co-coverage or co-area basis. In addition, it is important to note that antennas with that level of side-lobe performance may not be feasible in reality.

4.3 Increasing the minimum elevation angles of the HAPS user terminals

Increasing the minimum elevation angle of the HAPS user terminals would reduce the off-boresight gain in the direction of the conventional fixed service station, thereby reducing the level of interference between both stations. For instance increasing the minimum elevation angle in the UAC from 30° to 45° would reduce the separation distance by between 30% to 40% depending on the coverage area. However, additional platforms would be required to maintain complete coverage, thereby increasing the potential for interference from the platform to other systems in the fixed service. Therefore, this mitigation technique would not improve the extent to which frequency sharing is possible.

4.4 DCA

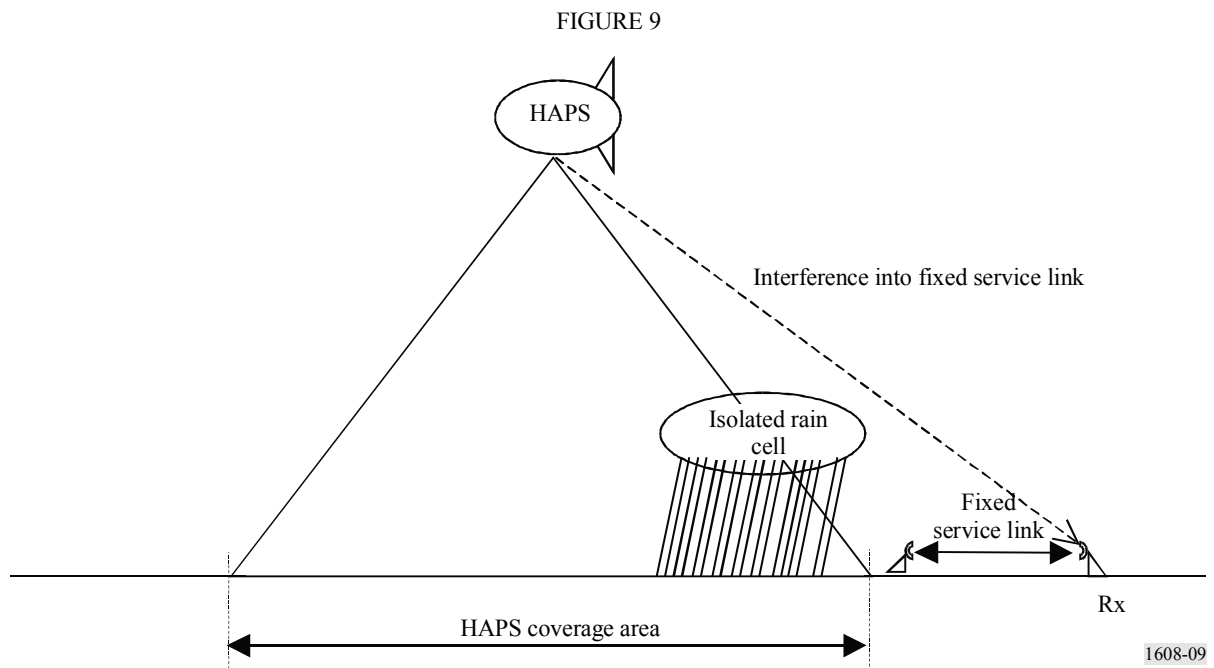
It could not be confirmed whether DCA would have a significant impact on sharing between HAPS in the fixed service and conventional fixed service systems. It should be noted, however, that DCA would lead to a reduction in the total number of channels available to both HAPS systems in the fixed service and conventional fixed service systems, thereby reducing the available system capacity.

4.5 Environmental screening

Locating HAPS user terminals in locations that exploit local screening by buildings, trees etc., can significantly increase the possibility of frequency sharing. However, it must be recognized that such improvements can only be obtained on an ad hoc basis for particular situations and it would be difficult to include in network planning.

4.6 ATPC

Although ATPC would reduce interference into conventional systems in the fixed service, these conventional systems could suffer increased levels of interference during periods of isolated rain cells. For example in Fig. 9, the rain cell is isolated to the edge of the HAPS coverage region, but the interference to conventional systems in the fixed service is increased as the HAPS increases its transmit power to counter signal fading due to the isolated rain cell. This increase in interference will have an impact on all the fixed links that are deployed within the visible range of the HAPS. Therefore, ATPC would not improve the extent to which frequency sharing is possible.



5 Conclusion

The Annex provides a comprehensive analysis of the extent to which sharing would be possible between conventional systems in the fixed service and HAPS systems in the fixed service. A summary of the results is provided in Table 9.

On balance, frequency sharing between HAPS systems in the fixed service and conventional systems in the fixed service will be possible only if the conventional systems in the fixed service are deployed beyond the visible range of the HAPS. In cases where the HAPS coverage extends to user terminals at 5° elevation, i.e. user terminals located in an RAC, this implies a separation distance of at least 500 km between the edge of HAPS coverage area and the conventional systems in the fixed service.

TABLE 9
Summary of results

Interference source	Victim	Comments
Conventional systems in the fixed service	HAPS user terminal	Co-area deployment will not be feasible. Separation distances will be required between coverage areas
HAPS user terminals	Conventional systems in the fixed service	Co-area deployment will not be feasible. Separation distances will be required between coverage areas
Conventional systems in the fixed service	HAPS	Interference should be acceptable as long as fixed service systems are located outside HAPS coverage areas
HAPS	Conventional systems in the fixed service	This scenario dominates. It will only be possible to deploy conventional systems in the fixed service outside the visible range of the platform