RECOMMENDATION ITU-R F.1609-1

Interference evaluation from fixed service systems using high altitude platform stations to conventional fixed service systems in the bands 27.5-28.35 GHz and 31-31.3 GHz

(Question ITU-R 212/9)

(2003-2006)

Scope

This Recommendation describes interference evaluation methodologies from the fixed service (FS) using high altitude platform stations (HAPS) to conventional FS systems in the bands 28 GHz (27.5-28.35 GHz) and 31 GHz (31-31.3 GHz). Examples of interference calculations using these methodologies are also provided in Annexes 1 to 3 for both point-to-point and point-to-multipoint fixed wireless access (FWA) stations.

The ITU Radiocommunication Assembly,

considering

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

b) that since the 47 GHz bands, stated in *recognizing* a) below, are more susceptible to rain attenuation in those countries listed in Nos. 5.537A and 5.543A of the Radio Regulations (RR), the frequency range 18-32 GHz has been studied in ITU-R for possible identification of additional spectrum;

c) that the bands 27.5-28.35 GHz and 31-31.3 GHz are allocated to the FS on a primary basis,

recognizing

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

b) that RR No. 5.537A states that the allocation to the FS in the band 27.5-28.35 GHz may also be used by HAPS in the listed countries, and the use by HAPS is limited to operation in the HAPS-to-ground direction and shall not cause harmful interference to, nor claim protection from, conventional types of FS systems or other co-primary services;

c) that RR No. 5.543A states that the allocation to the FS in the band 31-31.3 GHz may also be used by HAPS in the ground-to-HAPS direction in the listed countries, and the use by HAPS shall not cause harmful interference to, nor claim protection from, conventional types of FS systems or other co-primary services, taking into account RR No. 5.545;

d) that RR No. 5.543A also states that the use of HAPS in the band 31-31.3 GHz shall not cause harmful interference to the passive services having a primary allocation in the band 31.3-31.8 GHz, taking into account the interference criteria given in Recommendations ITU-R SA.1029 and ITU-R RA.769;

e) that Resolution 145 (WRC-03) urgently requested studies on technical, sharing and regulatory issues in order to determine criteria for the operation of HAPS in the bands 27.5-28.35 GHz and 31-31.3 GHz,

recommends

1 that the methodologies contained in Annexes 1 and 2 may be used to evaluate interference from a HAPS-based system to a conventional FS system (point-to-multipoint (P-MP) and point-to-point (P-P)) (see Note 1 and Note 2);

2 that the methodology contained in Annex 3 may be used to evaluate interference from a HAPS to a conventional FS system in the 27.5-28.35 GHz band;

3 that the methodologies contained in Annexes 1, 2 and 3 may be used to develop bilateral agreements between administrations.

NOTE 1 – Recommendation ITU-R F.1569 should be referred to for typical parameters regarding a HAPS-based system.

NOTE 2 – The interference evaluation from a HAPS-based system to the fixed wireless access (FWA) system is discussed for the worst interference scenario in Annex 1 and Annex 2. Adopting interference mitigation techniques described in Recommendation ITU-R F.1608 may shorten the required separation distance.

NOTE 3 – In Annexes 1 and 2, the numerical parameter such as transmission output is fixed. For other parameters, it will not be as difficult to calculate on the basis of the results described there. Furthermore, Recommendation ITU-R F.758 lists some system parameters, some of which include the worst case from the viewpoint of the interference issues.

Annex 1

Methodology for interference evaluation from systems in the FS using HAPS to FWA systems (P-MP) in the bands 27.5-28.35 GHz and 31-31.3 GHz

1 Introduction

This Annex provides a methodology for interference evaluation, technical parameters, and operational techniques to be used for sharing studies between systems in the FS using HAPS and FWA systems operating in P-MP in the bands 27.5-28.35 GHz and 31-31.3 GHz. P-MP systems normally consist of one base station and several subscriber stations.

In the FWA system, there is no rule to use these two frequency bands between FWA base station and FWA subscriber station. Therefore, all interference situations have to be considered.

2 Calculation methodology of interference from HAPS-based system to FWA system (P-MP)

2.1 Interference from HAPS airship to FWA station

The interference power from the spot beam of HAPS airship to FWA station, I (dB(W/MHz)), is obtained by equation (1).

$$I = P_{Tx\_H_mB_n} + G_{Tx\_H_mB_n}(\theta_{H_mB_n\_F}) - L_s - L_{AtmHm\_F} + G_{Rx\_FWA}(\theta_{F\_H_m}) - L_{fRx\_FWA} \quad (1)$$

where:

$P_{Tx\_H_mB_n}$: transmission power density of spot beam (B_n) of HAPS (H_m) (dB(W/MHz))

$G_{Tx\_H_mB_n}(\theta_{H_mB_n\_F})$: antenna gain of spot beam of HAPS airship toward the direction of FWA station (dBi)

L_S: free space pass loss between HAPS airship and FWA station (dB) shown in the following:

$$L_S = 20 \log\left(\frac{4\pi d \times 1\,000}{\lambda}\right)$$

d: distance between HAPS airship and FWA station (km)

λ: wave length (m)

L_{AtmHm_F}: atmospheric absorption loss between HAPS airship and FWA station (dB) (for details, refer to Appendix 1 to Annex 1 and Annex 2 which is based on Recommendation ITU-R F.1404, where absorption is denoted by $A(h,\theta)$)

$G_{Rx\_FWA}(\theta_{F\_H_m})$: receive antenna gain of FWA station toward the direction of HAPS airship (dBi)

L_{fRx_FWA}: feeder loss of FWA station in the receive side (dB).

The ratio of the interference power to the receiver thermal noise, I/N, is obtained by equation.

$$I/N = I - 10 \log(293 \times k \times 10^{NF/10} \times 10^6) \quad \text{dB} \quad (2)$$

where:

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

NF: noise figure of FWA station (dB).

2.2 Interference from HAPS ground station to FWA station

The interference power from HAPS ground station to FWA station, I (dB(W/MHz)), is obtained by equation (3).

$$I = P_{Tx\_GS} - L_{fTx\_GS} + G_{Tx\_GS}(\theta_{H\_F}) - L_s - L_{Atm} - L_{Obs} + G_{Rx\_FWA}(\theta_{F\_H}) - L_{fRx\_FWA} \quad (3)$$

where:

P_{Tx_GS}: transmission power density from HAPS ground station (dB(W/MHz))

L_{fTx_GS}: feeder loss of HAPS ground station (dB)

$G_{Tx\_GS}(\theta_{H\_F})$: antenna gain of HAPS ground station toward the direction of FWA station (dBi)

L_S: free space pass loss between HAPS ground station and FWA station (dB)

L_{Atm}: atmospheric absorption loss between HAPS ground station and FWA station (dB), which is calculated by using Recommendation ITU-R P.676

L_{Obs}: shielding loss between HAPS ground station and FWA station (it is not included in the calculation of required separation distance) (dB)

$G_{Rx\_FWA}(\theta_{F\_H})$: receiving antenna gain of FWA station toward the direction of HAPS ground station (dBi)

L_{fRx_FWA}: feeder loss in FWA station (dB).

The ratio *I*/*N* is obtained by equation (2).

3 Assumptions for interference evaluation

3.1 HAPS system

The parameters of HAPS system are described in Recommendation ITU-R F.1569.

3.2 FWA system with P-MP operation

Section 1 in Appendix 2 describes the assumed parameters of the FWA system with P-MP operation to carry out the interference evaluation, which includes base station and subscriber station.

As for the FWA base station, the following three cases are considered from the viewpoint of antenna beam pattern and scheme of frequency reuse. Herein, it is assumed that the base stations are geographically installed every 2 km.

Case a): Assumed antenna beam pattern is based on Recommendation ITU-R F.1336 and frequency reuse is seemed to be comparatively realistic (segmented 4×4 frequency bands are used by four base stations and its antenna beam is 90° sector: a group of four stations is repeatedly installed).

Case b): Assumed antenna beam pattern is based on Recommendation ITU-R F.1336 and all base stations use same frequency assigned for the base station (therefore, omni pattern is assumed in azimuth direction).

Case c): Assumed antenna beam pattern is a reasonably realistic one, which many service providers would adopt (not listed in Recommendation), and frequency reuse scheme is the same as in Case a).

4 Examples of calculation result in the case of FWA system with P-MP operation

This section shows examples of calculated *I*/*N* characteristics and required separation distance. Regarding the system parameters of the FWA system with P-MP operation, three Cases a), b) and c) are considered for the base station. It is also supposed that the same type of FWA subscriber station is used for three base stations.

4.1 Interference from HAPS airship to FWA system

In examination of the interference from the HAPS airship to the FWA base station, it is supposed that 11×21 HAPS airships are deployed in the area of 500 km $\times$ 1 000 km. The *I*/*N* characteristics are evaluated as a function of distance between the FWA station and the nadir point of the HAPS airship locating in the middle of the 1 000 km side.

Through the calculation, it is assumed that the main beam of the FWA base station always directs toward the horizontal direction. On the other hand, it is supposed herein for the sake of the worst-case analysis that the FWA subscriber station directly points the HAPS airship up to 60° in elevation.

4.1.1 Interference from HAPS airship to FWA base station

Figures 1 and 2 show the *I*/*N* characteristics of the FWA base station of Cases a) and b) respectively, when it is subject to the interference from 11×21 multiple HAPS airships (refer to Fig. 3). The notation “front” in Fig. 1 means that the base stations point toward the centre of multiple HAPS airships face-to-face in azimuth direction. The “side” and “back” indicate the conditions that the base station sees the airship on its side and at its back, respectively. The indicated *I*/*N* shows the worst value among all spot beams of HAPS airships using frequency reuse scheme.

From both Figures, it is seen that the maximum *I*/*N* is about −15 dB. Therefore, under the conditions made here, it is said that the multiple HAPS airships may not give serious interference to the FWA base station. It is noted that front is equal to side and back in Fig. 2, because the antenna pattern is assumed to be omni characteristics in azimuth direction.

When the reasonably realistic beam pattern is used for the FWA base station as in Case c), the *I*/*N* is slightly reduced as shown in Fig. 4. In Case c), the maximum *I*/*N* is about −20 dB.

FIGURE 1

***I*/*N* characteristics in FWA base station of Case a) when interfered from 11 × 21 multiple HAPS airships**

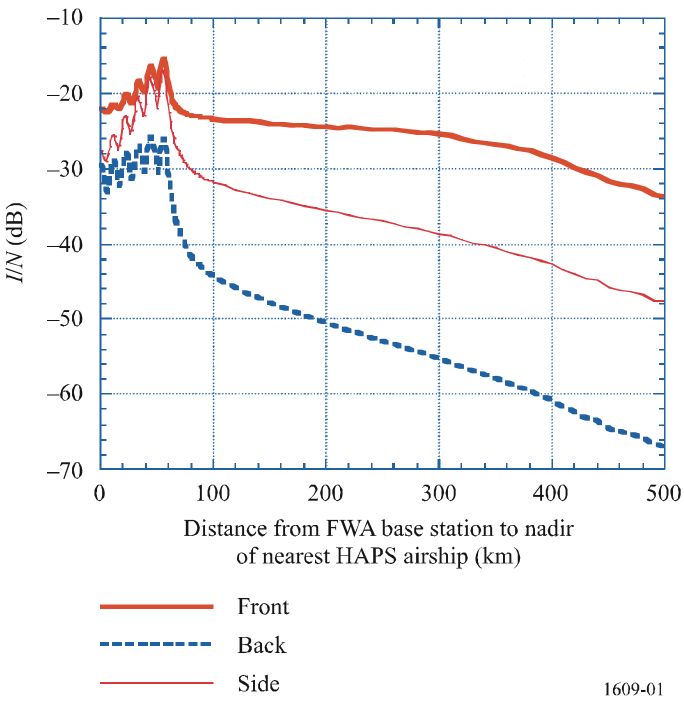


FIGURE 2

***I/N* characteristics in FWA base station of Case b) when interfered from 11 × 21 multiple HAPS airships**

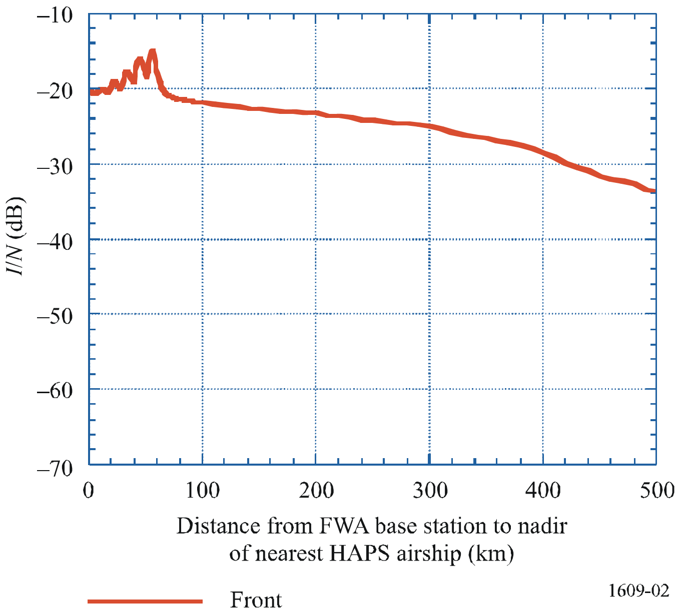


FIGURE 3

HAPS airships located in 500 × 1 000 km area

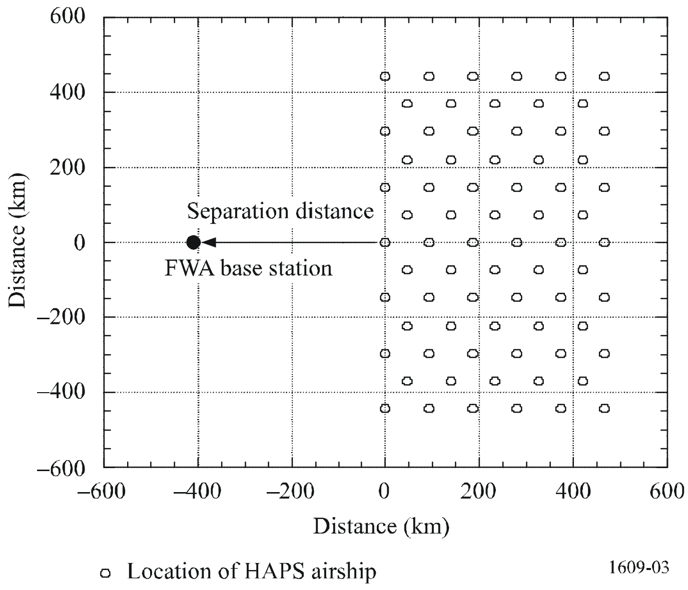
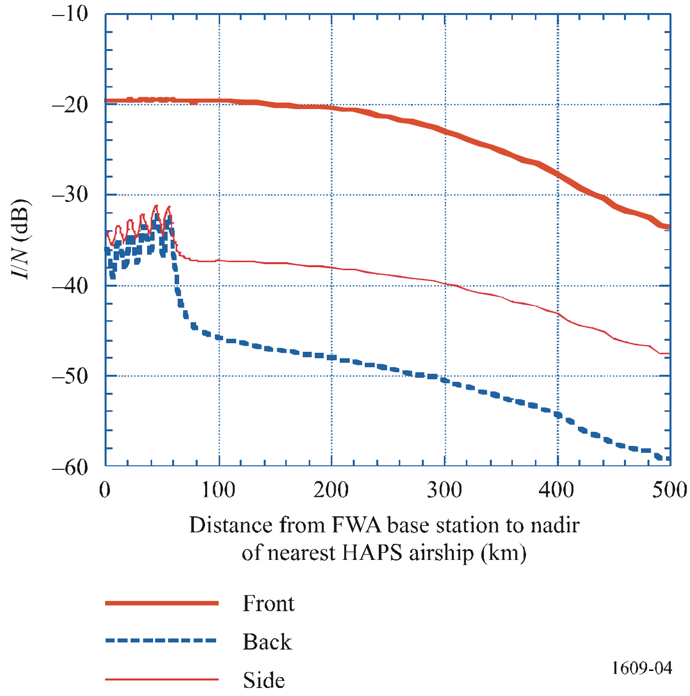


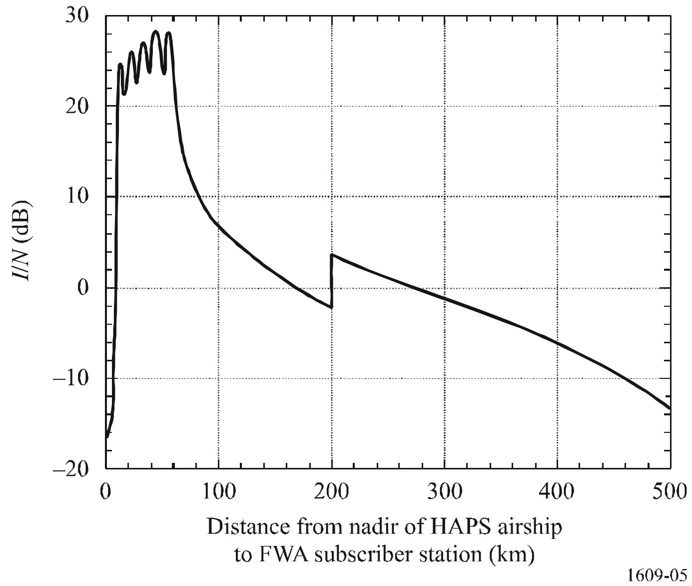
FIGURE 4
***I/N* characteristics in FWA base station of Case c) when interfered from 11 × 21 multiple HAPS airships**



4.1.2 Interference from HAPS airship to FWA subscriber station

Concerning the *I*/*N* characteristic of the FWA subscriber station, when interfered from a single HAPS airship, the worst *I*/*N* becomes a large value of about 30 dB as shown in Fig. 5. It is due to larger antenna gain of the FWA subscriber station than that of the base station and to the assumption that the FWA subscriber antenna directly points the HAPS airship with limitation of maximum elevation angle of 60°. Therefore, the HAPS airship will induce large interference to the subscriber station when the same frequency is used. It is noted in Fig. 5 that the distance of 200 km corresponds to the transition point for the use of 30 cm diameter antenna to that of 60 cm diameter antenna (refer to Note 1 of Table 2).

FIGURE 5
***I/N* characteristics in FWA subscriber station when interfered from single HAPS airship**



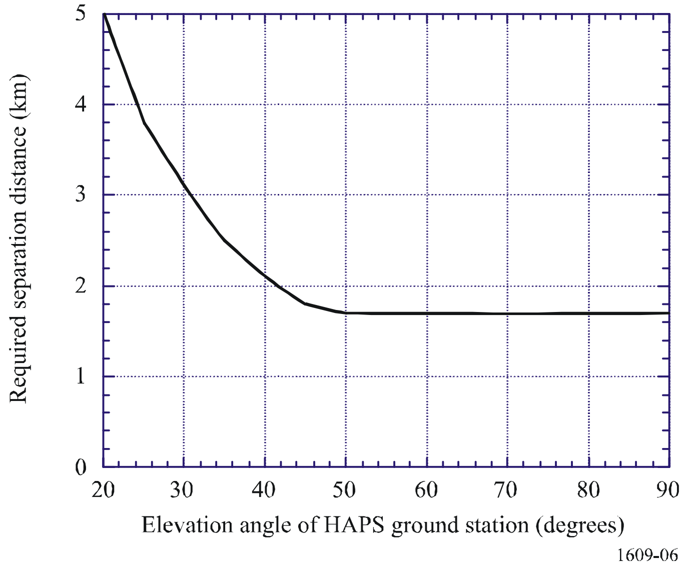
4.2 Interference from HAPS ground station to FWA system

Regarding the interference from the HAPS ground station to the FWA station, analysis is carried out only for the condition of line of sight. Furthermore, it is assumed that the altitude of the HAPS ground station and that of the FWA station (base station and subscriber station) is the same and that the antenna gain of the FWA base station directing toward the HAPS ground station is the same in the three Cases of a), b) and c). The calculation is made for only the case of the single entry, under the condition that the two stations, which are the HAPS ground station with elevation angle of more than 20° and the FWA station pointing horizontal direction, point face-to-face in azimuth. The assumed *I*/*N* value for this analysis is −15 dB.

4.2.1 Interference from HAPS ground station to FWA base station

Figure 6 shows the required separation distance when the HAPS ground station gives interference to FWA base station. Using the assumed *I*/*N* of −15 dB and the assumed minimum elevation angle of 20°, the separation distance is about 5 km. Considering that the FWA base station is installed repeatedly with frequency reuse by distance of 2-3 km, coexistence of the FWA base station and the HAPS ground station would be difficult unless any interference mitigation techniques are introduced.

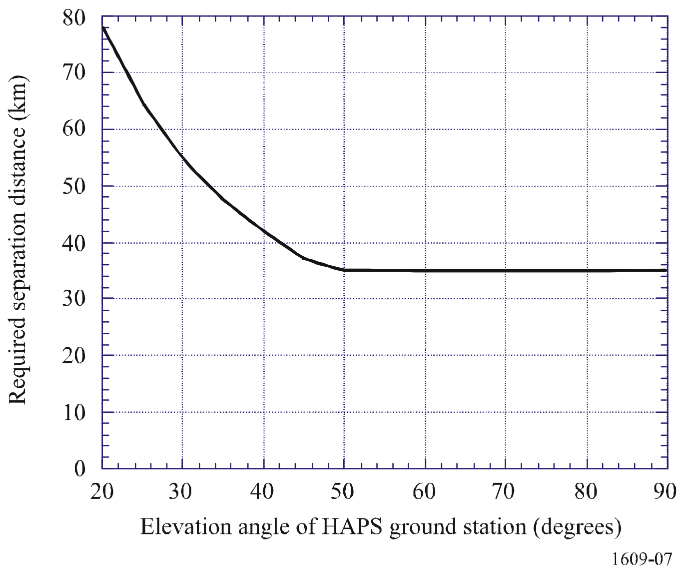
FIGURE 6
Required separation distance when HAPS ground station gives interference to FWA base station as a function of elevation angle of HAPS ground station



4.2.2 Interference from HAPS ground station to FWA subscriber station

Figure 7 shows the required separation distance when the HAPS ground station gives interference to the FWA subscriber station using the assumed *I*/*N* of −15 dB. Using the assumed *I*/*N* of −15 dB and the elevation angle of 20°, the separation distance is about 80 km. Coexistence of the FWA subscriber station and the HAPS ground station is impossible without interference mitigation techniques.

FIGURE 7
Required separation distance when HAPS ground station gives interference to FWA subscriber station as a function of elevation angle of HAPS ground station



5 Summary

This Annex shows a method to evaluate interference from the HAPS transmitters into FWA receivers (P-MP) in terms of I/N and evaluates the required separation distance for some assumed deployments of FWA stations and HAPS stations.

Annex 2

Methodology for interference evaluation from systems in the FS using HAPS to FWA systems (P-P) in the bands 27.5-28.35 GHz and 31-31.3 GHz

1 Introduction

This Annex provides a methodology for interference evaluation, technical parameters, and operational techniques to be used for sharing studies between systems in the FS using HAPS and FWA systems operating in P-P in the bands 27.5-28.35 GHz and 31-31.3 GHz. A P-P system consists of one pair of two radio stations directing face-to-face (in this Annex, this radio station is called FWA station for the sake of simplicity).

2 Calculation methodology of interference from HAPS-based system to FWA system (P-P)

Since the calculation methodology of interference between the HAPS system and FWA system with P-P operation is the same as that described in § 2 in Annex 1, therefore the equation for calculation is herein omitted.

3 Assumptions for interference evaluation

3.1 HAPS system

The parameters of HAPS system are described in Recommendation ITU-R F.1569.

3.2 FWA system with P-P operation

Section 2 in Appendix 2 describes the assumed parameters of the FWA system with P-P operation to carry out the interference evaluation.

4 Examples of calculation results in the case of FWA system with P-P operation

4.1 Interference from HAPS airship to FWA system

In examination of the interference from the HAPS airship to the FWA station, the I/N characteristics are evaluated as a function of distance between the FWA station and the nadir point of the HAPS airship. Through the calculation, it is supposed herein for the sake of the worst-case analysis that the FWA station directly points the HAPS airship up to 60° in elevation.

Concerning the *I*/*N* characteristic in the FWA station, when interfered from single HAPS airship, the worst *I*/*N* becomes a large value of about 30 dB as shown in Fig. 8. It is due to larger antenna gain of the FWA station and to the assumption that the FWA antenna directly points the HAPS airship with limitation of maximum elevation angle of 60°. Therefore, the HAPS airship will induce large interference to the FWA station when the same frequency is used. It is noted in Fig. 8 that the distance of 200 km corresponds to the transition point for the use of 30 cm diameter antenna to that of 90 cm diameter antenna (refer to Note 1 of Table 3).

4.2 Interference from HAPS ground station to FWA system

Regarding the interference between the HAPS ground station and the FWA station treated herein, analysis is carried out only for the condition of line of sight. Furthermore, it is assumed that the altitude of the HAPS ground station and that of the FWA station is the same. The calculation is made for only the case of the single entry, under the condition that the two stations, which are the HAPS ground station with elevation angle of more than 20° and the FWA station pointing horizontal direction, point face-to-face in azimuth. The assumed *I*/*N* value in this analysis for frequency sharing is −15 dB.

FIGURE 8

***I*/*N* characteristics in FWA station when interfered from single HAPS airship**

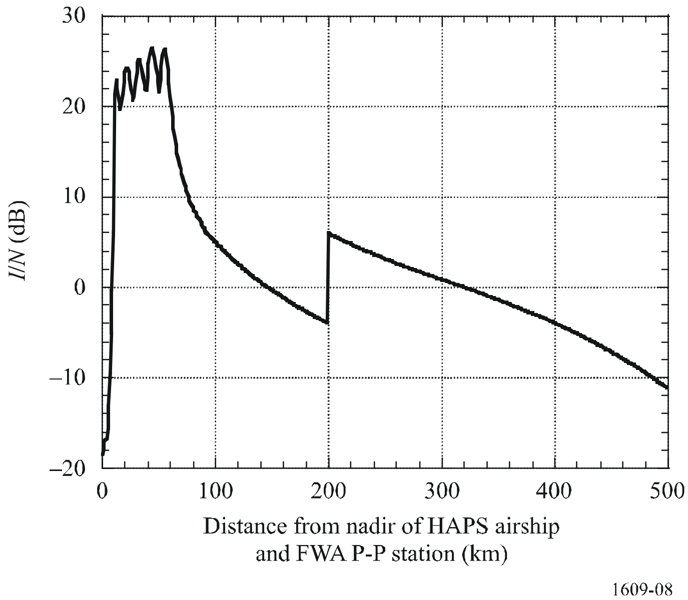
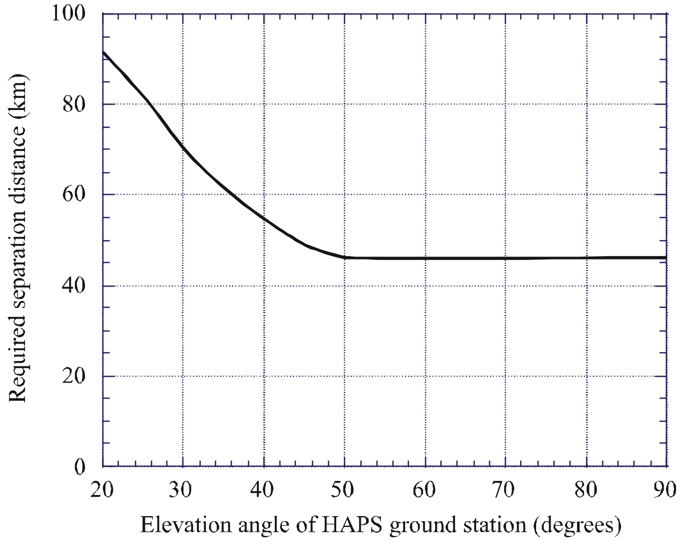


Figure 9 shows the required separation distance when the HAPS ground station gives interference to the FWA station. Using the *I*/*N* value of −15 dB and a maximum elevation angle of 20°, the separation distance is about 92 km. Coexistence of the FWA station (P-P) and the HAPS ground station is impossible without interference mitigation techniques.

FIGURE 9

Required separation distance when HAPS ground station gives interference to FWA station as a function of elevation angle of HAPS ground station



1609-09

5 Summary

This Annex shows a method to evaluate interference from the HAPS transmitters into FWA receivers (P-P) in terms of *I*/*N*, and evaluates the required separation distance for some assumed deployments of FWA stations and HAPS stations.

Frequency sharing between HAPS ground stations and FWA system on the terrestrial surface could be possible on co-location basis, using some proper means such as dynamic frequency assignment and/or sufficient coordination, which will be national matters. An efficient way to reduce interference between HAPS ground stations and FWA system is locating HAPS ground stations not to be seen directly from FWA system. It is also noted that the interfering signal is intercepted by hills and/or buildings for most of the cases that two stations are located more than 100 km apart.

Appendix 1
to Annexes 1 and 2

Propagation attenuation due to atmospheric gases in the slant path between HAPS airships and ground stations in the bands 27.5-28.35 GHz and 31-31.3 GHz

The propagation attenuation due to atmospheric gases in the slant path between HAPS airships and ground stations has been estimated using the minimum propagation attenuation due to atmospheric gases. This minimum propagation attenuation was determined in accordance with the method described in Recommendation ITU-R F.1404, which is, in turn, based on the methodology of Recommendation ITU-R P.676. The assumed climate parameters are given in Table 1 of Recommendation ITU-R F.1404.

The numerical formulae for atmospheric attenuation which approximates the theoretical values are given in the following sections, where:

$A_L(h,\theta)$, $A_M(h,\theta)$, $A_H(h,\theta)$: total atmospheric loss (dB) for the low-latitude (within 22.5° of the equator), mid-latitude (greater than 22.5°, but less than 45° from the equator) and high-latitude (45° or more from the equator) areas, respectively;

h: ground station altitude above sea level (km);

θ: elevation angle (degrees), respectively.

The approximation was carried out for $0 \le h \le 3$ km and $0° \le \theta \le 90°$. The actual elevation angle may be determined from the elevation angle developed under free space propagation conditions using the method in Recommendation ITU-R F.1333. For actual elevation angles below 0°, the attenuation for 0° should be used.

1 Frequency band 27.5-28.35 GHz

In this frequency band, the attenuation is slightly smaller at higher frequencies in the low-latitude and mid-latitude areas and slightly larger at higher frequencies in the high-latitude area. Therefore, the following formulae give the attenuation at 28.35 GHz in the case of the low-latitude and mid-latitude areas and the attenuation at 27.5 GHz in the case of the high-latitude area.

$$A_L(h,\theta) = 21.28 / \left[1 + 0.95050\theta + 0.030650\theta^2 + h(0.3381 + 0.44660\theta) + h^2(0.2331 + 0.11690\theta)\right] \quad (1a)$$

$$A_M(h,\theta) = 11.63 / \left[1 + 0.81670\theta + 0.026490\theta^2 + h(0.2688 + 0.44860\theta) + 0.1394h^2\right] \quad (1b)$$

$$A_H(h,\theta) = 8.77 / \left[1 + 0.82590\theta + h(0.2163 + 0.30370\theta) + 0.1067h^2\right] \quad (1c)$$

2 Frequency band 31-31.3 GHz

In this frequency band, the attenuation is larger at higher frequencies and, therefore, the following formulae give the attenuation at 31 GHz.

$$A_L(h,\theta) = 19.54 / \left[1 + 0.93230\theta + 0.025530\theta^2 + h(0.3416 + 0.44130\theta) + h^2(0.1980 + 0.080160\theta)\right] \quad (2a)$$

$$A_M(h,\theta) = 11.76 / \left[1 + 0.81370\theta + 0.020330\theta^2 + h(0.2740 + 0.39350\theta) + 0.1203h^2\right] \quad (2b)$$

$$A_H(h,\theta) = 9.52 / \left[1 + 0.81600\theta + h(0.2378 + 0.27220\theta) + 0.08949h^2\right] \quad (2c)$$

Appendix 2
to Annexes 1 and 2

Parameters of FWA system for sharing study

This Appendix describes the system parameters of FWA with P-MP operation, which include both the base station and subscriber station and the system parameters of FWA with P-P operation.

1 FWA system with P-MP operation

As for the FWA base station, the following three Cases are considered from the viewpoint of antenna pattern of the base station and reuse scheme of frequency. Herein, it is assumed that the base stations are installed every 2 km.

Case a): Assumed antenna beam pattern is based on Recommendation ITU-R F.1336-1 and frequency reuse is deemed to be comparatively realistic (segmented 4×4 frequency bands are used by four base stations and its antenna beam is 90° sector: a group of four stations is repeatedly installed).

Case b): Assumed antenna beam pattern is based on Recommendation ITU-R F.1336-1 and all base stations use same frequency assigned for the base station (therefore, omni pattern is assumed in azimuth direction).

Case c): Assumed antenna beam pattern is a reasonably realistic one, which many service providers would adopt (not listed in Recommendation), and frequency reuse scheme is the same as Case a).

Table 1 and Table 2 show the parameters of the FWA base station for the above three Cases and that of the FWA subscriber station which is assumed to be same for the three Cases, respectively. As for Case c), the cosec characteristic is used, which is manufactured by a certain antenna hardware provider.

TABLE 1

Parameters of base station in P-MP FWA system

Parameter	Case a)		Case b)		Case c)	
	31 GHz	28 GHz	31 GHz	28 GHz	31 GHz	28 GHz
Transmission output (dBW)	–5	–4	–5	–4	–5	–4
Output spectral density (dB(W/MHz))	–17	–18.1	–17	–18.1	–17	–18.1
Noise figure (dB)	7	6	7	6	7	6
Receiver thermal noise-calculated (dB(W/MHz))	–137	–138	–137	–138	–137	–138
Antenna gain (dBi)	15	15	15	15	15	15
Antenna pattern (azimuth, Fig. 10)	Rec. ITU-R F.1336(1)	Rec. ITU-R F.1336(1)	omni	omni	cosec characteristic	cosec characteristic
Antenna pattern (elevation, Fig. 11)	Rec. ITU-R F.1336(2)	Rec. ITU-R F.1336(2)	Rec. ITU-R F.1336(2)	Rec. ITU-R F.1336(2)	cosec characteristic	cosec characteristic
Feeder loss (dB)	0	0	0	0	0	0
Modulation	QPSK	QPSK	QPSK	QPSK	QPSK	QPSK

(1) Beam pattern is the mask of the measured characteristic shown in Fig. 15 of Recommendation ITU-R F.1336.

(2) Beam pattern is expressed by equations (1a), (1b) and (1c) in Recommendation ITU-R F.1336.

FIGURE 10

Assumed antenna beam pattern in azimuth direction

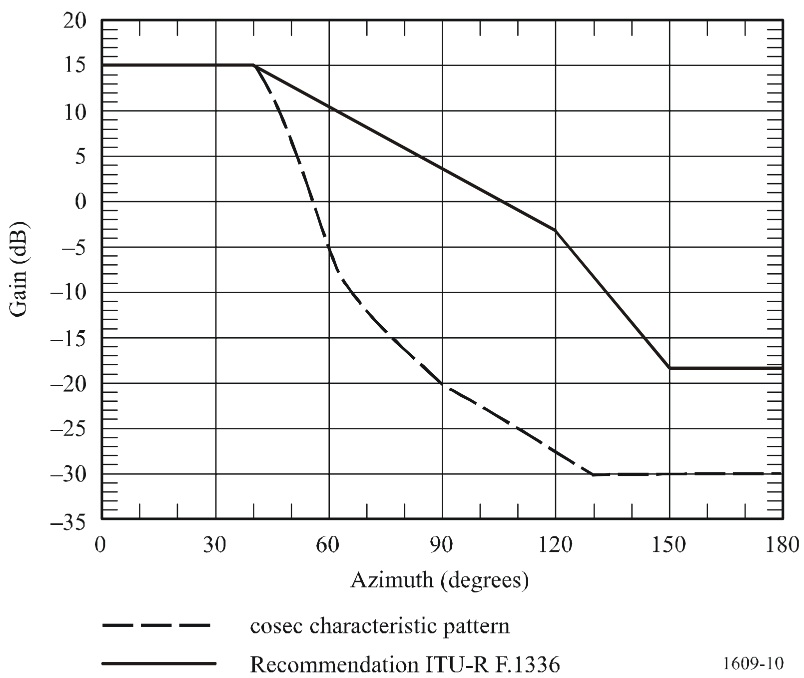
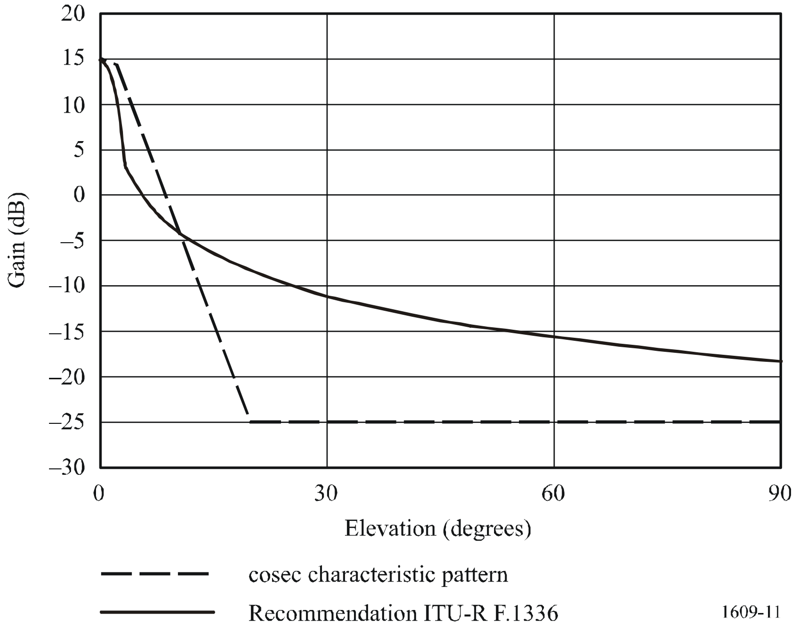


FIGURE 11

Assumed antenna beam pattern in elevation direction



2 FWA system with P-P operation

Table 3 shows the system parameters of the FWA station in P-P system. The transmission power control is not usually considered in the P-P FWA system. The FWA station always transmits the signal with power for the rain condition.

TABLE 2

Parameters of subscriber station in P-MP FWA system

Parameter	Rain faded		Clear-sky	
	31 GHz	28 GHz	31 GHz	28 GHz
Transmission output (dBW)	–10	–10	–23	–20
Output spectral density (dB(W/MHz))	–17	–18.1	–30	–28.1
Noise figure (dB)	7	6	7	6
Receiver thermal noise-calculated (dB(W/MHz))	–137	–138	–137	–138
Antenna gain (dBi)	37/43	36/42	37/43	36/42
Antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Feeder loss (dB)	0	0	0	0
Modulation	QPSK	QPSK	QPSK	QPSK

NOTE 1 – As for the antenna gain for 31 GHz, 43 dBi corresponds to the 60 cm diameter antenna for long distance, whereas 37 dBi corresponds to 30 cm for short distance. It is assumed that 30 cm antenna is used for the elevation of more than 5° and that 60 cm antenna is used otherwise. Such assumption is similarly made in the case of 28 GHz.

TABLE 3

Parameters of FWA station in P-P system

Parameter	31 GHz	28 GHz
Transmission output (dBW)	–3	–3
Output spectral density (dB(W/MHz))	–6	–6
Noise figure (dB)	7	8
Receiver thermal noise-calculated (dB(W/MHz))	–137	–136
Antenna gain (dBi)	37/46	36/46
Antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Feeder loss (dB)	0	0
Modulation	4-FSK	QPSK

NOTE 1 – As for the antenna gain for 31 GHz, 46 dBi corresponds to about 90 cm diameter antenna for long distance, whereas 37 dBi corresponds to about 30 cm for short distance. It is assumed that 30 cm antenna is used for the elevation of more than 5° and that 90 cm antenna is used otherwise. Such assumption is similarly made in the case of 28 GHz.

Annex 3

Methodology for interference evaluation using a stochastic approach from a HAPS to stations of the FWA systems in the 27.5-28.35 GHz band

1 Introduction

This Annex provides an interference evaluation methodology and evaluation examples for interference from a HAPS to the FWA system operating in the 27.5-28.35 GHz band using a stochastic approach in a realistic operation circumstance based. With respect to the interference to the FWA subscriber station, it is obvious that the FWA station antenna gain toward a HAPS is a dominant parameter. The interference is evaluated assuming that FWA subscriber stations antennas have the elevation angles in accordance with the stochastic distribution of typical FWA systems and the azimuth angles in random distribution.

The interference to FWA base stations are also evaluated with respect to the distance from HAPS, assuming the sector antenna are located horizontally and faced to the HAPS.

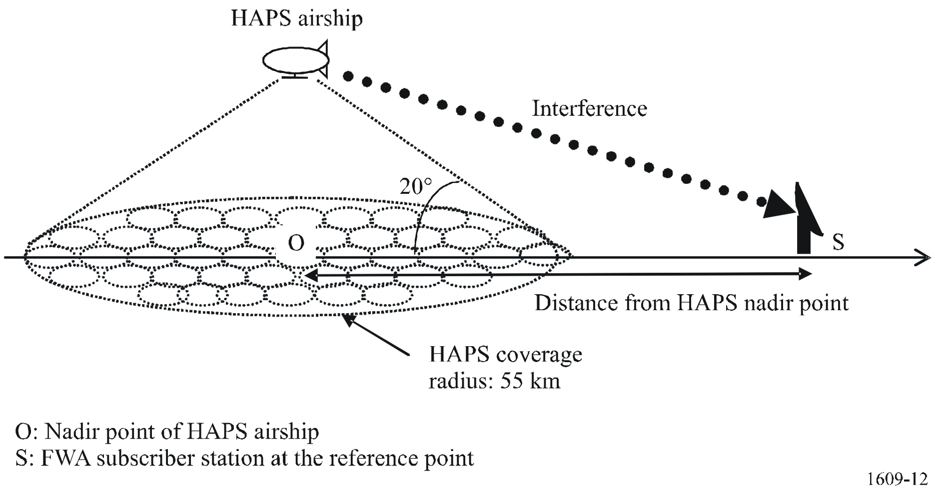
2 Simulation model

2.1 Calculation methodology

Interference from a HAPS airship to a station for FWA systems is calculated using a scenario as shown in Fig. 12. The methodology described in § 2.1 in Annex 1 to this Recommendation is applied under the following conditions.

FIGURE 12

Model of interference simulation



2.1.1 HAPS downlink

The technical characteristics of the HAPS system are based on Recommendation ITU-R F.1569. It is assumed that the interference power is the aggregate equivalent isotropically radiated power (e.i.r.p.) from all the spot beams of HAPS towards a reference point in the same frequency slot. Free space transmission is assumed for conservative evaluation.

2.1.2 FWA subscriber station

The parameters of the subscriber stations are described in Appendix 2 to the Annexes to this Recommendation. The subscriber stations are located at a reference point with the antenna pointing angles in accordance with the assumed deployment statistics as presented in § 2.3.

2.1.3 FWA base station

The parameters of the base stations are described in Appendix 2 to the Annexes to this Recommendation.

2.2 HAPS system

Typical configuration of the HAPS system is described in Recommendation ITU-R F.1569. Parameters used for evaluation are summarized in Table 4.

Table 4

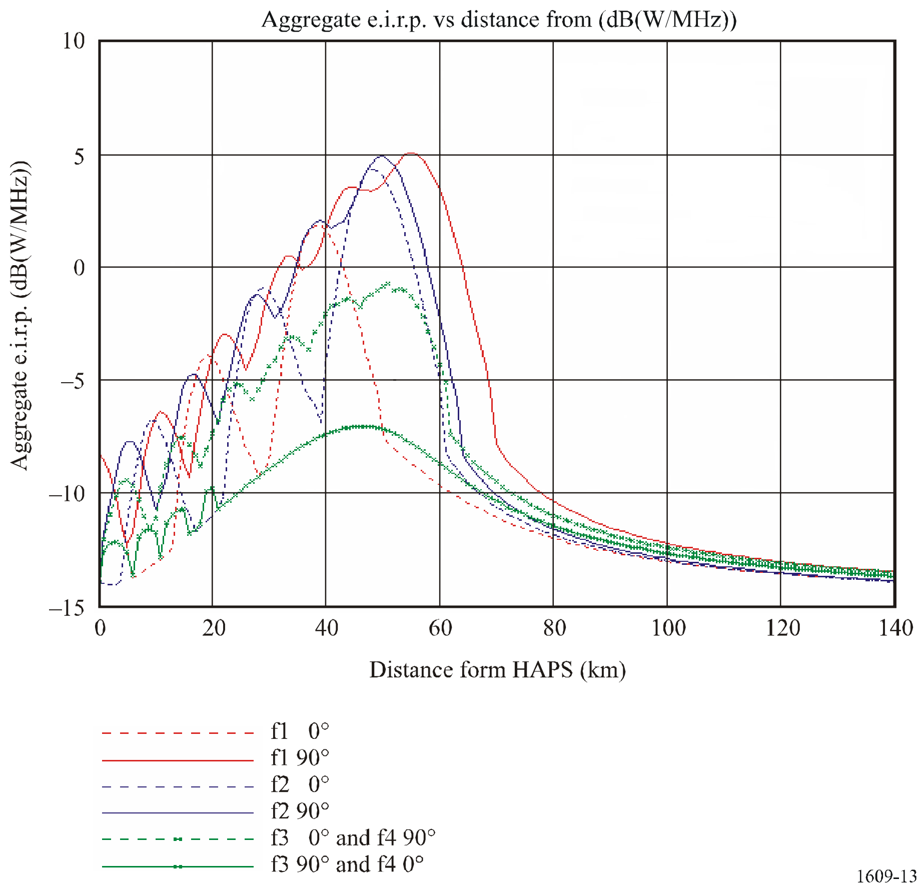
Downlink parameters of the HAPS system

Parameter	Description
Number of beams	397
Frequency reuse factor	4
Aggregate e.i.r.p.	Refer to Fig. 13 (f1 90°)
Antenna gain	16.5 to 29.5 dB
Antenna pattern	Recommendation ITU-R F.1245
Coverage area radius	55 km (minimum elevation angle 20°)

The 397 beams adopt the frequency reuse factor of four (4) so that the transmission power from the HAPS towards the ground varies for the frequency slots and the directions of radiation. Figure 13 shows the e.i.r.p. values for each frequency slot expressed as the parameters of the distance from the nadir point of the HAPS on two orthogonal directions in azimuth (0° and 90° from the *x* axis). The evaluation uses the e.i.r.p. for "f1 90°" which causes the worst interference to the FWA system outside the HAPS service area.

FIGURE 13

Aggregate e.i.r.p. of HAPS produced by 397 beams



2.3 FWA subscriber station

2.3.1 Subscriber station parameters

Parameters of the FWA subscriber station given in Table 2 in Appendix 2 to the Annexes to this Recommendation are used in this evaluation.

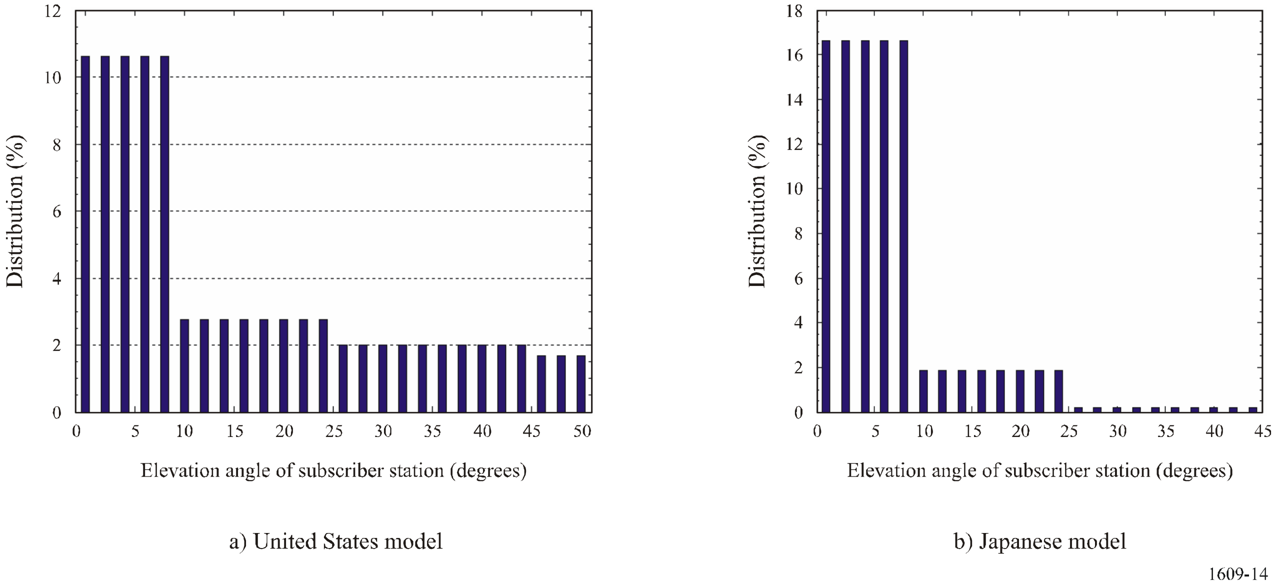
2.3.2 Deployment statistics

Elevation angle:

Recommendation ITU-R F.1498 provides two examples of the elevation angle statistics of the FWA system in the 38 GHz band, the United States model and the Japanese model in Figs. 6 and 8 in its Annex 1, respectively. Those examples are not sufficiently appropriate for the interference evaluation since the distribution is very coarse. This Recommendation assumes that the distribution is uniform in the respective ranges. For example, the United States model gives the distribution of 53% for the range of elevation angles less than 10°. This value is transferred 53/5% (=10.6%) at the elevation angles of 0°, 2°, 4°, 6°, 8° respectively in the calculation. The distributions of elevation angles used for evaluation are shown in Fig. 14.

FIGURE 14

Elevation angle distribution of FWA subscriber station



Azimuth angle:

It is assumed the azimuth angles of the subscriber stations are uniformly distributed.

Propagation characteristics:

In addition to the free-space loss, the atmospheric absorption loss for the mid-latitude area described in Appendix 1 is taken into account. Any effect of the terrain and building is not considered to make the study conservative though considerable loss may be expected in the practical.

Other factors:

The height of the antenna of the subscriber station is not considered in the simulation because it is not a critical factor under line-of-sight transmission conditions.

2.4 FWA base station

Parameters of the FWA base station given in Table 1 in Appendix 2 to the Annexes to this Recommendation are used in this study. The base station antenna is of a sector type with the maximum gain of 15 dB and its pattern in the elevation plane is in accordance with Recommendation ITU-R F.1336. It is assumed the hub station antenna is faced to the nadir point of the HAPS with the elevation angle of 0°.

3 Results of calculation

For the FWA subscriber station, values of interference to noise (*I*/*N*) ratio are evaluated as a function of distance between the station and the nadir point of the HAPS. Figures 15 and 16 show the probability exceeding the criteria of *I*/*N*= –20 dB and –10 dB for the subscriber stations having the assumed distribution statistics of elevation angles. They indicate that *I*/*N* can remarkably be reduced when subscriber stations are separated by 70 km away from the HAPS.

For the FWA base station, the calculated *I*/*N* ratios could be very small outside the HAPS service area as shown in Fig. 17.

FIGURE 15

I/N probability of FWA subscriber station: United States model of EL distribution

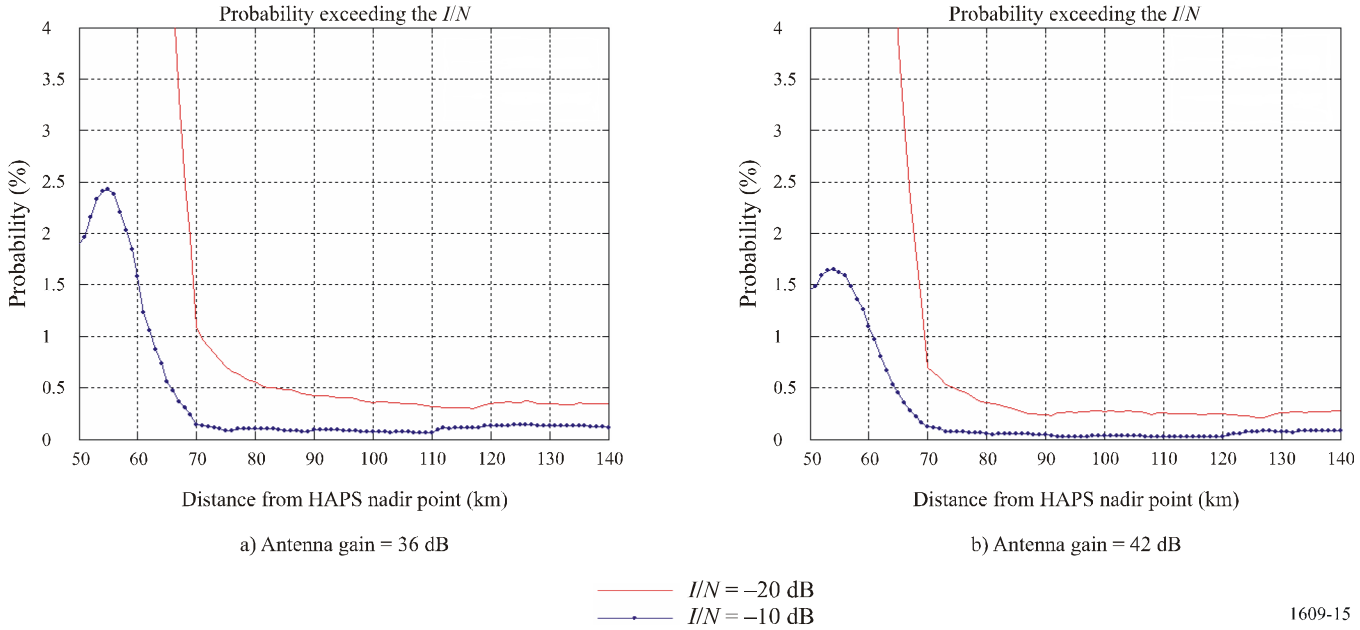


FIGURE 16

I/N probability of FWA subscriber station: Japanese model of EL distribution

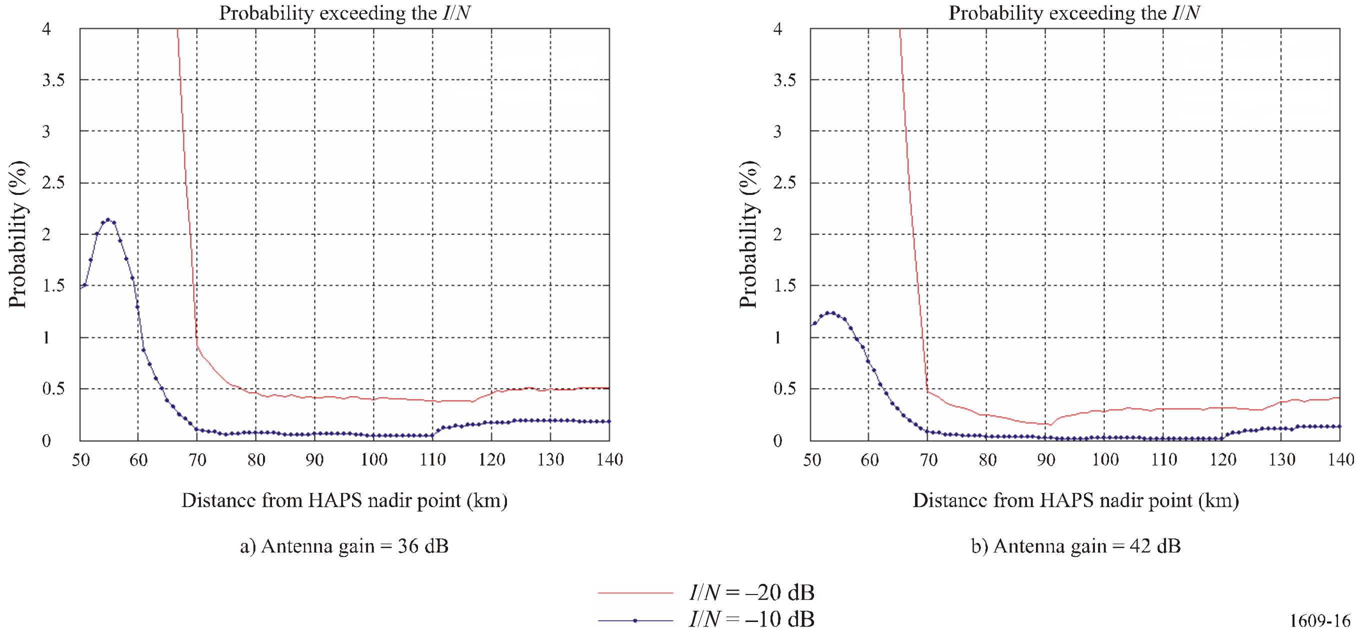
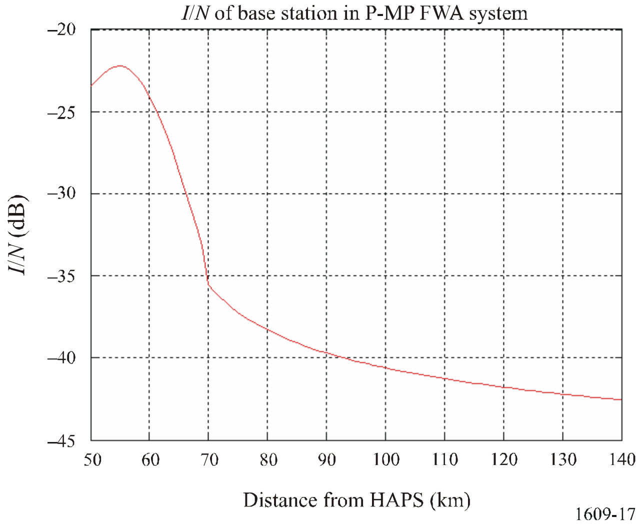


FIGURE 17

***I/N* of FWA base station**



4 Summary

It has been demonstrated that the probability of interference from a HAPS airship to an FWA subscriber station can be remarkably reduced when taking into account stochastic factors of the FWA system. The example evaluation indicates that the probability of noticeable interference would remarkably be reduced where a FWA subscriber station is separated from the HAPS nadir point by a range of 70 km.

Regarding the FWA base station, the maximum *I/N* would be less than –20 dB even under the adverse assumptions.

It should be noted this evaluation is still conservative and the interference could be reduced further in real operational conditions, taking into account other propagation factors including building blocking, atmospheric attenuations and rain attenuations.