HAPS 지상국과 고정위성업무 수신기와의 공유조건 분석

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Analyzing the sharing conditions between HAPS ground stations and FSS receiver

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요 약

ITU-R은 긴급사안으로 결의 122를 통하여 47.2-47.5 GHz 및 47.9-48.2 GHz 대역에서 HAPS지구국이 우주국 수신기와의 공유를 원활하게 하기 위해서 적용 가능한 전력 제한치를 연구할 것을 요청하였다. 하지만 현재까지 이것과 관련된 연구는 진행되지 않은 상태이다. 이미 개발된 권고서 ITU-R SF.1481-1를 통하여 HAPS를 이용한 FS 시스템과 FSS 시스템간의 공유 가능성을 분석하기 위한 방법과 시스템 특성 파라미터가 제시되었으며, 위 주파수 대역에서 일반적인 HAPS에 대한 시스템 특성에 관하여 권고서 ITU-R F.1500에 또한 제시되었다.

본 논문에서는 결의 122에 따라서 HAPS 지상국에 적용 가능한 전력 제한치에 대한 결과를 제시한다. 이미 권고서 ITU-R SF.1481-1에 언급되었듯이 HAPS 지상국과 FSS 위성시스템간의 공유를 위해서는 충분한 이격거리가 필요하다. FSS 위성수신기로의 이러한 간섭레벨을 줄이기 위해서 HAPS 지상국의 전력 감소와 낮은 부엽레벨을 갖는 안테나 빔패턴의 적용을 고려하여 분석된 공유조건 결과들의 예들을 제시한다.

키워드 : 성층권통신, 고정위성업무, 공유, 간섭

ABSTRACT

Under Resolution 122 (Rev. WRC-03),ITU-R is invited to study, as a matter of urgency, power limitations applicable for HAPS ground stations to facilitate sharing with space station receivers in the bands 47.2-47.5 GHz and 47.9-48.2 GHz. However, there have been no studies on this issue. Recommendation ITU-R SF.1481-1, which was developed during past study period, provides methodology and system characteristics for analyzing the sharing feasibility between systems in the FS using HAPS and systems in the FSS. System characteristics for a typical HAPS in the bands above are also given in Recommendation ITU-R F.1500.

This paper provides the results on power limitations applicable for HAPS ground stations in accordance with Resolution 122 (Rev. WRC-03). As already shown in ITU-R Recommendation the results show that a sufficient separation distance is required for sharing between HAPS ground stations and FSS satellite systems. We obtain some examples of the sharing conditions considering reducing the power level of HAPS ground stations and using the antenna beam pattern with the low sidelobe to decrease the interference level affecting FSS satellite receiver.

Key words : HAPS, FSS, sharing, interference

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1. Introduction

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 high altitude platform stations (HAPS). These frequency bands are also allocated to the fixed satellite services (FSS) for the uplink (Earth-to-space) as co-primary services.

According to Resolution 122 revised in WRC-2003, ITU-R is invited to study, as a matter of urgency, power limitations applicable for HAPS ground stations to facilitate sharing with space station receivers. From this point of view, it is important to analyze the sharing problem from HAPS user terminals to the receivers of a satellite.

Recommendation ITU-R SF.1481 has already provided the study results on interference from HAPS user terminals to the receivers of a satellite but the results have not given any information on the specific separation distance between HAPS nadir and an earth station of satellite system for sharing. In this paper, using the system parameters in Recommendation ITU-R F.1500 and the interference calculation in Recommendation ITU-R SF.1481, the behavior of interference distributions is examined with latitude at which HAPS nadir and an earth station of satellite are located. The interference distributions are also calculated with the antenna beam patterns of HAPS user terminals defined in Recommendation ITU-R F.699 and F.1245 respectively. From the interference analysis, the required separation distance between HAPS user terminals and a space receiver is obtained to meet the interference criteria of a satellite receiver. For the systems to be shared in co-coverage, the proposed power reduction scheme should be applied to HAPS user terminals instead of the approach such as the separation distance [1]. The main idea is that in the clear sky condition, the power of HAPS user terminals may be reduced within rain margin, while in rainy condition, it is restored to original power. It is the easy way to keep the HAPS link margin and to reduce the interference to a satellite receiver. Depending on the antenna beam patterns of HAPS user terminals the appropriate parameters are obtained and validated by calculating the interference distributions.

Finally, for the examples of this analysis, the required separation distance and the interference distribution when the power reduction is applied to HAPS user terminals are obtained at latitude 38 degrees.

2.. Methodology for interference analysis

2.1. Scenarios

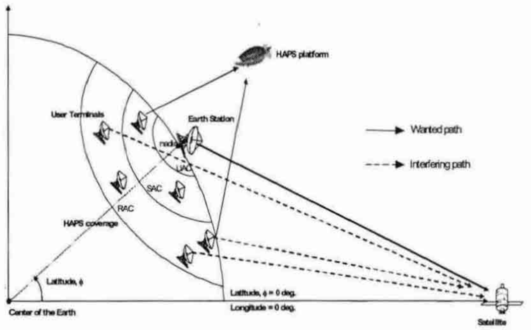

Figure 1: Interference scenario

HAPS consists of a platform such as an airship or an aircraft and user terminals. A platform is assumed to be located at 21 km above sea level and HAPS user terminals are randomly distributed in the areas, UAC (Urban Area Coverage), SAC (Suburban Area Coverage), and RAC (Rural Area Coverage). The regions depend on the elevation angle from horizontal plane to a platform. The antenna beams of the user terminals always direct to the platform.

The satellite system includes a satellite in space and its earth station on the ground. To obtain the behavior of interference distribution with the latitude, the earth station is located at the nadir of HAPS (that is, the centre of HAPS service coverage) with its antenna beam pointed to the satellite receiver. The interference levels can be obtained by calculating the off-axis angles between HAPS user terminals and a satellite receiver when the antenna parameters, positions of HAPS, and size of service areas are known.

2.2. System parameters

HAPS service coverage zones are divided into UAC, SAC, RAC determined by elevation angles as shown in Table 1. They have 100 user terminals in each zone respectively and the transmitting power and antenna gain of user terminals are different from zones as shown in Table 2. The parameters mentioned in Table 1 and 2 were adopted from [2]. 100 HAPS user terminals are distributed randomly in each zone with the requirement in Table 1.

Table 1: HAPS coverage zones

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

Table 2: User terminal transmitter parameters

Communication to (total numbers)	Power density (dBW/2MHz)	Antenna gain (dBi)
UAC (100)	- 8.2	23
SAC (100)	-7	38
RAC (100)	-1.5	38

Table 3: GSO FSS satellite parameters

Maximum antenna gain (dBi)	51.8
Interference criterion (dB(W/MHz))	-150.5
Antenna pattern	Rec. ITU-R S.672-4

The parameters for satellite receiver are defined in Table 3 [3] and those for earth station are not needed when interference from HAPS user terminals to satellite receiver is considered. The interference criterion for satellite receiver is -150.5 dB (W/MHz).

To calculate the interference level, antenna beam patterns for HAPS user terminals and satellite receiver should be defined. In this analysis two antenna beam patterns are considered for HAPS user terminals. The antenna beam pattern of Recommendation ITU-R F.1245 [5] is considered as well as that of Recommendation ITU-R F.699 [4] mentioned in Recommendation F.1500. In cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100, the equations of section 2.2 described in Recommendations ITU-R F.699 and ITU-R F.1245 are used for the antenna beam patterns of HAPS user terminals. For that of a satellite receiver Recommendation ITU-R F.672-4 [6] is used.

As an example of the antenna beam patterns Fig. 2 shows the antenna beam pattern from Recommendation ITU-R F.1245 has lower sidelobe than that from Recommendation ITU-R F.699.

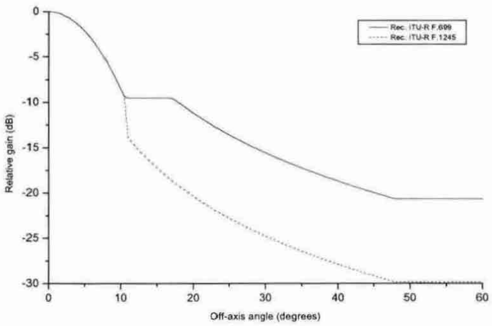

Figure 2: Antenna beam patterns for HAPS user terminals

2.3. Interference calculation

The expected received power density can be calculated from [2];

$$P_r = P + G_t - L_{tf} + G_r - L_{rf} - L_a - L_p - 10 \log B - 20 \log(4\pi d/\lambda) - 60 \text{ dB(W/MHz)} \qquad (1)$$

where:

P_r : expected received carrier power density (dB(W/MHz))

P : transmitting output power density (dB(W/MHz))
G_t : transmitting antenna gain (dBi)
L_{tf} : antenna feeder loss (dB)
G_r : gain of the receiving antenna (dBi)
L_{rf} : receiving antenna feeder loss (dB)
L_a : atmospheric absorption for a particular elevation angle (dB)
L_p : attenuation due to other propagation effects (dB)
B : bandwidth (MHz)
λ : wavelength (m)
d : distance (km).

In (1), the interference power can be calculated considering the antenna gain on the off-axis angle instead of maximum antenna gain and distance form HAPS user terminal to a satellite receiver. In this analysis, the band- width B is assumed to be 2 MHz.

3. Study results

In this section, the interference level from HAPS user terminals to a space station receiver is calculated with scenario and system parameters mentioned in section 2. The scenario that the earth station of satellite is located at HAPS nadir (the center of HAPS coverage) may be used to consider the worst interference condition from HAPS to satellite. Totally 300 HAPS user terminals as interference sources to satellite are assumed and finally the interference level can be obtained by calculating the offset angle between HAPS user terminals which is directed to HAPS platform and a satellite receiver and the gain from the antenna beam pattern of HAPS user terminals and a satellite receiver. When the interference level is calculated it is assumed that the positions of 300 HAPS user terminals have 1,000 random trials in this analysis.

Figure 3 shows the calculation result with the latitude of HAPS nadir and an earth station of satellite. The reference level is assumed to be -150.5 dB (W/MHz) as mentioned in Table 3. The result shows that as the latitude of HAPS nadir and an earth station is increased, the interference is increased, and that finally HAPS and satellite system can't be shared in the worst scenario in which an earth station of satellite is located at the center of HAPS coverage. For example, at latitude20 degrees, the fact that the CDF (Cumulative Distribution Function) is 40 % at the reference interference level, -150.5 dB (W/MHz) indicates that 400 of 1,000 HAPS user terminal distributions is below the criterion but 600 of them exceed it. All cases in distributions exceed the interference criterion at above latitude 40 degrees.

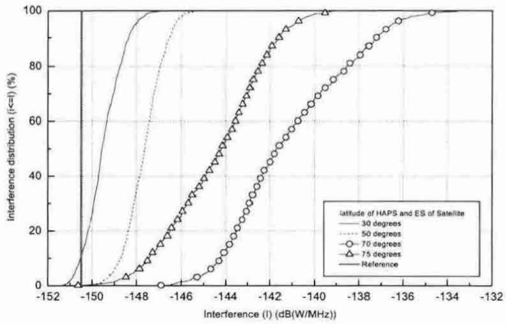

Figure 3: An example of CDF with the latitude of HAPS and ES of satellite (using the antenna beam pattern from Recommendation ITU-R F.699)

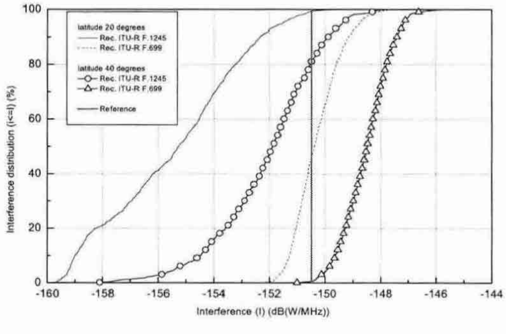

Figure 4: CDF with antenna beam patterns (antenna beam pattern of Rec. ITU-R F.699 vs. Rec. ITU-R F.1245)

Figure 4 shows the CDF difference using the antenna beam patterns of Recommendation ITU-R F.699 and Recommendation ITU-R F.1245. The result shows HAPS user terminals with the antenna beam pattern of Recommendation ITU-R F.1245 give less harmful interference than HAPS user terminals with antenna beam pattern of Recommendation ITU-R F.699 do to the space station receiver at same latitude.

3.1. Separation case

Generally the separation distance is introduced in the ease way to find the sharing condition between systems. Recommendation ITU-R SF.1481 has already provided the study results on interference from HAPS user terminals to the receivers of a satellite but the results have not given any information on the specific separation distance between HAPS nadir and an earth station of satellite system for sharing. In this section, the specific separation distance satisfying the condition for HAPS to share with satellite system is calculated as shown in Figure 5. But for the systems to be shared in co-coverage, the power reduction scheme should be applied to HAPS user terminals instead of this approach.

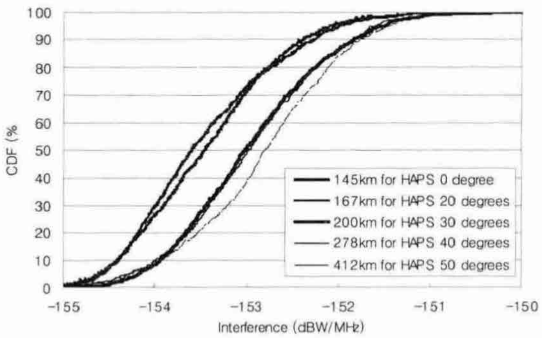

Figure 5: Separation distance with latitude [1]

3.2. Co-coverage case

To reduce interference power from HAPS user terminals to the FSS space receiver, the maximum power level from the user terminals should be specified. This section shows examples to specify the maximum power level from the user terminals of HAPS with antenna beam patterns mentioned in Recommendation ITU-R F.699 and Recommendation ITU-R F.1245 respectively.

The power reduction of the HAPS user terminals given in Recommendation ITUF.1500 is carried out so that interference avoidance of HAPS user terminals with FSS space stations can be achieved even in co-coverage areas. It is assumed that HAPS user terminals have power control scheme.

As shown in Fig.3 and Fig. 4, since the interference is different from the latitude of HAPS and the earth station of the satelliteand the antenna beam pattern of HAPS user terminals it is necessary to specify the appropriate power with the latitude and antenna beam pattern.

Table 4: Sharing parameters with latitude of HAPS nadir (using antenna beam pattern of Recommendation ITU-R F.699)

CASE	Lat. of HAPS & SAT ES	Transmitter parameters	UAC	SAC	RAC
			Elevation angles (90°-30°)	Elevation angles (30°-15°)	Elevation angles (15°-5°)
A	0°~30°	Number of user terminals	100	100	100
		Antenna gain	23 dBi	38 dBi	38 dBi
		Power	−13.2 dBW	−7 dBW	−1.5 dBW
B	30°~50°	Number of user terminals	100	100	100
		Antenna gain	23 dBi	38 dBi	38 dBi
		Power	−13.2 dBW	−12 dBW	−6.5 dBW
C	50°~58°	Number of user terminals	100	−	−
		Antenna gain	23 dBi	−	−
		Power	−13.2 dBW	−	−
D	above 58°	Number of user terminals	100	−	−
		Antenna gain	23 dBi	−	−
		Power	−8.2 dBW	−	−

Table 5 : Sharing parameters with latitude of HAPS nadir (using antenna beam pattern of Recommendation ITU-R F.1245)

CASE	Lat. of HAPS & SAT ES	Transmitter parameters	UAC	SAC	RAC
			Elevation angles (90°-30°)	Elevation angles (30°-15°)	Elevation angles (15°-5°)
A	0°~30°	Number of user terminals	100	100	100
		Antenna gain	23 dBi	38 dBi	38 dBi
		Power	−10.7 dBW	-7 dBW	-1.5 dBW
B	30°~50°	Number of user terminals	100	100	100
		Antenna gain	23 dBi	38 dBi	38 dBi
		Power	−12.2 dBW	−11 dBW	−5.5 dBW
C	50°~58°	Number of user terminals	100	–	–
		Antenna gain	23 dBi	–	–
		Power	−10.7 dBW	–	–
D	above 58°	Number of user terminals	100	–	–
		Antenna gain	23 dBi	–	–
		Power	−8.2 dBW	–	–

Table 4 shows the parameters for the HAPS user terminals with the power reduction when the antenna beam pattern of Recommendation ITU-R F.699 is applied to the HAPS user terminals. In the cases of C and D in the Table, HAPS user terminals in SAC and RAC are excluded since the possibility that main beam of HAPS user terminal is directed to the receiver of satellite is increased due to the low elevation angle in higher latitude.

Table 5 shows the parameters for the HAPS user terminals with the power reduction when the antenna beam pattern of Recommendation ITU-R F.1245 is applied to the HAPS user terminals. Due to the same reason as stated above, in the cases of C and D in the Table, HAPS user terminals in SAC and RAC are also excluded.

Figure 6 shows the possibility of interference avoidance of HAPS user terminals with FSS space station by up to 5 dB power reduction of HAPS user terminals.

Figure 7 shows the possibility of interference avoidance of HAPS user terminals with FSS space station by up to 4dB power reduction of HAPS user terminals.

For the low latitude (below 30degrees) the powerof HAPS user terminals in UAC is important factor, but for high latitude (above 30 degrees) those in SAC and RAC are the dominant factor. Figure 6 and 7 show all cases that satisfy the interference criterion.

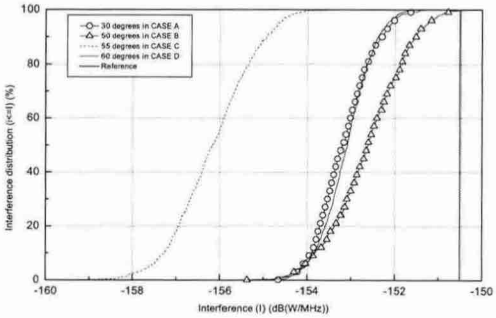

FIGURE 6 : CDF with the parameters of case A, B, C, and D (using the parameters in Table 5)

If HAPS user terminals are equipped with a power control system, they can reduce the transmit power in clear-sky conditions, not exceeding the interference criterion of the FSS space station receiver in co-coverage area. In clear-sky conditions, the reduction can be achieved up to the amounts of rain attenuation given in Recommendation ITU-R F.1500, e.g.

11.2 dB, 14.9 dB and 22.4 dB in UAC, SAC and RAC, respectively. In this analysis, the power reduction (for example: maximum 5 dB in the case of the parameters in Table 5, maximum 4 dB in Table 6) is assumed to show the possibility of interference avoidance in a co-coverage area. The reduction would be applicable in co-coverage areas. In rainy conditions, the reduced power would be restored.

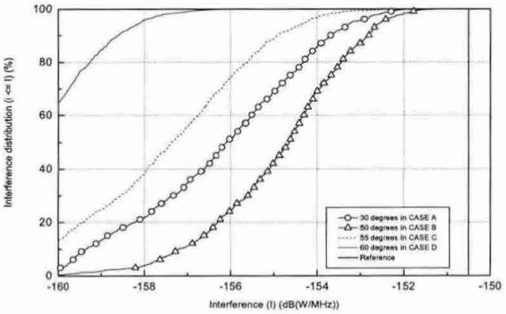

FIGURE 7 : CDF with the parameters of case A, B, C, and D(using the parameters in Table 6)

4. Applications

In this section, the practical examples for sharing are provided. Figure 8 shows the specific separation distance to meet the interference criteria at latitude 38 degrees. As shown in Figure 7, when the HAPS is located at latitude 38 degrees the separation distances are 256 km in higher latitude and 200 km in lower latitude. It means that when multiple HAPS platforms are applied to the service coverage it is impossible the sharing with FSS space receivers in this case.

Figure 9 shows the interference distributions to meet the interference criteria at latitude 38 degrees. In this case HAPS user terminals and an earth station of satellite are in co-coverage at latitude 38 degrees. Interference distributions are different from antenna beam pattern. In the future, the antenna beam pattern with low sidelobe should be considered for HAPS user terminals to facilitate the sharing between systems.

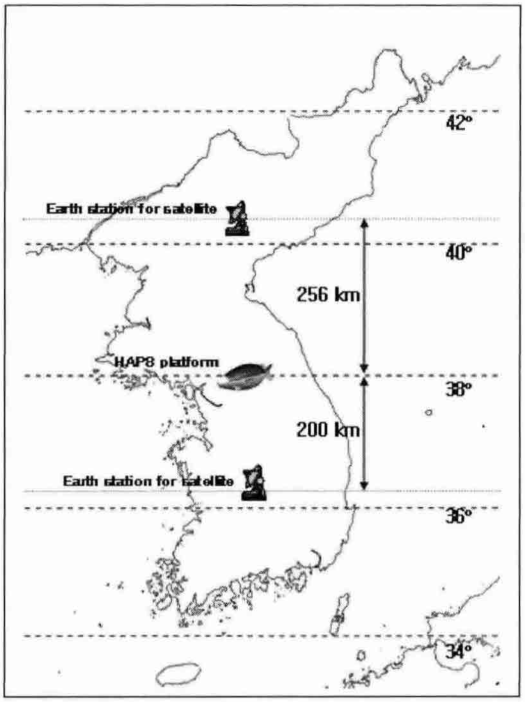

FIGURE 8 : Separation distance applying the specific example at latitude 30 degrees

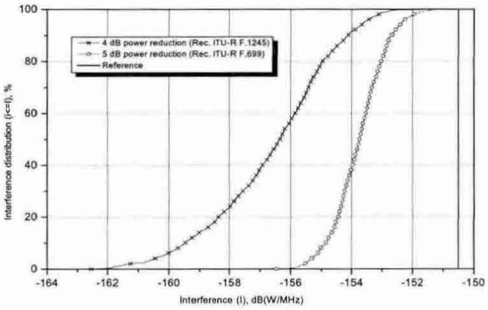

FIGURE 9 : Interference distributions at latitude 38 degrees

5. Conclusions

This paper deals with the sharing condition between HAPS user terminals and a satellite receiver in 47/48GHz. The separation distance to meet the interference criteria of FSS is calculated and when the systems are in co-coverage the interference distributions are also calculated by applying the power reduction scheme to the HAPS user terminals. The results show it is possible to share between HAPS user terminals and FSS receiver without any performance degradation for HAPS system, and that the possibility of interference avoidance of HAPS user terminals with FSS space stations.

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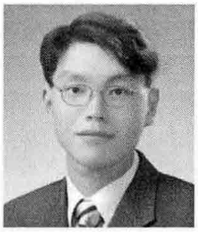

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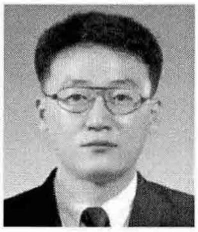

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