3-2-2 A Study of Frequency Sharing and Contribution to ITU for Wireless Communication Systems Using Stratospheric Platforms

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R&D for wireless communication systems using aircraft called high altitude platform keeping at an altitude of about 20 km has been made progress as a national project in Japan since 1998. In order to realize such novel wireless communication systems, allocation and maintenance of available frequency bands are the key issues. At this stage, following three frequency bands are allocated for the communication systems using stratospheric platforms; 2 GHz bands for IMT-2000, 31/28 GHz bands for fixed service and 47/48 GHz bands for fixed service. Among these frequency bands, 31/28 GHz bands were proposed by Japan and the use of the bands was allowed in WRC-2000 as the results of the frequency sharing and compatibility studies with the other services in ITU-R. On the allocation, however, stringent conditions are imposed and there still remain a lot of further studies in order to deregulate these conditions. This paper describes the current status of the frequency sharing and compatibility studies between the stratospheric platform communication systems and other radio systems in the 31/28GHz bands in the International Telecommunication Union (ITU).

Keywords
High altitude platform, Frequency sharing, Interference mitigation techniques, International Telecommunication Union (ITU)

1 Introduction

Studies in recent years have explored various aspects of a new wireless communications system that would be based on aircraft – or stratospheric platforms – that remain aloft in the stratosphere for extended periods, at an altitude of approximately 20 km[1][2][3]. Creating commercially successful systems based on such stratospheric platforms and making them a viable force in the wireless communications industry will require the acquisition and retainment of available frequency bands. However, the frequency bands suitable for a wireless communications system based on the stratospheric platforms are already occupied by a number of other radio services and no free space remains. Thus, to build such a system, we must clarify the requirements for frequency sharing with existing radio services, evaluate techniques capable of mitigating interference with different services in the ITU-R (Radiocommunications Sector of the International Telecommunication Union), and win approval for the new frequency band allocation at the WRC (World Radiocommunication Conference).

Due to efforts by Sky Station Inc. in the United States and some institutes in Japan, the WRC-97 in 1997 designated the 47/48 GHz bands[4] for the fixed service using stratospheric platform stations (defined by the ITU-R as High Altitude Platform Stations, or HAPS). However, this band is susceptible to rain attenuation, restricting its range of application, particularly in Japan, where rain is common. Japan’s Ministry of Public Management, Home Affairs, Posts and Telecommunications has been actively seeking to acquire lower frequency bands (31/28 GHz) suitable for broadband wireless access use between stratospheric platforms and terrestrial subscribers. This was a national effort supported by contribution documents produced by the Communications Research Laboratory in cooperation with the Telecommunication Advancement Organization (TAO). These concerted efforts have led to the allocation of 31.0-31.3 GHz band for uplink and 27.5-28.35 GHz band for downlink to the fixed service using stratospheric platform stations, an allocation granted at the WRC-2000 held in 2000 with support from Asia/Pacific nations such as South Korea and Australia. This frequency-band allocation has significant implications for Japan. At WRC-2000, the 2-GHz band was also allocated for the IMT-2000 service using the stratospheric platforms[5].

However, despite this band allocation, it must be noted that the 31/28 GHz bands granted at WRC-2000 is already in use by other radio services. Thus, another urgent issue that must be clarified is the issue of frequency sharing with other wireless services. WRC places strict limits on fixed services; only 12 countries, located mostly in Southeast Asia, may use this band; the use of these bands shall not call harmful interference to, nor claim protection from, other types of services using the same or adjacent frequency band and until WRC-03, to be held in 2003, only the lower-half of the band (31.0-31.15 GHz) of the 31.0-31.3 GHz band may be used. We have encouraged the ITU-R to study frequency sharing and compatibility, presenting many contribution documents of relaxing these restrictions in the upcoming WRC-03 and proposing suggestions to help other new businesses gain access to this frequency band. In this paper, we introduce part of the 31/28 GHz-band frequency-sharing study as presented to the ITU-R and our activities in relation to the ITU.

Section 2 details the system parameters for a fixed service relying on a 31/28 GHz-band stratospheric platform system that serves the frequency sharing study conducted by the ITU-R. Using the model and parameters proposed in section 2, we present in section 3 examples of frequency sharing and compatibility studies, including a fixed satellite service provided by geostationary satellite, FWA (Fixed Wireless Access), and space science services. Section 4 summarizes interference mitigation techniques to facilitate frequency sharing with other services. Section 5 describes our contributions to the ITU. Section 6 provides a brief summary of this paper.

2 Wireless communications system for fixed service using the Ka-band stratospheric platform[4]

This section presents the parameters of the Ka-band stratospheric platform wireless communications system using the 31.0-31.3 GHz band for the uplink and 27.5-28.35 GHz band for the downlink. This system forms the basis of the ITU-R's study of frequency sharing and compatibility among wireless services using the same and adjacent frequencies. Fig.1 is a schematic drawing of this wireless communications system.

The ITU-R has proposed the following specifications for use as guidelines in creating a Ka-band stratospheric platform system:

a) A stratospheric platform station (HAPS) is installed aboard a stationary airship, which is kept aloft at a fixed altitude of 20-25 km.

b) Electrical power necessary for communications should be provided by solar cells mounted on top of the airship; this energy will be used during daytime, while at nighttime regenerative fuel cells charged during the day will be used.

c) An antenna installed on the bottom of the airship will transmit multi-spot beams, providing high-speed wireless access channels to ground stations located within the airship's range with an elevation angle of at least 20 degrees.

d) Each beam emitted from the multi-spot beam antenna forms a cell on the ground.

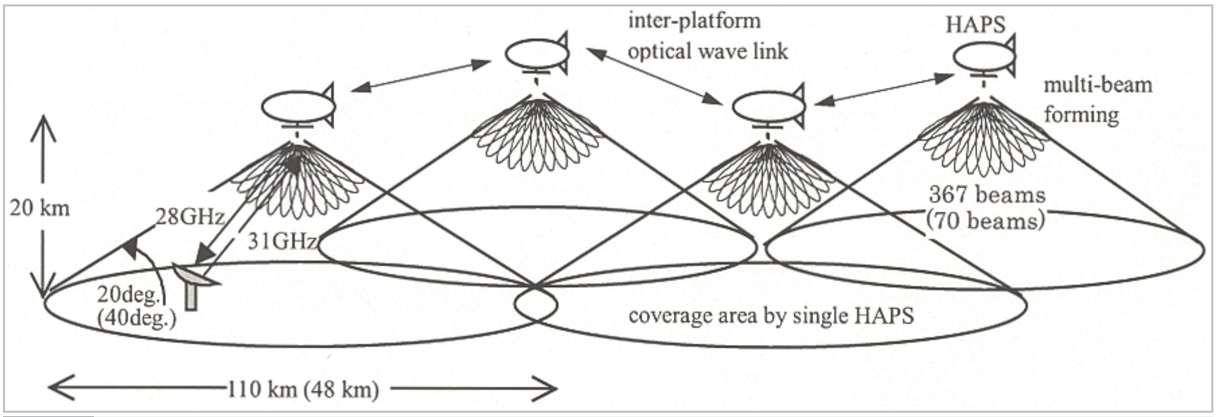

Fig.1 Schematic illustration of the Ka-band wireless communications system for fixed service using the stratospheric platform

The frequency reuse factor in this cell configuration is set to 4 or greater, accounting for inter-spot-beam isolation.

e) The surface of the airship is coated with an aluminum film, resulting in attenuation above the airship itself due to shielding effects upon radio waves emitted from the bottom antenna toward the ground.

f) More than one airship is deployed to cover a wide ground area, and airships are connected through an optical broadband wireless channel to provide an all wireless mesh-type network.

High antenna gain must be achieved by using multi-spot beams created with an apparatus carried aloft in the platform, as touched on in c) in order to realize a high-speed access channel between the platform and ground stations. This channel is expected to have a transmission rate around 20 Mbps per one carrier, the anticipated transfer rate for signal transmission within a few years. The method of multi-spot beams also provides highly efficient band use, since the same frequency band can be reused in different cells, allowing easy handling of any increase in the number of subscribers. The assumed ground cell formed by the multi-spot beams is a circle of about 6 km in diameter.

The service area covered by a single HAPS is determined by the minimum operational elevation angle. If the minimum elevation angle is 20 degrees, each HAPS must have 367 beams. If the minimum elevation angle is 40 degrees, around 70 beams are needed. Multi-beam antennas can be composed of arrayed horn antennas or phased array antennas. However, hardware such as nearly 400 multi-beam-emitting mechanism must be made significantly more compact and lighter to provide sufficient capacity.

Reducing the minimum elevation angle broadens the service area served per HAPS. But doing so also increases the number of beams and the transmission power required to compensate for the greater signal attennation caused by rain and the greater distance of signal propagation. Such design changes would also increase the difficulty of frequency sharing with other services and create additional radio-wave shielding problems generated by buildings and mountains. Thus, we set the minimum elevation angle for typical operations at 20 degrees in the case of a stratospheric platform system using the 31/28 GHz band. Fig.2 illustrates one possible configuration for HAPS deployment for a service in Japan employing a minimum elevation angle of 20 degrees. Selection of this minimum angle will require 95 airborne platforms.

Fig.3 shows an example of a terrestrial cell configuration using multi-beam antennas with a minimum operational elevation angle of 20 degrees. As previously described, the number of spot beams is 367, and every cell is a circle of about 6 km in diameter. This multi-beam design reduces the width of the beam covering the service coverage periphery and corre-

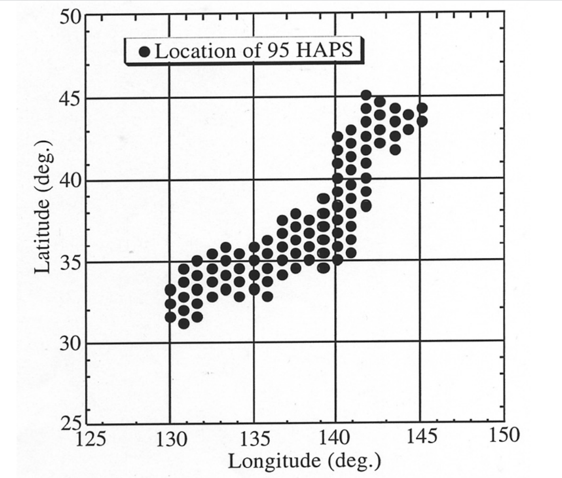

Fig.2 *Example of HAPS deployment for stratospheric platform system in Japan (assuming a minimum elevation angle = 20 degrees)*

spondingly reduces the sidelobe level, reducing interference with other services. On the other hand, elliptic beams of different beam-widths must be transmitted for the coverage beams of differing angles. Thus, another approach to this solution will be required for practical implementation. As a more feasible technique, we are also investigating a cell-configuration method using circular beams of five different beam-widths to cover the service area[6]. Our study indicates that this method – using about 400 circular beams with a total of five different beam-widths – can cover nearly the same area as that shown in Fig.3, with no increase in interference.

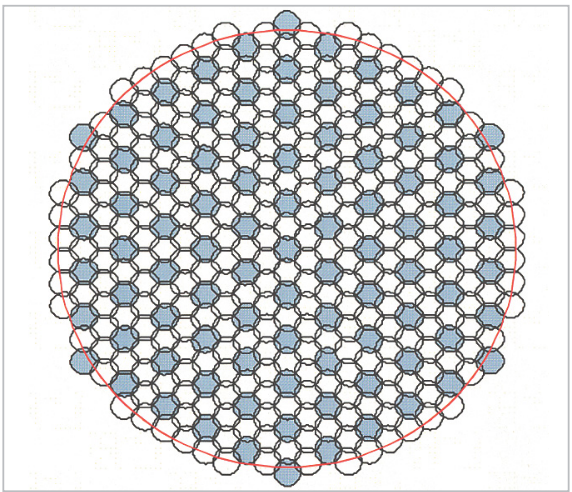

Fig.3 *Example of terrestrial footprints formed by an airship (minimum elevation angle = 20 degrees; 367 cells)*

In the above case, the frequency reuse factor is set at four. In Fig.3, the filled cells use the same frequency band. Theoretically, the minimum frequency reuse factor is three in such a hexagonal cell configuration. However, the frequency reuse factor becomes at least four due to restrictions affecting inter-spot-beam isolation. In general, the worst-case scenario is assumed by ITU-R when addressing interference with other services. Thus, the frequency reuse factor is set at four in the frequency-sharing model study adopted by the ITU-R.

Table 1 shows two examples of parameter settings for link budgets for the Tokyo area. One is the link budget for a ground station having an elevation angle of 20 degrees (at the service coverage edge), while the other is for a ground station having an elevation angle of 90 degrees (located directly under the airship). The transmission rate was assumed to be 20 Mbps for both uplink and downlink for a single carrier. We assumed that the uplink was equipped with Automatic Transmitting Power Control (ATPC) of up to 6 dB to compensate for rain attenuation. The link availability was assumed to be 99.4%. We performed the link budget analysis on the basis of the magnitude of gain at the spot beam edge (3 dB lower than in the main beam center).

3 Current status of frequency sharing study in ITU-R

This section introduces part of the ITU-R's study on frequency sharing and compatibility between the 31/28 GHz-band HAPS-based fixed service system and other services. The 31.0-31.3 GHz band allocated to the uplink for the fixed service using HAPS is already in used by other fixed and mobile services. The adjacent band (31.3-31.8 GHz) is allocated to space science services. The 27.5-28.35 GHz band allocated to the downlink of the HAPS-based fixed service has been allocated to the uplink for the fixed satellite service, as well as for fixed and mobile services. Employing the 31/28 GHz-band HAPS system discussed in

Table 1 *Link budget analysis for the Tokyo area (elevation angles: 20 degrees and 90 degrees)*

	Unit	Uplink	Downlink	Uplink	Downlink
Elevation angle	degrees	20 (edge of service coverage)		90 (nadir of HAPS)	
Frequency	GHz	31.28	28	31.28	28
Bandwidth	MHz	20	20	20	20
Transmission antenna					
Power	dBW	-10.3	-14.48	-10.3	-15.23
Feeder loss	dB	0.5	0.5	0.5	0.5
Gain	dBi	35	29.51	35	16.46
eirp	dBW	24.2	14.5	24.2	0.7
eirp (per MHz)	dBW/MHz	11.2	1.5	11.2	-12.3
Propagation distance	km	58.5	58.5	20	20
Free-space propagation loss	dB	157.7	156.7	148.4	147.4
Rain attenuation	dB	12.6	10.91	7.85	6.8
Link availability at Tokyo	%	99.4	99.4	99.4	99.4
Gases absorption loss	dB	0.4	0.4	0	0
PFD	$dBW/m^2/MHz$	—	-105.2	—	-109.3
Receiver antenna					
Gain	dBi	29.51	35	16.46	35
Feeder loss	dB	0.5	0.5	0.5	0.5
Receiving power	dBW	-117.5	-119	-116.1	-119
Noise temperature (K)	K	700	500	700	500
Noise temperature (dBW/Hz)	dBW/Hz	-200.2	-201.6	-200.2	-201.6
Maximum acceptable Interference level	dBW/MHz	-150.2	-151.6	-150.2	-151.6
Receiving loss	dB	2.5	2.5	2.5	2.5
Interference power		(I/N=10%)	(I/N=10%)	(I/N=10%)	(I/N=10%)
Receiving C/N_0	dB(Hz)	79.7	79.7	81.1	79.7
User data rate (Mbit/s)	Mbit/s	13.3	13.3	13.3	13.3
User data rate (dB(Hz))	dB(Hz)	71.2	71.2	71.2	71.2
Required E_b/N_0 (QPSK, BER=10^{-6})	dB	10.5	10.5	10.5	10.5
Coding gain (Co-Vi, K=7, r=2/3)	dB	5	5	5	5
Required E_b/N_0	dB	5.5	5.5	5.5	5.5
Required C/N_0	dB(Hz)	76.7	76.7	76.7	76.7
Link margin	dB	3	3	4.4	3

Section 2, we describe frequency sharing with the fixed satellite service (uplink) using the 28 GHz band in Section 3.1, frequency sharing with the terrestrial fixed service using the 31/28 GHz band in Section 3.2, and compatibility with the Earth exploration satellite service (passive) using the adjacent band (31 GHz band) in Section 3.3.

3.1 Frequency sharing with fixed satellite service[7]

The 28 GHz band has been allocated to the uplink for the fixed satellite service (FSS). The ITU-R has investigated the issue of interference with the fixed satellite services provided by satellites remaining in geostationary orbit (GSO-FSS). This case requires the consideration of two kinds of interference in the HAPS downlink (28 GHz band): (a) interference with GSO-FSS space stations (satellites) caused by HAPS and (b) interference with HAPS ground stations caused by GSO-FSS earth stations. GSO-FSS system parameters are determined with reference to the ITU system model (ITU-R Rec. S.1328), which provides the worst-case scenario in terms of interference. We examine item (a) based on the total amount of interference provided by 95 HAPS deployed in the sky above Japan, as shown in Fig.2. The estimated results are shown in Fig.4. The two lower lines indicate the interference caused by a single HAPS providing the greatest interference, while the two upper lines indicate the total interference generated by 95 HAPS. The horizontal axis shows the longitude (east longitude) of the GSO-FSS space station (geostationary satellite). The dotted lines indicate the results, taking into account shielding effects of up to 15 dB caused by the airship, described in “e” in Section 2. These results show that the intensity of interference is I/N=1% or lower (N: thermal noise in the receiver system of the geostationary satellite) for most geostationary satellites deployed at those longitudes. In comparison, interference is higher in satellites located at east longitudes near 60 degrees and 220 degrees. This is because the main beam used in the HAPS downlink directed to the edge of service coverage approaches those satellites. It is possible to further reduce interference by improving the radiation pattern of the HAPS-borne antennas and adopting the ATPC technique to the downlink for the HAPS-base system. Section 4 will provide more detailed discussion of interference mitigation techniques.

We have evaluated the intensity of interference (b) by the required separation distance between the HAPS ground station and the GSO-FSS earth station, assuming that the acceptable interference level at the HAPS ground station is given by I/N=10% (N: thermal noise in the receiver system of the HAPS ground station). Assuming that the GSO-FSS earth station is located at 38 degrees north latitude (Tokyo) in the center, we have calculated the probability for deploying HAPS ground stations at points around the center. In this example, the azimuth angle is set in a range between 0-350 degrees at 10-degree intervals for each HAPS ground station at each point, and the elevation angle is set in a range between 20-90 degrees at 10-degree intervals. The probability for each combination of the angles to provide the above acceptable interference level is plotted. If p=0, no combination of angles will satisfy the interference criterion; if p=100, every combination of the azimuth and elevation angles will satisfy interference criterion. Fig.5 shows two peaks on the bottom side generated because the elevation angle of the GSO-FSS earth station in this azimuth direction reaches the minimum, the sidelobe gain of the antenna of the GSO-FSS earth station attains its highest value, and the required separation distance from the HAPS ground station increases. Fig.5 also indicates that it is impossible to install a HAPS ground station within 3 km of the GSO-FSS earth station located at 38 degrees north latitude, and that HAPS ground stations are unaffected by interference of the above acceptable values if they are at least 24 km from the GSO-FSS earth station. The probabilities of most of the areas of 0<p<100 in Fig.5 are 95% or higher. Thus, it is possible to reduce interference to predetermined acceptable levels in most stratospheric platform ground stations located even within 24 km of the GSO-FSS ground station by adjusting the position of the airship.

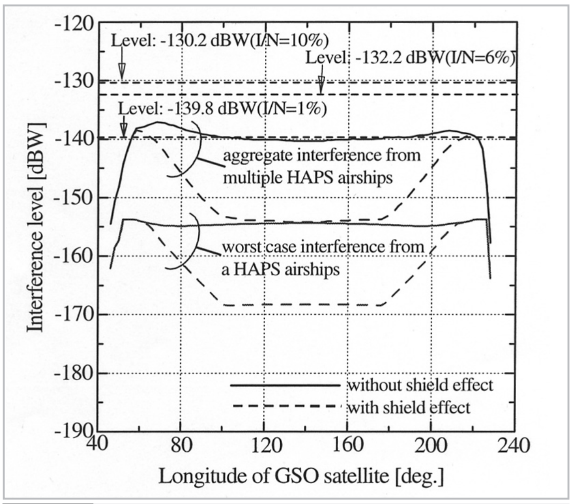

Fig.4 *Interference with GSO-FSS satellites caused by the HAPS downlink*

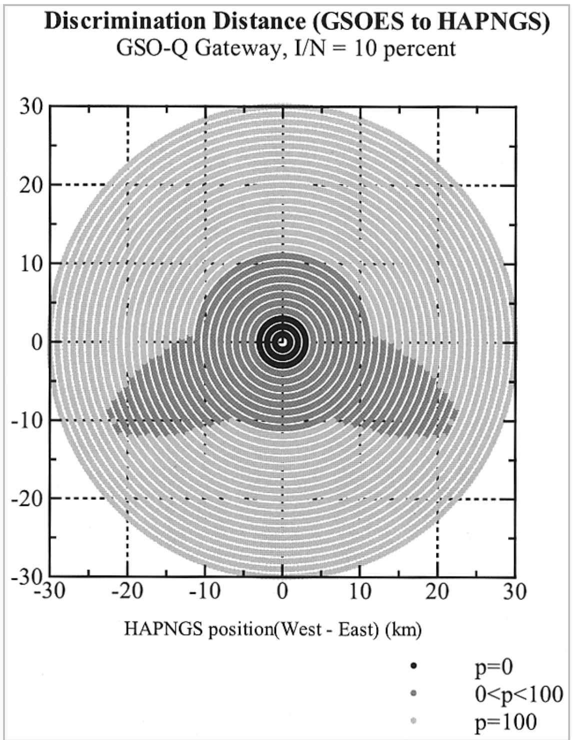

Fig.5 *Probability for deploying HAPS ground stations (the center is the GSO-FSS earth station)*

As indicated by the above study, the 31/28 GHz-band HAPS system can share the same band with the 28 GHz-band GSO-FSS by deploying HAPS in appropriate positions.

3.2 Frequency sharing with FWA P-MP system[8]

The 31 and 28 GHz bands have also been used for terrestrial fixed service. This section discusses the FWA (Fixed Wireless Access) P-MP (Point-to-Multipoint) system as an example of terrestrial fixed service for the study of interference with the HAPS system. The following four interference scenarios must be considered:

a) interference with FWA stations (hub station and substation) caused by HAPS airships

b) interference with HAPS airships caused by FWA stations (hub station and substation)

c) interference with FWA stations (hub station and substation) caused by HAPS ground stations

d) interference with HAPS ground stations caused by FWA stations (hub station and substation)

Of the above four scenarios, this paper addresses only a). We determined the parameters of the FWA P-MP system for the interference level calculations. We assume that the FWA hub stations are deployed at 2 km intervals and that each hub station uses a 90-degree sector beam. The antenna pattern for each sector beam takes the realistic pattern that is expected to be employed by a number of service providers. For the form of frequency reuse patterns, we assume that each FWA hub station will use four different frequency bands corresponding to each sector and that each hub station in a group of four hub stations use different frequency group. Thus, 16 frequency bands are to be used.

Fig.6 shows the relative positional relations between HAPS airships and the FWA station. In Fig.6, HAPS airships, 11×21=231 in total, are deployed in a 500 km×1000 km area. The FWA station is to be positioned to the left of the position directly under the airship located in the center of the left end in the array of the 231 HAPS airships. The characteristics of the ratio between the intensity of interference and thermal noise (I/N performance) in the FWA hub station are shown in Fig.7. In Fig.7, “front” means the result provided when the antenna main beam of the FWA hub station is directed to the center of the HAPS airship fleet with regard to the azimuth orientation (namely, rightward direction in Fig.6). Meanwhile, “side” and “back” are the results provided when it is parallel (directly above or directly under in Fig.6) or directly behind (leftward in Fig.6) the HAPS airship fleet. The elevation angle of the main beam of the FWA hub station is set to zero degrees. The results in Fig.7 imply that the maximum I/N is about -20 dB. Thus, frequency sharing is possible.

The intensity of interference caused by a single HAPS airship is shown in Fig.8 with the I/N characteristics of the FWA substation. The maximum I/N reaches about 30 dB in this case—a large value far exceeding I/N=−15

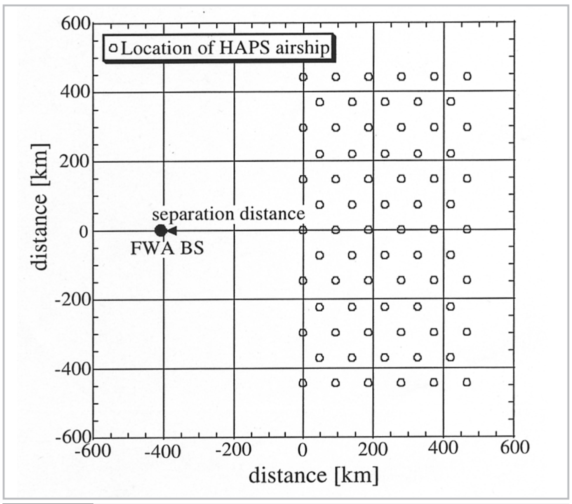

Fig.6 11 x 21 HAPS airships deployed in 500 km x 1000 km area

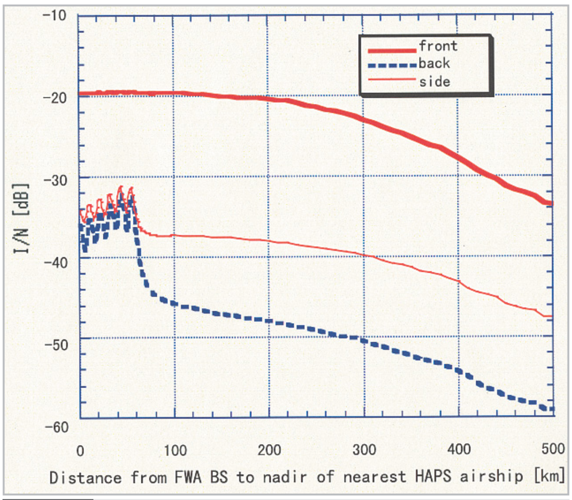

Fig.7 I/N characteristics of interference with the FWA hub station caused by the 11 x 21 HAPS airships

dB, regarded as the acceptable level of interference in an FWA substation. This is because the antenna gain of the FWA substation is larger than that of the FWA hub station, and because the main beam emitted from the antenna of the FWA substation is occasionally directed to a HAPS airship, with the elevation angle of the main beam of the FWA substation station antenna limited to 60 degrees. If one frequency band is shared with an FWA substation in the same area, the HAPS airship is likely to cause serious interference with the FWA substation. In this case, interference mitigation techniques such as dynamic channel assignment (DCA) are required.

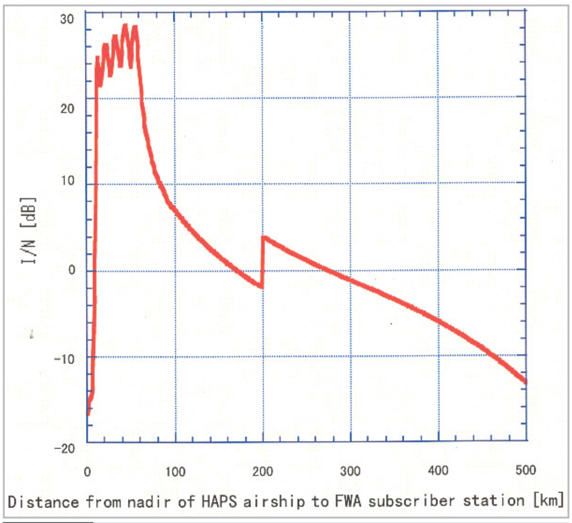

Fig.8 I/N characteristics in the FWA substation with regard to interference caused by one HAPS station

3.3 Compatibility with space science service using passive sensors[9][10]

Allocated to the uplink for the fixed service by HAPS, the 31.3-31.8 GHz band next to the 31.0-31.3 GHz band has also served space science missions such as Earth exploration satellite service (passive) and radio astronomy service. A space science service that uses passive sensors in this frequency band is vulnerable to foreign radio waves. Unwanted emission by the HAPS uplink into this foreign band must be reduced to very low levels. For interference with Earth exploration satellite service (passive) and radio astronomy service, a magnitude of −105.85 dB (W/ MHz), which is the unwanted emission level derived from theoretical design, is used for interference evaluation. It has been indicated that the HAPS system and space science service can be compatible if the unwanted emission is limited to this level. CRL has developed an RF transmission module for the 31 GHz band in order to examine the possibility of attaining the assumed level of unwanted emission. Fig.9 illustrates the measurement results. This figure shows the radiation power per MHz. The measurement results indicate that the level of −76 dBm/ MHz (−106 dB (W/ MHz)) for the signals of a bandwidth of 20 MHz is attained in frequency ranges at least 40 MHz from the carrier frequency. This RF module, which we developed, was constructed by the commercialized components available in the open market. If this module is modified to comply with present specifications, the unwanted emission into foreign bands will be reduced to required levels at reasonable cost. These results indicate that a HAPS system using the 31 GHz band for its uplink is likely to be compatible with space science service.

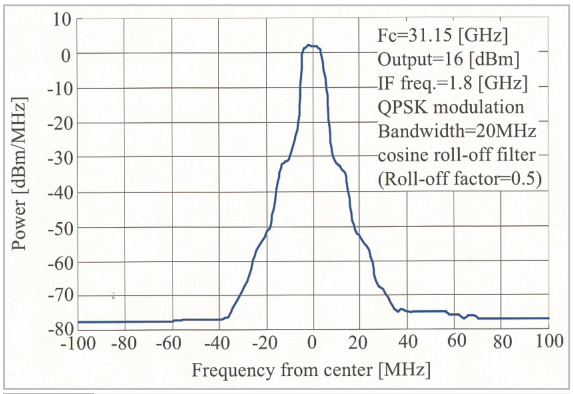

Fig.9 Measured spectrum (per 1 MHz) of the output signal emitted from the developed 31 GHz-band RF module

4 Interference mitigation techniques[11]

This section describes the interference mitigation techniques expected to facilitate sharing of same and adjacent frequency bands between the 31/28 GHz-band HAPS system and other services. Table 2 summarizes the interference mitigation techniques and the interference scenarios for their applications.

4.1 Limitations to operational elevation angle

If the operational elevation angle of the HAPS ground station is set at an angle of at least 20 degrees, the separation angle between the direction of the main beam of the HAPS ground station and those of the other services that may interfere with HAPS increases, and the sidelobe gain of the antenna of the HAPS ground station decreases. This makes it possible to reduce interference with the HAPS ground station caused by the GSO-FSS earth station, interference between the FWA stations (hub station and substation) and HAPS ground stations, and interference with radio astronomy service caused by the HAPS ground station. As a result, since the required separation distance meeting the interference criterion can be narrowed, it becomes easy to share the same frequency band.

4.2 Improvement in the radiation pattern of the HAPS-borne antenna and HAPS ground station antenna

Interference with satellites caused by the HAPS airship can be reduced by improving the radiation pattern (for main-lobe, side-lobe, back-lobe) of the beams emitted from the HAPS-borne antenna. Our study indicates that the radiation power of the side-lobe and back-lobe can be lowered by about 5 dB by employing the 4-cluster beams shown in Fig.10. This improvement results from the combination of reduced transmission power due to a gain in the direction to the bore site and a decrease in sidelobe gain.

The improvement in radiation pattern in the HAPS ground station (gain depression at elevation angles smaller than the minimum operational elevation angle for the HAPS system) also effectively reduces interference between the HAPS ground station and the terrestrial stations of the other services (GSO-FSS, FWA, radio astronomy).

4.3 Dynamic channel assignment

Dynamic Channel Assignment (DCA) was originally developed as an effective method for increasing the capacity of subscribers inside the same system by searching for an unused frequency or time slot to activate it. However, if DCA is used in a communications system that allocates a frequency or time slot in response to user request, it can reduce interference to/from other services. An example of adopting DCA to the HAPS system is shown below under the following conditions:

(i) The HAPS airship or the HAPS ground station is equipped with an apparatus capable of frequency monitoring;

(ii) The apparatus monitors the frequency

Table 2 Interference mitigation techniques

Interference mitigation Techniques \ Systems sharing the same frequency		Fixed satellite service (in-band interference)		To/from Fixed Service (in-band)	Space science service (out-of-band interference)	
		To FSS satellite	From FSS/ES		To EESS satellite	To RAS station
1)Limitations to operational elevation angle			√	√		√
2)Improvement in the radiation pattern of the borne antenna and ground antenna		√	√	√		√
3)Shielding effect by HAPS airship envelope		√				
4)Dynamic Channel Assignment			√	√		
5)Automatic transmitting power control	uplink			√	√	√
	downlink	√		√		

FSS/ES: FSS Earth Station, EESS: Earth Exploration-Satellite Service, RAS: Radio Astronomy Service FSS: Fixed Satellite Service √: Effective

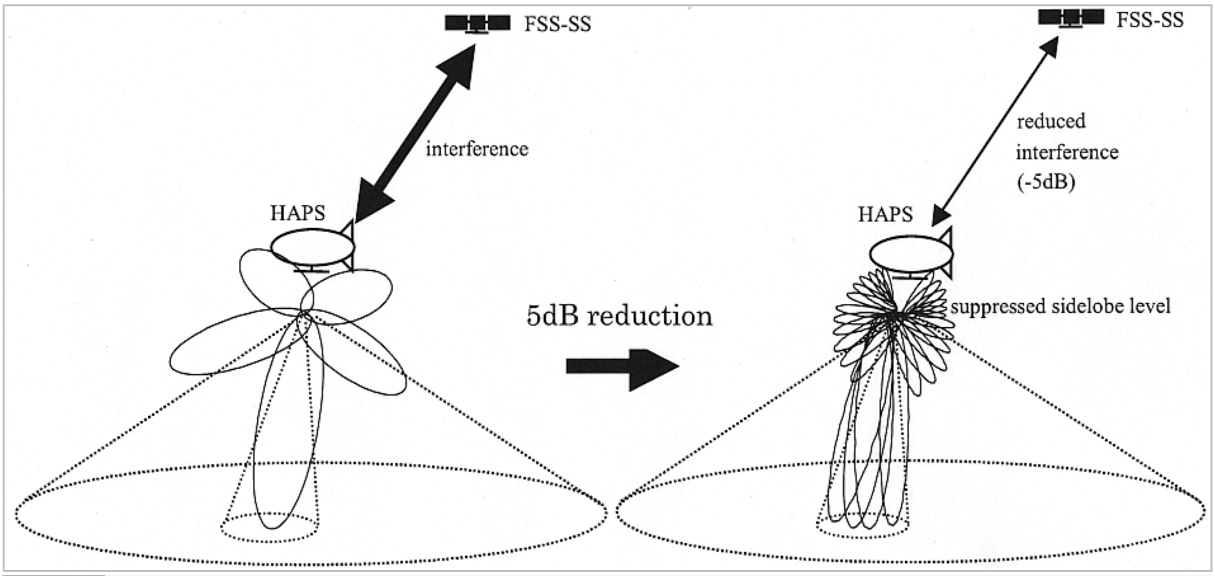

Fig.10 Radiation pattern improvement by beam-shaping

status of the other services; and

(iii) The HAPS system allocates unused frequency or unused time slots to the communications channel. When a frequency is shared with the FWA system in the same service area, DCA is an indispensable technology. A detailed study of DCA will be required to allow frequency sharing with other services.

4.4 Automatic transmitting power control (ATPC)

Rain attenuation must be taken into account when designing an outdoor wireless communications system that employs high-frequency millimeter and sub-millimeter waves. To compensate for rain attenuation, the automatic transmitting power control (ATPC) scheme, which monitors weather or receiving power and automatically adjusts transmission power accordingly, increases transmission power when it rains and reduces

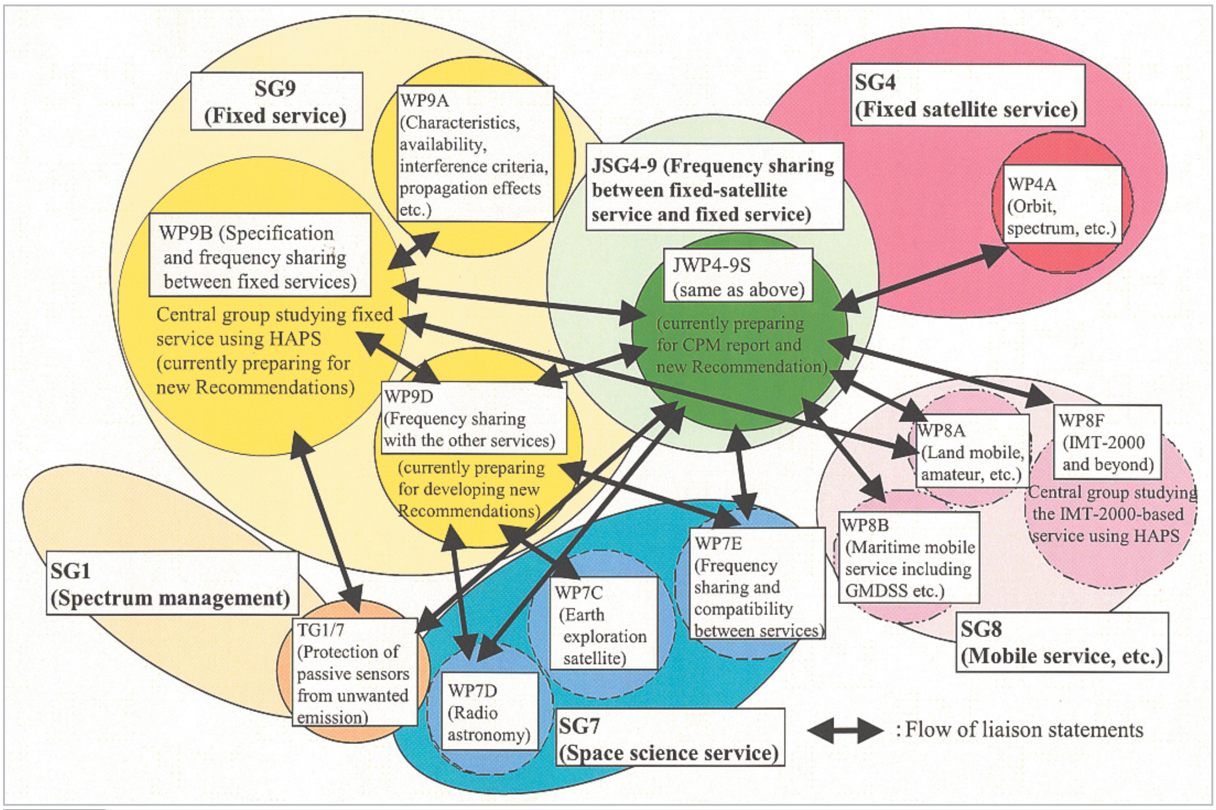

Fig.11 *Relations between HAPS-related working parties at the ITU-R*

it when the weather is clear. Since the primary function of ATPC scheme is to cut surplus transmission power, it also helps reduce interference. Deploying ATPC in the HAPS ground station will reduce interference with GSO-FSS earth stations, FWA stations, and space science service. In addition, if each spot-beam transmitter borne in HAPS is equipped with ATPC, interference with GSO-FSS satellites and FWA stations will be reduced. Although ATPC requires high transmission power during periods of rain, the areas and duration of such high power transmission are actually quite limited. In practice, interference caused by a few spot-beams is unlikely to be a problem.

5 Contribution to activities at ITU

This section describes the organizational structure of the ITU-R involved in the 31/28 GHz HAPS-based system and CRL/TAO's contribution to the ITU-R activities.

5.1 Organization of ITU-R

The ITU-R has seven Study Groups (SGs) classified by work, and each SG has Working Parties (WPs) classified into more detailed categories for intensive discussion of technological issues concerning frequency sharing. The HAPS-based system using the 31/28 GHz band, which is linked to fixed services, is discussed in SG9. WP9B under SG9 has been assigned the topic of system properties of fixed services and relevant matters is studying the HAPS-based system (as explained in Section 2), frequency sharing with FWA (Section 3.2), interference mitigation techniques (Section 4), effects upon other services across international borders (not discussed here), and other issues. WP9D, which is assigned the task of investigating frequency sharing with other services, except for the fixed satellite service (FSS), discusses compatibility between the space science service and HAPS-based system in terms of the use of adjacent frequencies (Section 3.3). Liaison documents are sent to WP7C (Earth exploration satellite

Table 3 *CRL/TAO activities at ITU meetings*

Year	Month	Meeting	Major results
1997	October-November	WRC-97 (Geneva)	Definition of "HAPS", Allocation of 47/48 GHz bands
1998	February	WP9B, 4-9S (Geneva)	PDNR input 1
	September	WP9B, 4-9S (Geneva)	PDNR input 1
1999	April	WP9B, 4-9S (Geneva)	PDNR input 1, WD output 1
	September	APG (Brisbane)	APT common proposal
	October	SC (Geneva)	Draft for regulation-related document
	November	CPM (Geneva)	WRC document preparation
2000	January	APG (Tokyo)	APT common proposal
	February	CITEL (Buenos Aires)	Explanation of APT common proposal
	March	WP7C, 7D (Vancouver)	Reply liaison output
	May-June	WRC-2000 (Istanbul)	Allocation of 31/28 GHz bands, Allocation of 2GHz band, Modification to Resolution 1, Preparation of new Resolution 1
	August	WP7C, 7D (Orlando)	Reply liaison output
	September	WP9B, 4-9S, SG-9 (Geneva)	PDNR input 6, Draft of new Question 1
2001	April	WP9B, 9D, 4-9S (Geneva)	PDNR input 2, WD input 2
	May	WP7C, 7D, 7E (Geneva)	Reply liaison output
	October	WP9B, 9D, 4-9S, SG-9, JSG4-9S (Geneva)	DNR output 2

APT: Asia Pacific Telecommunity, APG: APT Group Meeting, SC: Special Committee,
CPM: Conference Preparatory Meeting, CITEL: Inter-American Telecommunication Commission,
DNR: Draft New Recommendation, PDNR: Preliminary Draft New Recommendation, WD: Working Document

service) and WP7D (radio astronomy service) under SG7, which has been assigned the task of handling science service for discussion also in WP7C and WP7D about achieving compatibility with the space science services. Frequency sharing with FSS (Section 3.1) is discussed by WP4-9S, a joint working party between SG4 and SG9 in charge of the frequency sharing between FSS and fixed service. When HAPS is used in mobile services, WPs under SG8 will be involved. These organizational relations are shown in Fig.11.

5.2 Contribution to the ITU-R

Led by the Ministry of Public Management, Home Affairs, Posts and Telecommunications, Japan has accelerated its drive to secure a frequency band (31/28 GHz) for fixed services using HAPS and for relaxing the pertinent limitations on its use. CRL and TAO have backed the national activities from technological aspects by presenting a number of contribution documents. Table 3 summarizes CRL/TAO's involvement in the ITU meetings as of October 2001.

As shown in Table 3, related WP meetings, lasting 7-10 days, are held every 2-3 months. As a matter of fact, we are busy year-round preparing contribution documents for such meetings and arranging domestic council meetings. The acquisitions of the 47/48 GHz band at WRC-97 and the 31/28 GHz band at WRC-2000 are the results of such diligent-widespread efforts and activities, as previously mentioned in this paper. Table 4[12] summarizes the frequency bands available in communication systems using HAPS and other services that may share those frequencies with HAPS after WRC-2000. Table 5[12] shows the footnotes regarding the 31/28 GHz band allocation table for the fixed services using HAPS. This band allocation was realized mainly through Japan's efforts.

As underscored in the tables, several restrictions apply to use of the 31/28 GHz band. At the coming WRC-03, we will try to

Table 4 *Frequency band allocated to HAPS (after WRC-2000)*

Frequency band	Regions	Direction of radio waves	Available services	Services sharing the frequency bands
47.9-48.2GHz 47.2-47.5GHz	All regions	Uplink and downlink	Fixed service	Fixed service, Mobile service, Fixed satellite service (Uplink), There is a neighboring band used in radio astronomy service
31.0-31.3GHz	12 Asian countries	Uplink	Fixed service	Fixed service, Mobile service, Space research mission in part of the regions. There is an adjacent band used in space science service (using passive sensors)
27.5-28.35GHz	12 Asian countries	Downlink	Fixed service	Fixed service, Mobile service, Fixed satellite service (Uplink)
1885-1980MHz 2010-2025MHz 2110-2170MHz	Region 1 and Region 3 (All regions except for South and North America)	Uplink and downlink	IMT-2000 base station	Fixed service, Mobile service (Particularly ground-based IMT-2000 service and conventional mobile communication services)
1885-1980MHz 2110-2160MHz	Region 2 (South and North America)	Uplink and downlink	IMT-2000 base station	

Table 5 *Footnotes regarding the use of the band 31/28 GHz by HAPS*

Article S5 Frequency allocation table for the band 27.5-28.5GHz FIXED

S5.537A (S5.5SSS)

In Bhutan, Indonesia, Iran (Islamic Republic of), Japan, Maldives, Mongolia, Myanmar, Pakistan, the Dem. People's Rep. of Korea, Sri Lanka, Thailand and Viet Nam, the allocation to the fixed service in the band 27.5-28.35GHz may also be used by high altitude platform stations (HAPS). <u>The use of the band 27.5-28.35GHz by HAPS is limited to operation in the HAPS-to-ground direction and shall not cause harmful interference to, nor claim protection from, other types of fixed-service systems or other co-primary services.</u>

Article S5 Frequency allocation table for the band 31-31.3GHz FIXED

S5.543A (S5.5RRR)

In Bhutan, Indonesia, Iran (Islamic Republic of), Japan, Maldives, Mongolia, Myanmar, Pakistan, the Dem. People's Rep. of Korea, Sri Lanka, Thailand and Viet Nam, the allocation to the fixed service in the band 31.0-31.3GHz may also be used by high altitude platform stations (HAPS) in the ground-to-HAPS direction. <u>The use of the band 31.0-31.3GHz by systems using HAPS shall not cause harmful interference to, nor claim protection from, other types of fixed-service systems or other co-primary services, taking into account No. S5.545. The use of HAPS in the band 31.0-31.3GHz shall not cause harmful interference to the passive services having a primary allocation in the band 31.3-31.8GHz, taking into account the interference criteria given in Recommendations ITU-R SA.1029 and ITU-R RA.769. The administrations of the countries listed above are urged to limit the deployment of HAPS in the band 31.0-31.3GHz to the lower half of this band (31.0-31.15GHz) until WRC-03.</u>

clarify the conditions for frequency sharing in order to relax those restrictions, and then embody our proposals in the Radio Regulations and ITU-R Recommendations. Table 6 summarizes our technical contribution documents addressing the 31/28 GHz-band HAPS-based system, open as of October 12, 2001.

Our two contribution papers (F.[KA-HAPS], F.[HAPS-EESS]) were validated as Draft New Recommendations (DNRs) at the SG9 Meeting in October 2001. DNR documents are one step removed from authorization as ITU-R Recommendations. With regard to the four Preliminary Draft New Recommendations, we continue their study at related WPs to embody our proposals in DNRs at the next SG meeting (listed in Table 7 along with other scheduled major meetings). Pushing ahead these six proposals concurrently involves a staggering amount of effort, considering the massive amount of time and work required for the validation of even a single

Table 6 *Contribution documents on the 31/28 GHz-band HAPS*

Provisional document number	Status of the document as of October 12 in 2001	Outlines
F.(KA-HAPS)	DNR (Draft new recommendation)	Document describing the HAPS system characteristics for use in the evaluation of interference with other services (see Section2)
F.(HAPS-IB)	PDNR (Preliminary draft new recommendation)	Document describing interference level for the HAPS system downlink affecting the other terrestrial fixed service across international boarders
F.(HAPS-MT)	PDNR (Preliminary draft new recommendation)	Document describing interference mitigation techniques to facilitate frequency sharing between the HAPS-based system and the other services (see Section4)
F.(HAPS-EESS)	DNR (Draft new recommendation)	Document describing parameters and evaluation methodologies regarding the interference from the HAPS-based system to the Earth exploration service (passive) (see Section 3.3)
F.(HAPS-RAS)	PDNR (Preliminary draft new recommendation)	Document describing parameters and evaluation methodologies regarding the interference from the HAPS-based system to the radio astronomy service as well as the operational requirements of the HAPS-based system for their compatibility (see Section3.3)
F.(HAPS-FSS)	PDNR (Preliminary draft new recommendation)	Document describing parameters and evaluation methodologies regarding the interference between the fixed satellite service and the HAPS downlink (see Section 3.1)

Table 7 *Major meetings in the future (until WRC-03)*

Year	Month	Meeting	Major goal
2002	February	WP7C, 7D	Reply liaison output
	April	WP9A, 9B, 9D, 4-9S, SG-9, JSG4-9S (Geneva)	DNR output
	Not determined	Special Committee (SC)	Preparation of regulation-related documents
	November	CPM (Geneva)	WRC preparation document (CPM report) output
2003	Top of the year	APG	APT common proposal
	near May	Radio Assembly (RA)	Final approval of the draft recommendation
	May-June	WRC-2003 (Venezuela)	Elimination of limitations to the 31/28GHz-band allocation

proposal for ITU Recommendation. If those six proposals are successfully embodied in ITU Recommendations at the Radio Assembly held in 2003, Japan can take pride in its enormous efforts.

6 Summary

This paper has described fixed services principally utilizing the 31/28 GHz-band stratospheric platform system (HAPS), focusing on the status of the studies on its frequency sharing with the other services at ITU. We plan to proceed with detailed research for the upcoming WRC-03. The stratospheric platform system introduced in Section 2 is the primary model used in the study of frequency sharing at ITU and may determine the system parameters for actual implementation. Considering the growing need for limited frequency resources, research on frequency sharing will become increasingly important for wireless communication technologies, including stratospheric platform wireless communications system. The interference mitigation techniques described in Section 4 and the technology for cutting surplus radiation affecting neighboring bands described in Section 3 are expected to serve a wide range of frequency sharing technologies, not limited to the stratospheric platform system. It is our hope that our research will contribute to further improvements in such technologies.

7 Acknowledgments

We are grateful to people at Mobile Satellite Communications Division, Radio Department, Ministry of Management, Home Affairs, Posts and Telecommunications, Mr. Masayoshi Murotani (former Chairman of ITU-R SG9) now at NTT-DoCoMo, and Mr. Akira Hashimoto (Chairman of ITU-R WP9B) as well as those in Telecommunication Advanced Organization for their help in our activities for acquiring a frequency band for HAPS.

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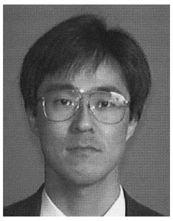
Antennas Onboard Stratospheric Platform, Frequency Sharing



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R&D Program on Telecom and Broadcasting System Using High Altitude Platform Stations