

RECOMMENDATION ITU-R F.1569

Technical and operational characteristics for the fixed service using high altitude platform stations in the bands 27.5-28.35 GHz and 31-31.3 GHz

(Question ITU-R 212/9)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that new technology utilizing high altitude platform stations (HAPS) in the stratosphere is being developed;
- b) that the World Radiocommunication Conference (Geneva, 1997) (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;
- c) that since the 47 GHz bands 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 for possible identification of additional spectrum in ITU-R;
- d) that the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000) made a provision for the use of HAPS in the FS service in the bands 27.5-28.35 GHz and 31-31.3 GHz in certain countries on a non-interference, non-protection basis in order to address issues of rain attenuation associated with the 47 GHz bands (RR Nos. 5.537A and 5.543A), under the condition that the use of the band 31-31.3 GHz is limited to the lower half of the band (31-31.15 GHz) until WRC-03;
- e) that Resolution 122 (Rev.WRC-2000) urgently requested studies on technical, sharing and regulatory issues in order to determine criteria for the operation of HAPS in the bands referred to in *considering* d) above;
- f) that the 31.3-31.8 GHz band is allocated to the radio astronomy, Earth exploration-satellite service (EESS) (passive) and space research service (passive), and it is necessary to appropriately protect these services from unwanted emissions from HAPS ground stations operated in the band 31-31.3 GHz, taking into account RR No. 5.340 and the interference criteria given in Recommendations ITU-R SA.1029 and ITU-R RA.769,

noting

- a) that receivers in the HAPS-based system in the bands 27.5-28.35 GHz and 31-31.3 GHz are designed to operate under the maximum aggregate interference of 10% of the receiving system thermal noise at HAPS platforms and HAPS ground stations,

recommends

- 1 that HAPS using the bands 27.5-28.35 GHz and 31-31.3 GHz be operated between the altitude of 20 to 25 km;
- 2 that the frequency reuse factor of the cell illuminated by the spot beams of HAPS antenna be equal to or more than four in the bands 27.5-28.35 GHz and 31-31.3 GHz (see Note 1);
- 3 that, the signal power attenuation due to the shielding effect of the metal-coated airship body in the frequency range 18-32 GHz be calculated with the following equations:

$$\begin{array}{lll} 0 & \text{dB} & \text{for } 0^\circ \leq \theta < 90^\circ \\ 0.5(\theta - 90) & \text{dB} & \text{for } 90^\circ \leq \theta < 120^\circ \\ 15 & \text{dB} & \text{for } 120^\circ \leq \theta \leq 180^\circ \end{array}$$

where θ is the separation angle to the direction of interest from the nadir direction of HAPS;

- 4 that automatic transmitting power control (ATPC) technique may be used to reduce probability of unacceptable interference to other services and to increase link availability in the HAPS-based system;
- 5 that the upper bound of the number of simultaneously transmitting carriers at the ground station in the HAPS-based system determined by available bandwidth in the uplink and the bandwidth of each transmitting signal be taken into account for sharing study;
- 6 that the HAPS-based system in Annex 1 be used for the relevant studies in ITU-R in the bands 27.5-28.35 GHz and 31-31.3 GHz.

NOTE 1 – The term “frequency reuse factor” in *recommends 2* means the number of divided frequency sub-bands for the effective frequency use in the communication system with cellular configuration. For example, when the frequency reuse factor is 4, one of the divided frequency sub-bands is used repeatedly in every 4 cell.

ANNEX 1

Typical technical parameters for the FS using HAPS in the bands 27.5-28.35 GHz and 31-31.3 GHz

1 Introduction

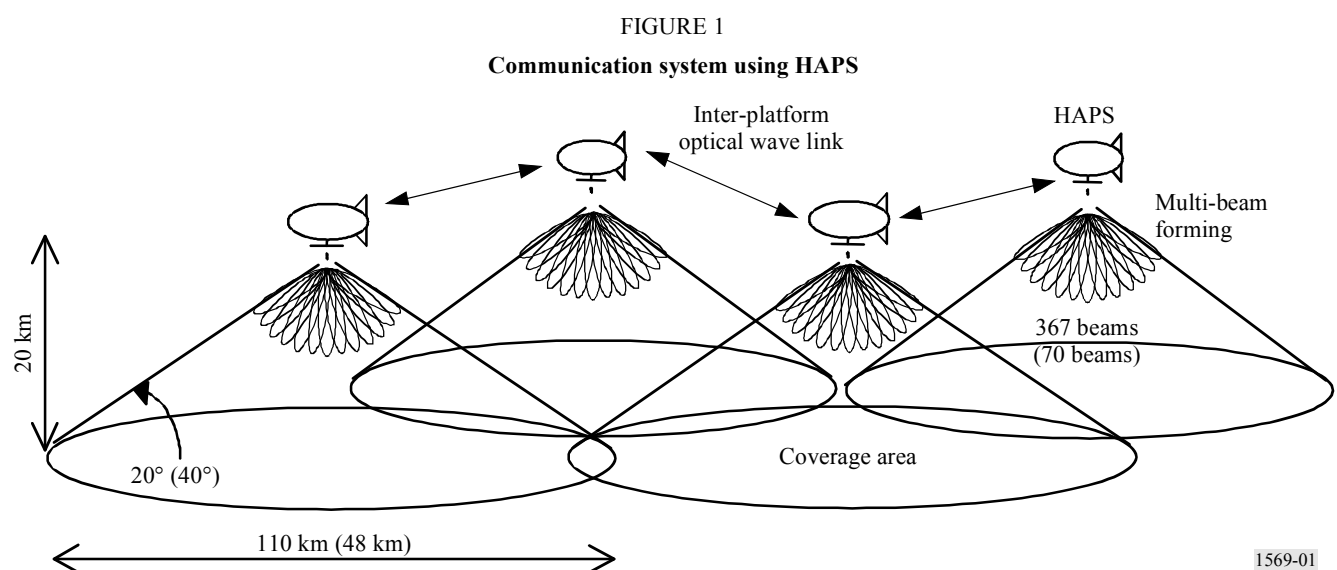
This Annex provides typical technical characteristics for the FS using HAPS in the frequency range of 18-32 GHz focusing on the bands 27.5-28.35 GHz and 31-31.3 GHz, which may be used in the relevant studies.

2 Outline of a typical HAPS-based system

A typical HAPS system in the frequency range 18-32 GHz may have the following features:

- a HAPS is mounted on an airship controlled to be located at a nominal fixed point at the altitude of 20 to 25 km;
- the airship is supplied with electric power necessary for the system maintenance and the operation of communication mission from solar batteries being put on the upper surface of the airship and second batteries being charged for night-time use;
- the airship is equipped with a multi-spot beam antenna under its bottom providing access links to the ground stations with a certain minimum elevation angle;
- each beam formed by the multi-spot beam antenna corresponds to a cell on the ground with at least four times frequency reuse;
- the gas envelope of the airship is made of the skin material with metal layer such as that of aluminium, which is expected to block electromagnetic waves in the frequency around 18-32 GHz or higher;
- multiple airships are deployed to cover a wide range of area on the ground and the stations on board them are connected by wireless links such as optical wave links to build an all-wireless mesh-like network.

Figure 1 illustrates an image of communication system using HAPS. Two examples for minimum elevation angle, 20° and 40° , are shown in the Fig. 1.



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3 Altitude of HAPS

The altitude of HAPS is defined in RR No. 1.66A as 20-50 km. The line-of-sight coverage from a HAPS becomes large at higher altitude. The atmospheric density, however, decreases significantly at higher altitude. Table 1 shows the atmospheric density and pressure at various altitudes. The atmospheric density at the altitude of 50 km is much lower than that at the altitude of 20 km by about 1/90. This means the airship at the altitude of 50 km needs Helium gas as 90 times as that at the altitude of 20 km and needs the body length as 4.5 times. Assuming that a 200 m long airship is needed at the altitude of 20 km to carry a certain weight a 900 m long airship is needed at the altitude of 50 km to carry the same weight. It is absolutely impossible to build such a huge airship with the current and near-future technology.

TABLE 1

The atmospheric density and pressure in the stratosphere

Altitude (km)	Atmospheric density (kg/m ³)	Pressure (hpa)
0	1.22	1 013
15	0.195	121
20	0.0889	55.3
25	0.0401	25.5
30	0.0184	12
50	0.00103	0.798

Figure 2 shows an average wind profile in the upper atmosphere. The wind speed has a local minimum around the altitude of 20-25 km. It becomes larger at the altitude higher than 25 km and is four times larger at the altitude of 50 km than at that of 20 km. To keep the position of the airship at a nominal fixed point against the wind, much larger propulsion power is necessary, which also requires heavier batteries for night operation. On this point of view, the operation of an airship at an altitude less than 25 km is reasonable reflecting the current technology.

Taking into account the above considerations, it can be concluded that the altitude of HAPS is less than about 25 km from a technical viewpoint.

4 Minimum operational elevation angle

The minimum operational elevation angle determines the area of service coverage by a single HAPS. If the smaller minimum elevation angle is assumed, the larger the service coverage can be obtained. The rain path, however, becomes longer and the required e.i.r.p. increases because the larger rain margin is needed.

The typical value of the minimum operational elevation angle for a HAPS system using 28/31 GHz band may be more than 20°. An operation with a smaller elevation angle needs higher e.i.r.p. in uplinks and downlinks because of a longer propagation path and larger rain attenuation. It could cause a difficult sharing situation between HAPS system and other systems such as satellite systems, fixed service, space science services and so on. Moreover, shadowing by buildings or mountains will degrade site availability for lower elevation angle in the urban or mountain areas.

Elevation angles smaller than 20° could be introduced under the conditions that:

- e.i.r.p.s in uplinks and downlinks with the elevation angle more than 20° are kept to constant values and these can be increased only for links with smaller elevation angle;
- appropriate minimum operation angle is determined in accordance with sharing requirement with other services at each area; and
- ATPC is appropriately used in uplinks and downlinks.

A larger minimum elevation angle, for instance 40°, is also possible in order to reduce interference to/from other services and to increase the site availability against shadowing by buildings or mountains. The larger the minimum elevation angle is, the more the number of HAPS will be needed to cover a certain area on the ground, while the total number of the spot beams for all the HAPS is unchanged.

5 On-board multibeam antenna

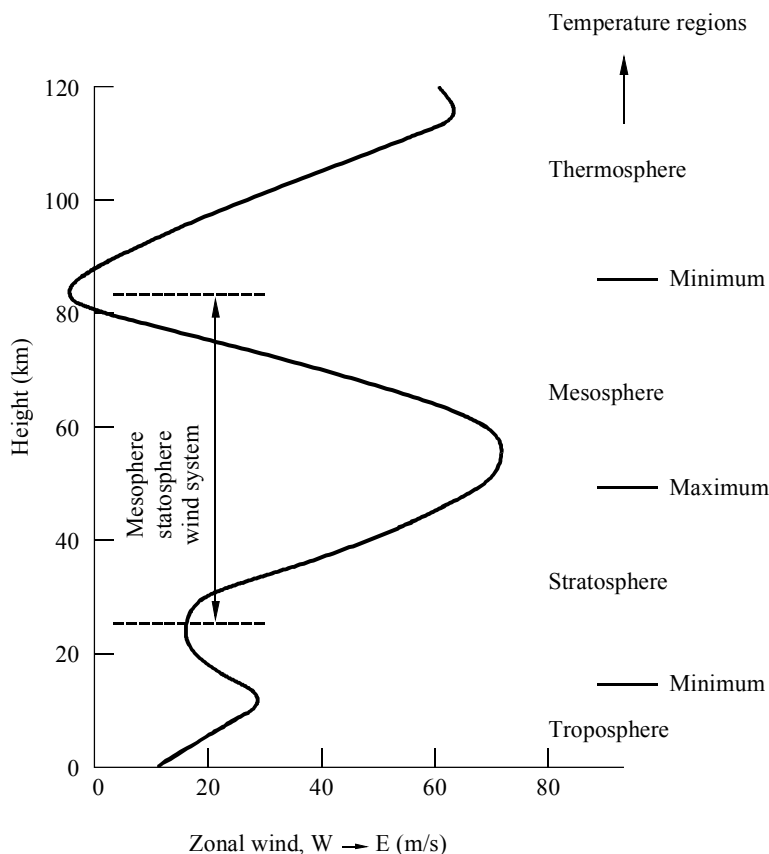
A multi-spot beam antenna (multibeam antenna) is preferable for the purpose to cover many subscriber ground stations by a single HAPS with a high frequency reuse efficiency.

Figure 3 shows a typical footprint given by a multibeam antenna when the minimum elevation angle is 20°. The number of the spot beams is 367. All of the footprint sizes of the single beam are equal (up to 6 km in diameter) in this case. This can be achieved by assigning the different antenna gain to each spot beam according to its elevation angle (see Table 2) and using elliptical beam patterns. This multibeam design is expected to give smaller interference into/from other services with the path in low elevation angles because the beams near the edge of the service coverage in small elevation angle have higher gain, narrower beamwidth, and smaller side-lobe level than the beams near the centre of the service coverage do. In the design of link budget, the gain at the edge of the spot beam is assumed to be –3 dB. Figure 4 shows an example of the elliptical beam pattern for the spot beam (the elevation angles are 20° and 90°). The pattern for the spot beam with the elevation angle of 90° is given by Recommendation ITU-R F.1245 and is a circular beam. The elliptic patterns for the spot beams with the elevation angel less than 90° are modified from the

pattern given by Recommendation ITU-R F.1245. They consist of two Recommendation ITU-R F.1245 patterns for the major and minor axes of the elliptic pattern. For sharing studies that use the side-lobe level of this elliptic pattern, it is preferable for safety to use the side lobe of the major axis even for that of the minor axis (solid curve in Fig. 4). The Recommendation ITU-R F.1245 pattern may also be used for the antenna of HAPS ground station without modification.

FIGURE 2

Average wind profile in the upper atmosphere

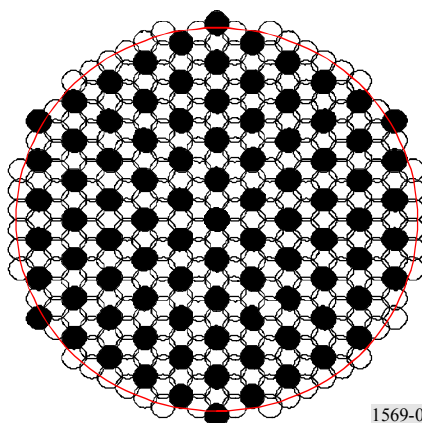


General magnitude of zonal winds in the upper atmosphere, illustrated by a height profile for 45° N in January. (Committee on Space Research (COSPAR) International Reference Atmosphere. Akademie-Verlag, 1972.)

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FIGURE 3

Typical footprint illuminated by a multibeam antenna on-board HAPS using 28/31 GHz
(equal spot-beam footprint)



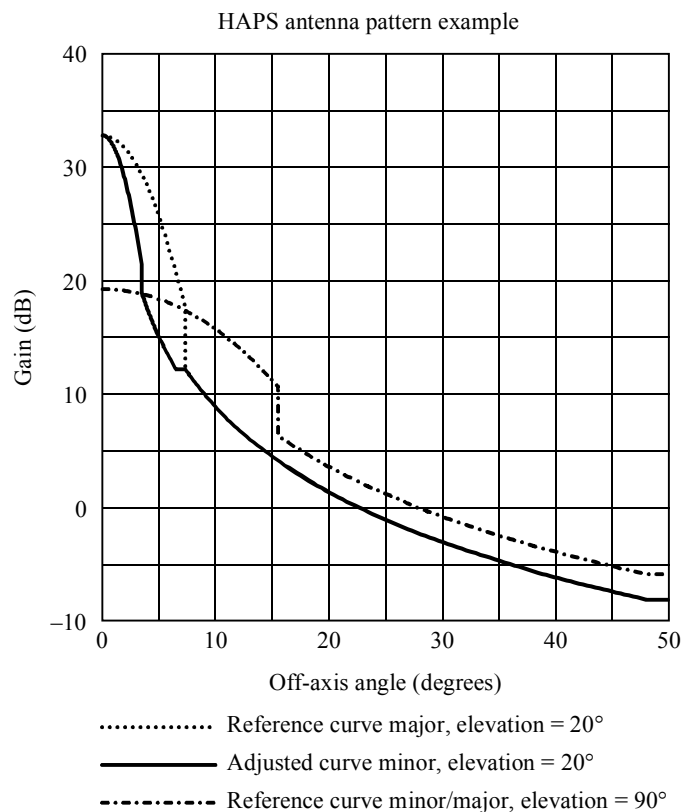
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TABLE 2

Typical gain assignment to the spot beams

Elevation angle at the beam centre (degrees)	81	66	53.9	44.7	37.8	32.6	28.5	25.2	22.5	20.3	20
Spot beam peak gain (dBi)	19.5	19.7	20.8	22.4	24.2	25.9	27.6	29.1	30.5	31.9	32.5

FIGURE 4

**Typical elliptic mask pattern of a spot beam
(elevation angle = 20° and 90°)**

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The frequency reuse factor of spot beams is assumed to be four for sharing studies, because it could give the worst aggregate interference into other co-primary services from the downlink of HAPS. It may be difficult to keep sufficient inter-beam isolation within a permissible level with the smaller reuse factor than four.

6 Shielding effect by airship on backward radiation

The envelope of a HAPS airship will be coated by metal film (typically aluminium). This coating will block the backward radiation from the on-board antenna installed at the base of the airship, because the body size of the airship will be considerably large compared with the wavelength of the signal.

In order to obtain the attenuation by the shielding effect, a simple two-dimensional scattering problem shown in Fig. 5 is considered. The relative electromagnetic power on the surface of the cylinder in the direction of φ (degree) is expressed by equation (1) as functions of carrier signal frequency and radius of cylinder.

$$P = 20 \log_{10} \left| \frac{1}{\pi ka} \sum_{n=0}^{\infty} \epsilon_n \frac{(-j)^{n-1}}{H_n^{(1)'}(ka)} \cos n\varphi \right| \quad \text{dB} \quad (1)$$

where:

a : radius of cylinder

$k = 2\pi/\lambda$ (λ is the carrier wavelength)

ϵ_n ($n = 0$), 1 ($n \neq 0$) and $H_n^{(1)'}(x)$: derivative of the n -th order Hankel function of the first kind.

FIGURE 5
2-D scattering model of a plane wave (H-wave) by infinite conducting cylinder

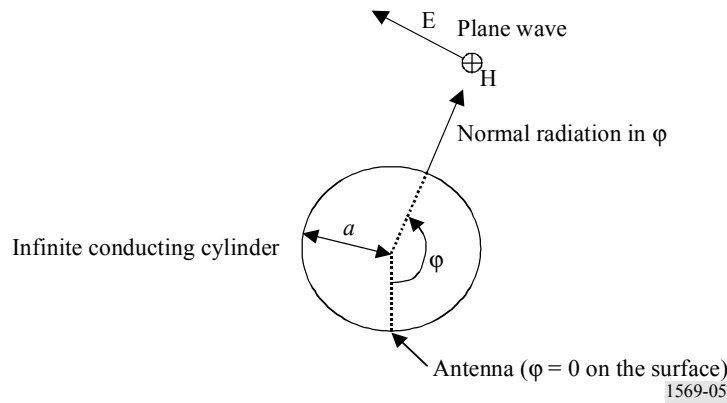


Figure 6 shows the relative electromagnetic power on the cylinder surface in case of $a = 7.5$ m and frequency = 20 GHz. Attenuation by the shielding effect increases as the cylinder radius becomes larger or as frequency becomes higher. Therefore the attenuation mask expressed by equation (2) associated with the shielding effect of the HAPS airship body could be used for a HAPS system using the airship with the radius larger than 7.5 m and carrier signal frequency higher than 20 GHz:

$$\begin{array}{lll} 0 & \text{dB} & \text{for } 0^\circ \leq \theta < 90^\circ \\ 0.5(\theta - 90) & \text{dB} & \text{for } 90^\circ \leq \theta < 120^\circ \\ 15 & \text{dB} & \text{for } 120^\circ \leq \theta \leq 180^\circ \end{array} \quad (2)$$

where θ is the separation angle to the direction of interest (such as a satellite) from the nadir direction of HAPS as shown in Fig. 7. It is noted that the antenna gain at $\theta = 90^\circ$ should be used in the calculation of backward radiation power from the antenna at the base of the airship, because the wave transmitted in the direction of $\theta = 90^\circ$ propagates along the round body surface and is radiated backward.

