International Telecommunication Union

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Deployment and technical characteristics of broadband high altitude platform stations in the fixed service in the frequency bands 6 440-6 520 MHz, 21.4-22.0 GHz, 24.25-27.5 GHz, 27.9-28.2 GHz, 31.0-31.3 GHz, 38.0-39.5 GHz, 47.2-47.5 GHz and 47.9-48.2 GHz used in sharing and compatibility studies

F Series

Fixed service

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R F.2439-0

Deployment and technical characteristics of broadband high altitude platform stations in the fixed service in the frequency bands 6 440-6 520 MHz, 21.4-22.0 GHz, 24.25-27.5 GHz, 27.9-28.2 GHz, 31.0-31.3 GHz, 38.0-39.5 GHz, 47.2-47.5 GHz and 47.9-48.2 GHz used in sharing and compatibility studies

(2018)

1 Introduction

This Report provides deployment and technical characteristics for the fixed service using high altitude platform stations (HAPS) in the frequency bands: 6 440-6 520 MHz, 21.4-22.0 GHz, 24.25-27.5 GHz, 27.9-28.2 GHz, 31.0-31.3 GHz, 38.0-39.5 GHz, 47.2-47.5 GHz and 47.9-48.2 GHz, in accordance with Resolution **160 (WRC-15)**. It provides information on broadband HAPS links used in sharing and compatibility studies in the frequency bands listed above, and in adjacent bands.

This Report includes the HAPS systems characteristics in the bands 6 440-6 520 MHz, 21.4-22.0 GHz, 24.25-27.5 GHz, 27.9-28.2 GHz, 31.0-31.3 GHz, 38.0-39.5 GHz, 47.2-47.5 GHz and 47.9-48.2 GHz that are used in the sharing and compatibility studies under WRC-19 agenda item 1.14.

2 Glossary

CPE	Customer premises equipment
DL	Down link
e.i.r.p.	Equivalent isotopically radiated power
G/T	Figure of merit
GW	Gateway
HAPS	High altitude platform station
LHCP	Left hand circular polarisation
Ptx	Transmit power
RHCP	Right hand circular polarisation
RF	Radio frequency
Tx	Transmitter
UL	Up link

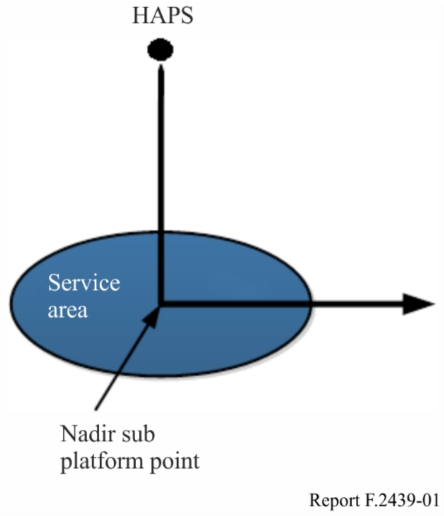
3 Deployment and system characteristics of HAPS systems

This section outlines the deployment scenarios for HAPS. It also identifies a number of different HAPS systems.

HAPS typically consist of an aerial platform that flies over a pre-defined footprint in order to provide communication services to users located within the given circular radius of the nominal nadir platform point as illustrated in Fig. 1 below. The HAPS communicates with a set of fixed CPEs or Gateway stations on the ground located within the service area.

FIGURE 1

HAP System Service Area



HAPS utilizes one or more gateway connections (feeder links) from a number of locations within the platform service area.

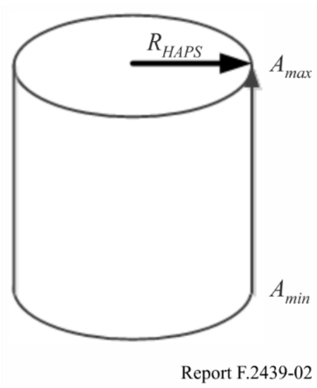
4 Platform geometry

Each platform has the ability to provide coverage within a radius R_{user} from the nadir sub-platform point as illustrated in Fig. 1. This typically corresponds to a large area. For example, at a 20 km altitude, a platform can cover up to 50 km radius, assuming user terminal elevation angles > 20 degrees in the coverage area and under certain circumstances up to 200 km radius with terminal elevation angles greater than 5 degrees.

Once in position, the HAPS will remain within a cylindrical volume. The HAPS may change altitudes over time, bounded by an upper and lower limit, as defined in RR No. **1.66A**. This flight path typically remains constrained to a volume that can be represented using a cylinder as illustrated in Fig. 2. The cylinder's radius, R_{HAP} is the maximum distance from the nominal centre that the platform will fly while providing service. A_{min} is the platform's minimum altitude and A_{max} is the platform's maximum altitude.

FIGURE 2

HAPS volume of movement



The design of the cylinder (see Fig. 2) together with the specified positions of the FS terminal in the service area define the variation in the geometry of the FS links. This provides the basis for related studies.

A generalisation of the platform geometric characteristics is provided in Table 1.

TABLE 1

Example platform geometric characteristics

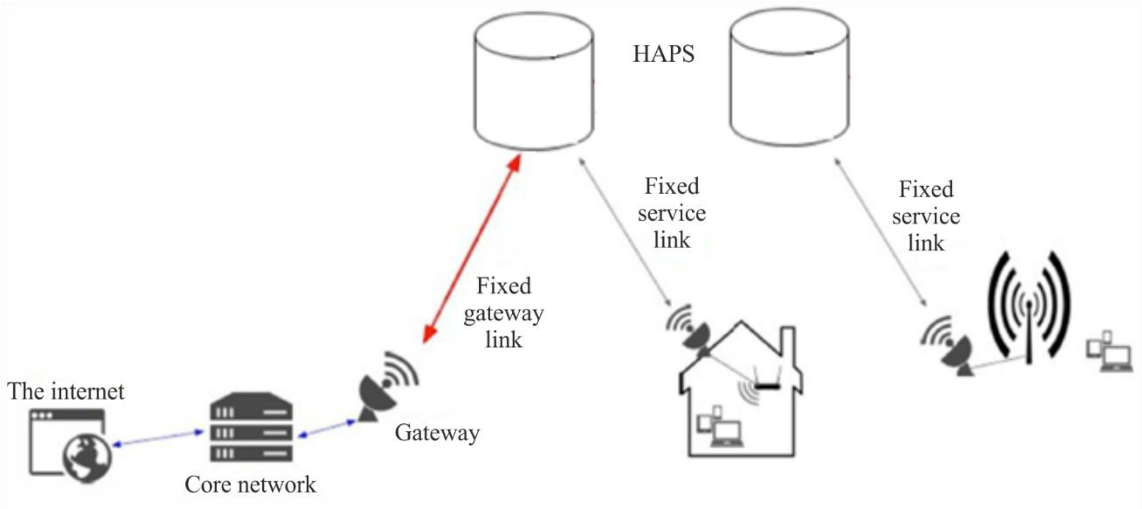
Parameters	Values
Platform service radius R_{user}	20 km to 50 km
Minimum platform altitude A_{min}	20 km
Maximum platform altitude A_{max}	26 km
Maximum platform flight radius R_{hap}	1 to 5 km

Specific parameters for different systems are outlined in § 6.

5 Illustrations of HAPS broadband systems

A systems level diagram, Fig. 3 below, is provided to illustrate the connectivity between HAPS and fixed service stations on the Earth, which together deliver broadband access.

FIGURE 3



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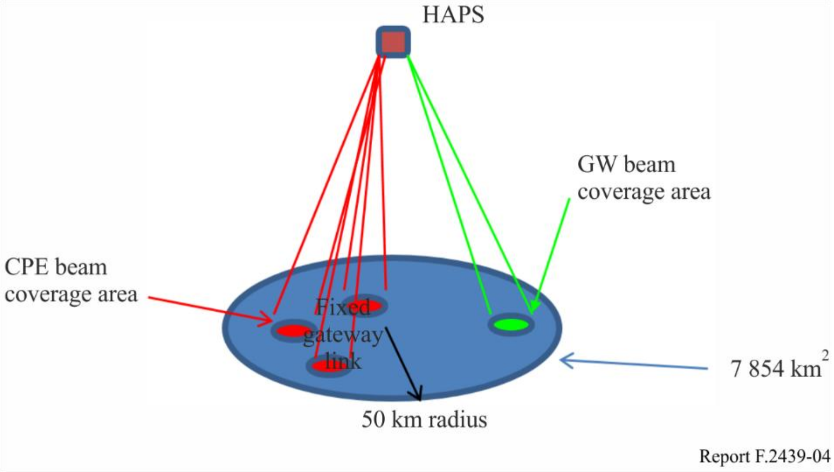
HAPS will provide the intermediate radiocommunication infrastructure that connects smaller networks (whose CPEs will be the points of entry) with the gateways which are located on the backbone.

Figure 4 provides an example outline of how services may be provided to customer premises equipment (CPE). The HAPS “Customer Premises Equipment” (CPE) is understood to be equipment for ground-based fixed links which communicate with the HAPS and redistribute their connectivity to end users by other wired or wireless means (e.g. International Mobile Telecommunications (IMT), 5.8 GHz Wireless Access Systems including radio local area networks (WAS/RLAN), etc.).

FIGURE 4

Example CPE beam gateway beam and HAPS coverage



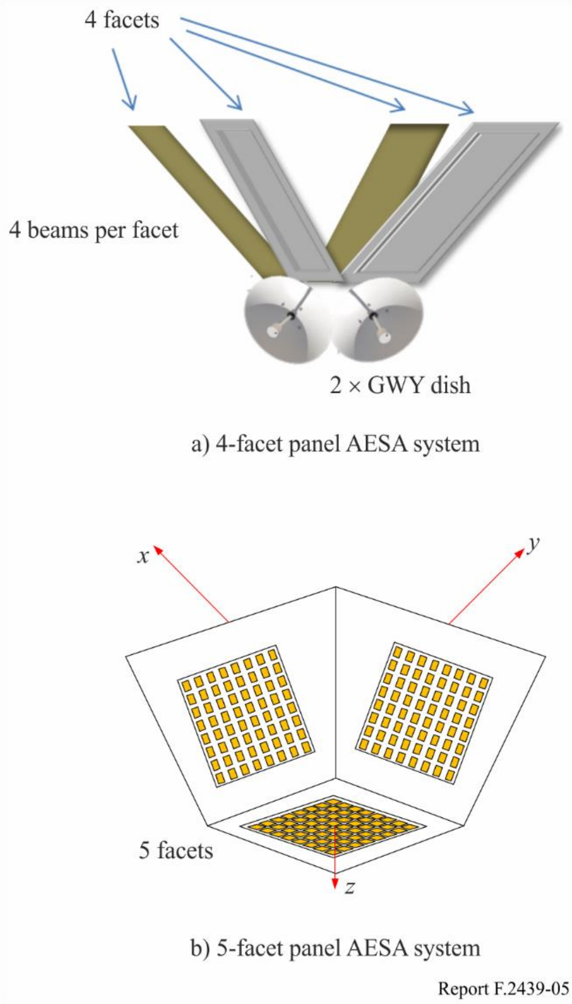
By means of adaptive antenna array (AAA) or active electronically scanned array (AESA) antenna technologies (see Annex 2), HAPS have the ability to form beams dynamically.

As far as AESA are concerned, receiver and transmitter beams can be controlled individually and may re-use the same frequencies. The panel element patches are assumed to provide 6 dBi gain each. In order to yield more gains, the number of elements may be adjusted accordingly. Two kinds of AESA systems are illustrated in this Report, i.e. four-facet panel and five-facet panel system, respectively.

In a four-facet panel AESA system, the HAPS AESA system is composed of a tilted four-facet panel configuration with four beams per facet as shown in Fig. 5.

FIGURE 5

Example for HAPS AESA frontend



An alternative is a five- facet panel AESA system which has a bottom facet in addition to the tilted four-facet panel. The tilted four-facet panel could provide coverage to those links with antenna elevation angle from 22 to 65 degrees, and the rest of the links are covered by the bottom facet. Each facet consists of several sub-arrays, more specifically, 4~8 beams per facet, assuming that the beams can sweep dynamically over the intended coverage region. For example, when a 12 ×12 antenna array is employed for each facet, the AESA system may provide up to 24 dBi array gain with four beams of each facet.

6 Various systems characteristics

Characteristics for different systems have been proposed in Table 2 below. Full technical characteristics for each of these systems are outlined in Annex 1. A representative system will be used for purposes of sharing and compatibility studies in applicable frequency bands.

TABLE 2

	System 1	**System 2**	**System 4a**	**System 4b**	**System 5**	**System 6**[(1)]
Frequency bands (GHz)	6.44-6.52 27.9-28.2 31.0-31.06	21.4-22.0 24.25-25.5 27-27.5 27.9-28.2 31.0-31.3 38.0-39.5 47.2-47.5 47.9-48.2	27.9-28.2 31-31.3 38-39.5	27.9-28.2 31-31.3 38-39.5	27.9-28.2 31.0-31.3 38.0-39.5	21.4-22.0 24.25-27.5 27.9-28.2 31.0-31.3 38.0-39.5 47.2-47.5 47.9-48.2
Platform service radius (km)	30 (CPE beam) 20 (GW beams)	50 (CPE beam) 30 (GW beam)	50	50	50	50
GW No. of beams	2	2	2	2	2~4[(2)]	1
CPE No. of beams	16	16	16	67	20~40[(2)]	4
CPE density	1 per beam in co-frequency	1 per beam in co-frequency	1 per beam	189 per beam[(3)]	1 per beam	4 per beam in co-frequency
Deployment environment (urban, etc.)	All	All	All	All	Rural and remote areas	Suburban and rural areas

(1) System 3 was merged with System 6.

(2) For System 5, the multi-beam HAPS is intended to cover different deployment scenarios, i.e. from low population density scenarios (<10 people per km^2) to high population density scenarios (>60 people per km^2). An antenna array system, which may consist of several sub-arrays and is able to form multiple beams simultaneously, is assumed to be deployed on the HAPS. The beam number of the antenna array system is assumed to be adjustable.

(3) 189 users/beam is the maximum number of CPEs per beam. Around 2.6% is the percentage of simultaneous active transmitting users per beam.

7 HAPS protection criteria

The HAPS protection criteria as used in the sharing studies under WRC-19 agenda item 1.14 are as follows:

- $I/N = -10$ dB should not be exceeded for more than 20% of the time;
- $I/N = +10$ dB should not be exceeded for more than 0.01% of the time.

Annex 1

Technical characteristics

6 400-6 520 MHz
HAPS --> GW (DL)

	System 1
Frequency (GHz)	6 440-6 520 MHz
Signal bandwidth (5% roll-off) (MHz)	50
No. of beams	1
No of co-frequency beams	1
Coverage radius/beam	−3 dB beamwidth
Polarization	RHCP/LHCP
Maximum platform Tx Gain (per beam) (dBi)	18.4
Platform Antenna Pattern	Recommendation ITU-R F.1245
Maximum platform e.i.r.p. per beam (dBW)	−6 (−9 per polarisation)
Maximum platform e.i.r.p. spectral density (dB(W/ MHz))	−23 (−26 per polarisation)
Nominal e.i.r.p. spectral density per beam (dB(W/MHz))[(1)]	−23 (−26 per polarisation)
GW antenna pattern	Recommendation ITU-R F.1245
GW antenna height above ground (m)	1-10
GW antenna gain (dBi)	28.8
System noise temp (K)	500
GW G/T (dB/K)	1.81

(1) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

21.4-22 GHz to be considered for Region 2 only (Res. 160 (WRC-15))
GW --> HAPS (UL)

	System 6(1)
Frequency (GHz)	21.4-22
Signal bandwidth (MHz)	571.4 (5% roll-off)
No. of beams	1
No of co-frequency beams	1
Coverage radius/beam (degrees)	−3 dB beamwidth
Polarization	RHCP/LHCP
GW antenna diameter (m)	2
GW antenna pattern	Rec. ITU-R F.1245
GW antenna gain (dBi)	51.4
GW antenna height above ground (m)	10
GW Tx power (W)	39.8
Maximum GW e.i.r.p. (dBW)	65.9
Maximum GW e.i.r.p. spectral density (dB(W/MHz))	38.3
Unwanted emissions mask	(2)
Platform antenna	Multi-band reflector
Platform antenna pattern	Rec. ITU-R F.1245
Platform antenna diameter (m)	0.2
Platform Rx gain (dBi)	31.4
System noise temperature (K)	600
Platform G/T (dB/K)	3.62

(1) Note that in system 6, the 21.4-22 GHz CPE uplink is not planned to be used for all implementations.

(2) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

HAPS --> GW (DL)

	System 6	**System 2**
Frequency (GHz)	21.4-22	21.4-22
Occupied bandwidth (MHz)	341	480 per beam
No. of beams	1	2
No of co-frequency beams	1	1
Coverage radius/beam	−3 dB beamwidth	−3 dB beamwidth
Polarisation	RHCP/LHCP	RHCP/LHCP
Platform Tx gain (per beam) (dBi)	32.6	34.3
Platform Antenna Pattern	Rec. ITU-R F.1245	Rec. ITU R F.1245
Platform antenna diameter (m)	0.2	0.3
Maximum platform e.i.r.p. per beam (dBW)	29.3	21.3 (18.3 per polarisation)
Maximum platform e.i.r.p. spectral density (dB(W/ MHz))	4.0	−5.5 (−8.5 per polarisation)
Power control range (dB) (1)		≤ 14.4
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (2)		−19.9 (−22.9 per polarization)
Unwanted emissions mask	(3)	Rec. ITU-R SM.1541
GW antenna diameter (m)	2	2
GW antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245
GW antenna height above ground (m)	10	1-10
GW antenna gain (dBi)	51.4	51
System noise temp	350	…
GW G/T (dB/K)	27.9	26.2

(1) This corresponds to the system capacity to operate within a range of e.i.r.p..

(2) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

(3) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

CPE --> HAPS (UL)

	System 6 [(1)]		
Frequency (GHz)	21.4-22		
Signal bandwidth (MHz)	117		
No. of beams	4		
No of co-frequency beams	4		
Coverage radius/beam (degree)	−3 dB beamwidth		
Polarisation	RHCP/LHCP		
CPE antenna diameter (m)	0.35	0.6	1.2
CPE antenna pattern	Rec. ITU-R F.1245		
CPE antenna gain (dBi)	35.6	40.2	46.3
CPE antenna height above ground (m)	10		
Maximum CPE e.i.r.p. (dBW)	33.2	37.9	43.9
Maximum CPE e.i.r.p. spectral density (dB(W/ MHz))	12.5	17.2	23.2
Unwanted emissions mask	[(2)]		
Platform Rx gain (dBi)	28.1	28.1	28.1
Platform antenna pattern	Rec. ITU-R F.1891		
System noise temperature (K)	600		
Platform G/T (dB/K)	0.3	0.3	0.3

(1) Note that in system 6, the 21.4-22 GHz GW uplink is not planned to be used for all implementations.

(2) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

HAPS --> CPE (DL)

	System 6			System 2
Frequency (GHz)	21.4-22			21.4-22
Occupied bandwidth (MHz)	600			95 per beam
No. of beams	4			16
No of co-frequency beams	4			4
Coverage radius/beam	−3 dB beamwidth			−3 dB beamwidth
Polarization	RHCP/LHCP			RHCP/LHCP
Platform Tx gain (dBi)	28.1			29
Platform antenna pattern	Rec. ITU-R F.1891			Annex 2
Platform antenna diameter	N/A			N/A
Maximum platform e.i.r.p. (dBW)	32.2			22 (19 per polarisation)
Maximum platform e.i.r.p. spectral density (dB(W/ MHz))	4.4			2.2 (−0.8 per polarisation)
Power control range (dB) (1)	…			≤ 10.7
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (2)	…			−8.5 (−11.5 per polarization)
Unwanted emissions mask	(3)			Rec. ITU-R SM.1541
CPE antenna diameter (m)	0.35	0.6	1.2	1
CPE antenna pattern	Rec. ITU-R F.1245			Rec. ITU-R F.1245
CPE antenna gain (dBi)	35.6	40.2	46.3	44.8
CPE antenna height above ground (m)	10			1-10
System noise temperature (K)	350			
CPE G/T (dB/K)	12.1	16.7	22.8	20.2

(1) This corresponds to the system capacity to operate within a range of e.i.r.p..

(2) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

(3) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

26 GHz to be considered for Region 2 only (Resolution 160 (WRC-15))
GW --> HAPS (UL)

	System 6
Frequency (GHz)	24.25-27.5
Signal bandwidth (MHz)	623 (1)
No. of beams	1
No of co-frequency beams	1
Coverage radius/beam (degrees)	3.4
Polarization	RHCP/LHCP
GW antenna diameter (m)	2
GW antenna pattern	Rec.ITU-R F.1245
GW antenna gain (dBi)	53.3
GW antenna height above ground (m)	10
Maximum GW Tx power (W)	1.04
Maximum GW e.i.r.p. (dBW)	52 (2)
Maximum GW e.i.r.p. spectral density (dB(W/ MHz))	24
Power control range (dB) (4)	16
Nominal e.i.r.p. spectral density per beam (dB(W/ MHz)) (5)	8
Unwanted emissions mask	(3)
Platform antenna	Multi-band reflector
Platform antenna pattern	Rec. ITU-R F.1245
Platform Rx gain (dBi)	33
System noise temperature (K)	600
Platform G/T (dB/K)	0.3

(1) To comply with the e.i.r.p. limits in RR No. 21.3 of Article 21.

(2) Feeder loss of 1.5 dB was considered.

(3) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(4) This corresponds to the system capacity to operate within a range of e.i.r.p.

(5) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

CPE --> HAPS (UL)

	System 6			System 2
Frequency (GHz)	24.25-27.5			25.25-25.5
Signal bandwidth (MHz)	117			60 per beam
No. of beams	4			16
No of co-frequency beams	4			4
Coverage radius/beam (degrees)	3.4			−3 dB beamwidth
Polarisation	RHCP/LHCP			RHCP/LHCP
CPE antenna diameter (m)	0.35	0.6	1.2	1
CPE antenna pattern	Rec. ITU-R F.1245			Rec. ITU-R F.1245
CPE antenna gain (dBi)	37.5	42.2	48.2	45.5
CPE antenna height above ground (m)	10			1-10
Maximum CPE e.i.r.p. (dBW)	33.2	37.9	43.9	35.5 (32.5 per polarisation)
Maximum CPE e.i.r.p. spectral density (dB(W/MHz))	12.5	17.2	23.2	17.8 (14.8 per polarisation)
Power control range (dB) (2)	≤ 10.8			≤ 10.8
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)	1.7	6.4	12.4	7 (4 per polarisation)
Unwanted emissions mask	(1)			Rec. ITU-R SM.1541
Platform Rx gain (dBi)	28.1	28.1	28.1	29
Platform antenna pattern	Rec. ITU-R F.1891			Annex 2
System noise temperature (K)	600			…
Platform G/T (dB/K)	0.3	0.3	0.3	4.2

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

HAPS --> CPE (DL)

	System 6			System 2
Frequency (GHz)	24.25-27.5			24.25-25.25 and 27-27.5
Occupied bandwidth (MHz)	938			225 per beams
No. of beams	4			16
No of co-frequency beams	4			4
Coverage radius/beam (degrees)	3.4			−3 dB beamwidth
Polarization	RHCP/ LHCP	RHCP/ LHCP	RHCP/ LHCP	RHCP/LHCP
Platform Tx Gain (dBi)	28.1	28.1	28.1	29
Platform antenna pattern	Rec. ITU-R F.1891			Annex 2
Platform antenna diameter (m)	N/A			N/A
Maximum platform e.i.r.p. per beam (dBW)	34.1	34.1	34.1	25 (22 per polarisation)
Maximum platform e.i.r.p. spectral density (dB(W/MHz))	4.4	4.4	4.4	1.48 (−1.52 per polarisation)
Power control range (dB) (2)	≤ 10.8			≤ 10.8
Unwanted emissions mask	(1)			Rec. ITU-R SM.1541
CPE antenna diameter (m)	0.35	0.6	1.2	1
CPE antenna pattern	Rec. ITU-R F.1245			Rec. ITU-R F.1245
CPE antenna gain (dBi)	37.5	42.2	48.2	45.5
CPE antenna height above ground (m)	10			1-10
System noise temperature (K)	350			290
CPE G/T (dB/K)	12.1	16.7	22.8	20.9

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

28 GHz is defined as fixed downlink for countries outside Region 2 (RR No. 5.537A)

HAPS --> GW (DL)

	System 1	**System 5**	**System 4a**	**System 4b**
Frequency (GHz)	27.9-28.2	27.9-28.2	27.9-28.2	27.9-28.2
Signal bandwidth (MHz)	60	300	300 per beam	300 per beam
No. of beams	1	2	2	2
No of co-frequency beams	1	2	1	1
Coverage radius/beam (degrees)	−3 dB beamwidth	−3 dB beamwidth	−3 dB beamwidth	−3 dB beamwidth
Polarization	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP
Maximum platform Tx gain (per beam) (dBi)	33.5	35.3	35.5	35.5
Platform antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Platform antenna diameter (m)	N/A	0.3	N/A	N/A
Maximum platform e.i.r.p. per beam (dBW)	29.5 (26.5 per polarisation)	23.3	19.7	19.7
Maximum platform e.i.r.p. spectral density (dB(W/MHz))	11.7 (8.7 per polarisation)	−1.47	−5	−5
Power control range (dB) [(1)]	35	…	9	9
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) [(2)]	−23.3 (−26.3 per polarisation)	…	−14 per polarization	−14 per polarization
GW antenna diameter (m)	N/A	2	2.4	2.4
GW antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R S.580-6	Rec. ITU-R S.580-6
GW antenna gain (dBi)	47.5	52.2	54.6	54.6
GW antenna height above ground (m)	1-10	2	…	…
System noise temp (K)	500	550	200	200
GW G/T (dB/K)	20.5	24.8	31.6	31.6

(1) This corresponds to the system capacity to operate within a range of e.i.r.p.

(2) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

HAPS --> CPE (DL)

	System 6		System 1	System 2	System 5		
Frequency (GHz)	27.9-28.2		27.9-28.2	27.9-28.2	27.9-28.2		
Signal bandwidth (5% roll-off) (MHz)	285.7	285.7	3.75 per beam	75 per beam	75 per per beam		
No. of beams	4		16	16	20		
No of co-frequency beams	4		4	4	5		
Coverage radius/beam (degrees)	−3 dB beamwidth		−3 dB beamwidth	−3 dB beamwidth	−3 dB beamwidth		
Polarization	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP		
Platform Tx gain (dBi)	28.1	28.1	29	29	24		
Platform Antenna Pattern	Rec. ITU-R F.1891	Rec. ITU-R F.1891	Annex 2	Annex 2	Annex 2		
Maximum platform Tx power (W)	1.3	1.3	N/A	0.5	1 (per beam)		
Maximum platform e.i.r.p. per beam (dBW)	27.6	27.6	3 (0 per polarisation)	22 (19 per polarisation)	24		
Maximum platform e.i.r.p. spectral density (dB(W/MHz))	3.0	3.0	−2.8 (−5.8 per polarisation)	3.3 (0.3 per polarisation)	5.25		
Power control range (dB) (2)	≤ 12.1		≤ 15	≤ 12.1	…		
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)	−9.1		−17.8 (−20.8 per polarisation)	−8.8 (−11.8 per polarisation)	…		
Unwanted Emissions Mask	(1)		N/A	Rec. ITU-R SM.1541	N/A		
CPE antenna diameter (m)	0.35	1.2	N/A	1	1.2	0.6	0.3
CPE antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245		
CPE antenna gain (dBi)	37.7	48.4	41.5	47	47.5	41.5	36.8
CPE antenna height above ground (m)	10		1-10	1-10	1-10		
System noise temp (K)	350		500	290	550		
CPE G/T (dB/K)	12.3	23	14.51	22.1	20.1	14.1	9.4

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

31 GHz is defined as fixed uplink in countries outside Region 2 (RR No. 5.543A)

GW -> HAPS (UL)

	System 1	**System 5**
Frequency (GHz)	31-31.06	31-31.3
Signal bandwidth (MHz)	60	300
No. of beams	1	2
No of co-frequency beams	1	2
Coverage radius/beam (degreees)	−3 dB beamwidth	−3 dB beamwidth
Polarization	RHCP/LHCP	RHCP/LHCP
GW antenna diameter (m)	N/A	2
GW antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245
GW antenna gain (dBi)	53	53
GW antenna height above ground (m)	1-10	1-10
Maximum GW Tx power (W)	N/A	5
Maximum GW e.i.r.p. (dBW)	54 (51 per polarisation)	58
Maximum GW e.i.r.p. spectral density (dB(W/MHz))	36.2 (33.2 per polarisation)	33.2
Power control range (dB) (1)	30	…
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (2)	6.2 (3.2 per polarisation)	…
Platform antenna	Dish	Multi-band reflector
Platform antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Platform antenna diameter (m)	N/A	0.3
Platform Rx gain (dBi)	34.4	35.3
System noise temperature (K)	700	800
Platform G/T (dB/K)	5.95	6.3

(1) This corresponds to the system capacity to operate within a range of e.i.r.p.

(2) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

HAPS --> GW (DL)

	System 6	**System 2**
Frequency (GHz)	31-31.3	31-31.3
Signal bandwidth (MHz)	285.7 (5% roll-off)	160 per beam
No. of beams	1	2
No of co-frequency beams	1	1
Coverage radius/beam	−3 dB beamwidth	−3 dB beamwidth
Polarization	RHCP/LHCP	RHCP/ LHCP
Platform Tx gain (dBi)	34.1	37.2
Platform antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Platform antenna diameter	0.2	0.3
Maximum platform e.i.r.p. per beam (dBW)	27.6	23.2 (20.2 per polarisation)
Maximum platform e.i.r.p. spectral density (dB(W/MHz))	3.0	1.16 (−1.84 per polarisation)
Power control range (dB) (2)	≤ 26	20
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)	−23	−18.84 (−21.84 per polarisation)
Unwanted emissions mask	(1)	Rec. ITU-R SM.1541
GW antenna diameter (m)	2	2
GW antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245
GW antenna gain (dBi)	54.5	53
GW antenna height above ground (m)	10	1-10
System noise temp (K)	350	300
GW G/T (dB/K)	28.1	28

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p..

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

CPE -> HAPS (UL)

	System 1	System 5		
Frequency (GHz)	31-31.06	31-31.3		
Signal bandwidth (MHz)	3.75 per beam	9.4 per beam		
No. of beams	16	20		
No of co-frequency beams	4	5		
Coverage radius/beam	−3 dB beamwidth	−3 dB beamwidth		
Polarization	RHCP/LHCP	RHCP/LHCP		
CPE antenna diameter (m)	N/A	1.2	0.6	0.3
CPE antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245		
CPE antenna gain (dBi)	48	47.5	41.5	36.8
CPE antenna height above ground (m)	1-10	1-10		
Maximum CPE Tx power (W)	…	2		
Maximum CPE e.i.r.p. (dBW)	26 (23 per polarisation)	46.5	40.5	35.8
CPE density (/km²)	1 co-frequency per beam	…		
Maximum CPE e.i.r.p. spectral density (dB(W/MHz))	20.3 (17.3 per polarisation)	26.75	20.75	16.05
Power control range (dB) (1)	20	…		
Nominal e.i.r.p. spectral density beam (dB(W/MHz)) (2)	0.3 (−2.7 per polarisation)	…		
Platform Tx gain (dBi)	29	24.7		
Platform antenna pattern	Annex 2	Annex 2		
System noise temp (K)	700	800		
Platform G/T (dB/K)	0.54	–4.3		

(1) This corresponds to the system capacity to operate within a range of e.i.r.p.

(2) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

HAPS --> CPE (DL)

	System 6		System 4a	System 4b	
Frequency (GHz)	31-31.3		31-31.3	31-31.3	
Signal bandwidth (MHz)	285.7		150 per beam	100 per beam	
No. of beams	4		16	67	
No of co-frequency beams	4		4	17	
Coverage radius/beam	−3 dB beamwidth		−3 dB beamwidth	−3 dB beamwidth	
Polarization	RHCP/LHCP		RHCP/LHCP	RHCP/LHCP	
Platform Tx gain (dBi)	28.1		34	18 to 25.5	
Platform antenna pattern	Rec. ITU-R F.1891		Rec. ITU-R F.1245	Rec. ITU-R F.1245	
Platform Tx power (W)	1.3		…	…	
Maximum platform e.i.r.p. per beam (dBW)	27.6		22.7	21	
Maximum platform e.i.r.p. spectral density (dB(W/ MHz))	3.0		1	1	
Power control range (dB) (2)	≤ 12.1		14	13	
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)	−9.1		−13 per polarization	−12 per polarization	
Unwanted emissions mask	(1)		…	…	
CPE antenna diameter (m)	0.35	1.2	1	0.74	0.3
CPE antenna pattern	Rec. ITU-R F.1245		Rec. ITU-R S.580-6	Rec. ITU-R S.580-6	
CPE antenna gain (dBi)	38.6	49.3	47.9	45.3	37.7
CPE antenna height above ground (m)	10		…	…	
System noise temperature (K)	350		200	200	200
CPE G/T (dB/K)	12.3	23	24.5	22.3	14.5

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

38-39.5 GHz to be considered on global level (Res.160 (WRC-15))

GW --> HAPS (UL)

	System 6	**System 2**	**System 5**	**System 4a**	**System 4b**
Frequency (GHz)	38-39.5	38-39.5	38-39.5	38-39.5	38-39.5
Signal bandwidth (MHz)	1 428.6	1 500 per polarisation/per beam	1 500	1 110 per beam	1 425 per beam
No. of beams	1	2	2	2	2
No of co-frequency beams	1	1	2	1	1
Coverage radius/beam (degrees)	1.3	−3 dB beamwidth	−3 dB beamwidth	−3 dB beamwidth	−3 dB beamwidth
Polarization	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP
GW antenna diameter (m)	2	2	2	2.4	2.4
GW antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R S.580-6	Rec. ITU-R S.580-6
GW antenna gain (dBi)	56.5	55	55.2	57.4	57.4
GW antenna height above ground (m)		1-10	1-10	…	…
Maximum GW Tx power (W)	9	5 per polarization	−5	…	…
Maximum GW e.i.r.p. (dBW)	64.5	65 (62 per polarisation)	50.2	56.4	57.5
Maximum GW e.i.r.p. spectral density (dB(W/MHz))	33.0	33.2 (30.2 per polarisation)	18.44	26	26
Power control range (dB) (2)		≤ 35	…	15	15
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)		−1.8 (−4.8 per polarisation)	…	11 per polarization	11per polarization
Unwanted emissions mask	(1)	…	…	…	…
Platform antenna	Multi-band reflector	Dish	Multi-band reflector	…	…
Platform antenna pattern	Rec. ITU-R F.1245	Rec. ITU R S.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Platform antenna diameter	0.2	0.3	0.3	N/A	N/A
Platform Rx gain (dBi)	35.3	39.3	37.9	38.2	38.2
System noise temperature (K)	600	300	800	590	590
Platform G/T (dB/K)	7.56	14.2	8.9	10.5	10.5

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

HAPS --> GW (DL)

	System 5
Frequency (GHz)	38-39.5
Signal bandwidth (MHz)	1 500
No. of beams	2
No of co-frequency beams	2
Coverage radius/beam (degrees)	−3 dB beamwidth
Polarization	RHCP/LHCP
Platform Tx gain (per beam) (dBi)	37.9
Platform antenna pattern	Rec. ITU-R F.1245
Maximum platform e.i.r.p. per beam (dBW)	27.9
Maximum platform e.i.r.p. spectral density (dB(W/MHz))	−3.86
GW antenna diameter	2
GW antenna pattern	Rec. ITU-R F.1245
GW antenna gain (dBi)	55.1
System noise temperature (K)	550
GW G/T (dB/K)	27.7

CPE --> HAPS (UL)

	System 6		System 2	System 5			System 4a	System 4b	
Frequency (GHz)	38-39.5		38-39.5	38-39.5			38-39.5	38-39.5	
Signal bandwidth (MHz)	117		26 per beam & per polarization	250			105 per beam	30 per beam	
No. of beams	4		16	30			16	67	
No of co-frequency beams	4		4	5			4	17	
Coverage radius/beam (degrees)	3.4		−3 dB beamwidth	−3 dB beamwidth			−3 dB beamwidth	−3 dB beamwidth	
Polarization	RHCP/LHCP		RHCP/LHCP	RHCP/LHCP			RHCP/LHCP	RHCP/LHCP	
CPE antenna diameter (m)	0.35	1.2	1	0.35	0.6	1.2	1	0.74	0.3
CPE antenna pattern	Rec. ITU-R F.1245		Rec. ITU-R F.1245	Rec. ITU-R F.1245			Rec. ITU-R S.580-6	Rec. ITU-R S.580-6	
CPE antenna gain (dBi)	40.6	51.4	49	40.2	44.9	50.9	49.8	47.2	39.3
CPE antenna height above ground (m)	10		1-10	1-10			…	…	
Maximum CPE e.i.r.p. (dBW)	40.3	51.0	49 (46 per polarisation)	44.2	48.9	54.9	50.2	43	35
CPE density (/km²)	…		1 co-frequency per beam	…			1 co-frequency per beam	1 co-frequency per beam	
Maximum CPE e.i.r.p. spectral density (dB(W/MHz))	19.6	30.3	33.5 (31.5 per polarisation)	20.2	24.9	30.9	30	35.5	26.5
Power control range (dB) (2)	≤ 25.3		25.3	…			15	16	12
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)	−5.7	5	9.2 (6.2 per polarisation)	…			15	19.5	14.5
Unwanted emissions mask	(1)		Rec. ITU-R SM.1541	…			…	…	
Platform Rx gain (dBi)	28.1	28.1	29	24.8			37.3	18 to 25.5	
Platform antenna pattern	Rec. ITU-R F.1891		Annex 2	Annex 2			Rec. ITU-R F.1245	Rec. ITU-R F.1245	
System noise temperature (K)	600		300	800			540	500	
Platform G/T (dB/K)	0.3	0.3	4.2	−4.2			10	−1.5	

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

HAPS --> CPE (DL)

	System 5			**System 4a**
Frequency (GHz)	38-39.5			38-39.5
Signal bandwidth (MHz)	250			100 per beam
No. of beams	30			16
No of co-frequency beams	5			4
Coverage radius/beam (degrees)	−3 dB beamwidth			−3 dB beamwidth
Polarization	RHCP/LHCP			RHCP/LHCP
Platform Tx gain (dBi)	24.8			37
Platform antenna pattern	Annex 2			Rec. ITU-R F.1245
Maximum platform e.i.r.p. per beam (dBW)	26.8			22
Maximum platform e.i.r.p. spectral density (dB(W/MHz))	2.82			2
Power control range (dB) (1)	…			14
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (2)	…			−12
CPE antenna diameter (m)	0.35	0.6	1.2	1
CPE antenna pattern	Rec. ITU-R F.1245			Rec. ITU-R S.580-6
CPE antenna gain (dBi)	40.2	44.9	50.9	49.8
System noise temperature (K)	550			200
CPE G/T (dB/K)	12.8	17.5	23.5	27.3

(1) This corresponds to the system capacity to operate within a range of e.i.r.p.

(2) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

47/48 GHz is defined for global level (RR No. 5.552A)

GW --> HAPS (UL)

	System 6		**System 2**
Frequency (GHz)	47.2-47.5	47.9-48.2	47.2-47.5 47.9-48.2
	When both are used in combination		
Signal bandwidth (5% roll-off) (MHz)	285.7	285.7	300 per beam & per polarization
No. of beams	1		2
No of co-frequency beams	1		1
Coverage radius/beam (degrees)	1.1	1.1	−3 dB beamwidth
Polarization	RHCP/LHCP	RHCP/LHCP	RHCP/ LHCP
GW antenna diameter (m)	2	2	2
GW antenna pattern	ITU RR Res. 122, *resolve* 3	ITU RR Res. 122, *resolve* 3	ITU RR Res. 122, *resolve* 3
GW antenna gain (dBi)	58.1	58.2	57
GW antenna height above ground (m)	10		1-10
Maximum GW Tx power (W)	10 (7 per polarisation)	10 (7 per polarisation)	10 (7 per polarisation)
Maximum GW e.i.r.p. (dBW)	68.1	68.2	67 (64 per polarization)
Maximum GW e.i.r.p. spectral density (dB(W/MHz))	42.2 (39.2 per polarisation)	42.2 (39.2 per polarisation)	42.2 (39.2 per polarisation)
Power control range (dB) (2)	≤ 44.4		≤ 44.4
Nominal e.i.r.p. spectral density per beam (dB(W/MHz)) (3)	−2.2	−2.2	−2.2 (−5.2 per polarisation)
Unwanted emissions mask	(1)		Rec. ITU-R SM.1541
Platform antenna	Multi-band Dish	Multi-band Dish	Multi-band Dish
Platform antenna pattern	Rec. ITU-R F.1245	Rec. ITU-R F.1245	Rec. ITU-R F.1245
Platform antenna diameter (m)	0.2	0.2	0.3
Platform Rx gain (dBi)	36	36.1	40.5
System noise temperature (K)	600		300
Platform G/T (dB/K)	8.19	8.32	15.7

(1) Examples include emission masks, IEEE 802.11 ad, DVB-s2x, etc.

(2) This corresponds to the system capacity to operate within a range of e.i.r.p.

(3) This corresponds to the maximum power at which the system operates under clear sky conditions for the link between the HAPS and the GW &/or CPE.

Annex 2

1 Antenna characteristics (HAPS system 2 CPE beam)

The antenna characteristics outlined below are applicable where directed by the Table in Annex 1 above (HAPS system 2 antenna characteristics CPE beam).

The beamforming antenna is based on an antenna array and consists of a number of identical radiating elements located in the yz-plane with a fixed separation distance (e.g. $\lambda/2$), all elements having identical radiation patterns and "pointing" (having maximum directivity) along the x-axis. Total antenna gain is the sum (logarithmic scale) of the array gain and the element gain.

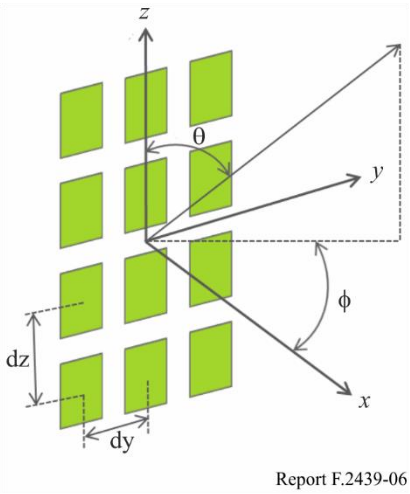
The θ and ϕ definition is based on the coordinate system are illustrated in Fig. 6 below.

FIGURE 6

Antenna model geometry

θ: elevation, range from 0 to 180 degree

ϕ: Azimuth, range from -180 to 180 degree



The radiation elements are placed uniformly along the vertical **z**-axis in the Cartesian coordinate system. The **x-y** plane denotes the horizontal plane. The elevation angle of the signal direction is denoted as θ (defined between 0° and 180°, with 90° representing perpendicular angle to the array antenna aperture). The azimuth angle is denoted as ϕ (defined between −180° and 180°).

The system will actively control all individual signals being fed to individual antenna elements in the antenna array in order to shape and direct the antenna emission diagram to a wanted shape, e.g. a narrow beam towards a user. It creates a correlated wanted emission from the antenna. The unwanted signal, caused by transmitter OOB modulation, intermodulation products and spurious emission components will not experience the same correlated situation from the antenna and will have a different emission pattern. A non-correlated antenna system has an antenna emission pattern similar to a single antenna element as outlined in Table 3.

1.1 Single element pattern

TABLE 3

Element pattern for antenna array model

Horizontal Radiation Pattern	$A_{E,H}(\varphi) = -min\left[12\left(\frac{\varphi}{\varphi_{3dB}}\right)^2, A_m\right] dB$
Horizontal 3dB bandwidth of single element/deg (φ_{3dB})	80
Front-to-back ratio: A_m and SLAv	30
Vertical Radiation Pattern	$A_{E,V}(\varphi) = -min\left[12\left(\frac{\theta - 90}{\theta_{3dB}}\right)^2, SLA_V\right] dB$
Vertical 3dB beamwidth of single element/deg (θ_{3dB})	65
Single element pattern	$A_E(\varphi, \theta) = G_{E,max} - min\{-[A_{E,H}(\varphi) + A_{E,V}(\theta)], A_m\}$
Element Gain (dBi), GE,max	6

1.2 Composite antenna pattern

Table 4 illustrates the derivation of the composite antenna pattern, $A_A(\theta,\varphi)$. $A_A(\theta,\varphi)$ is the resulting beamforming antenna pattern from logarithmic sum of the array gain, $10\log_{10}\left(\left|\sum_{m=1}^{N_H}\sum_{n=1}^{N_V} W_{i,n,m}.V_{n,m}\right|^2\right)$, and the element gain $A_E(\theta,\varphi)$. The composite pattern for the antenna should be used where the array serves one or more CPEs with one or more beams, with each beam indicated by the parameter *i*.

TABLE 4

Composite antenna pattern for AESA beam forming

Configuration	Multiple columns (NV × NH elements)
Composite array radiation pattern in dB $A_A(\theta,\varphi)$	For beam i: $$A_{A,Beami}(\theta,\varphi) = A_E(\theta,\varphi) + 10log_{10}\left(\left|\sum_{m=1}^{N_H}\sum_{n=1}^{N_V} W_{i,n,m}.V_{n,m}\right|^2\right)$$ the super position vector is given by: $$V_{n,m} = exp\left(i.2\pi\left((n-1).\frac{d_v}{\lambda}.\cos(\theta) + (m-1).\frac{d_H}{\lambda}.\sin(\theta).\sin(\varphi)\right)\right),$$ n=1,2,...N_V; m=1,2,...N_H; the weighting is given by: $$W_{i,n,m} = \frac{1}{\sqrt{N_H N_V}} exp\left(i.2\pi\left((n-1).\frac{d_v}{\lambda}.\sin(\theta_{i,etilt}) - (m-1).\frac{d_H}{\lambda}.\cos(\theta_{i,etilt}).\cos(\varphi_{i,escan})\right)\right)$$

TABLE 4 (*end*)

Configuration	Multiple columns (NV × NH elements)
Antenna array configuration (Row × Column)	HAPS AESA10x20
Horizontal radiating element spacing d/lambda	0.5
Vertical radiating element spacing d/λ	0.5

There is need to introduce a normalization factor to the calculation of the antenna directivity in each direction in order to ensure that the total array directivity is equal to 0 dB.

The expression for the composite array radiation pattern:

$$\breve{G}_{dB}(\theta,\varphi) = A_{E\,dB}(\theta,\varphi) + 10\log_{10}\left\{1 + \rho\left[\left|\sum_{m=1}^{N_H}\sum_{n=1}^{N_V} w_{m,n}(\theta,\varphi,\varphi\mathrm{scan},\mathrm{etilt})\,v_{m,n}(\theta,\varphi,\varphi\mathrm{scan},\mathrm{etilt})\right|^2 - 1\right]\right\}$$

where:

- $v_{m,n}$ called the ‘super position vector’ can be understood as the steering vector giving the phase shift due to array placement
- $w_{m,n}$ depicts the weighting factor, is a function of the antenna beam pointing angles φ-scan and the electrical tilt and aims at tuning side lobe levels.

This actual array gain that has to be performed in any sharing studies should be normalised as follows:

$$D(\theta,\varphi,\varphi\mathrm{scan},\mathrm{etilt}) = \frac{\breve{G}(\theta,\varphi,\varphi\mathrm{scan},\mathrm{etilt})}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}\breve{G}(\theta,\varphi,\varphi\mathrm{scan},\mathrm{etilt})\sin(\theta)\,d\theta\,d\varphi}$$

to ensure that the total radiated power equal P_{Tx} where P_{Tx} is the conducted power input to the array system. Consequently, this contribution accounts this normalization factor in the computation of the HAPS station antenna gain (HAPS→CPE). Figure 7 provides the normalization faction versus azimuth and elevation electronical tilts.

FIGURE 7

Normalization factor

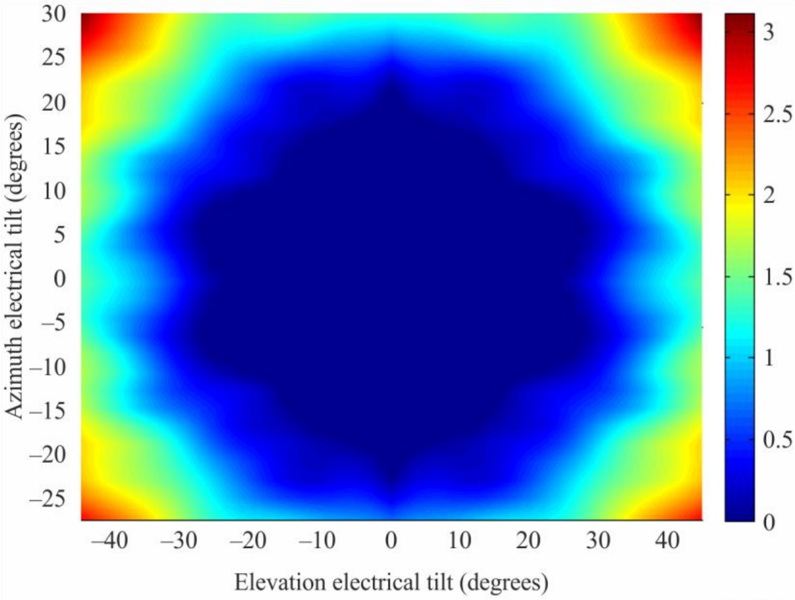


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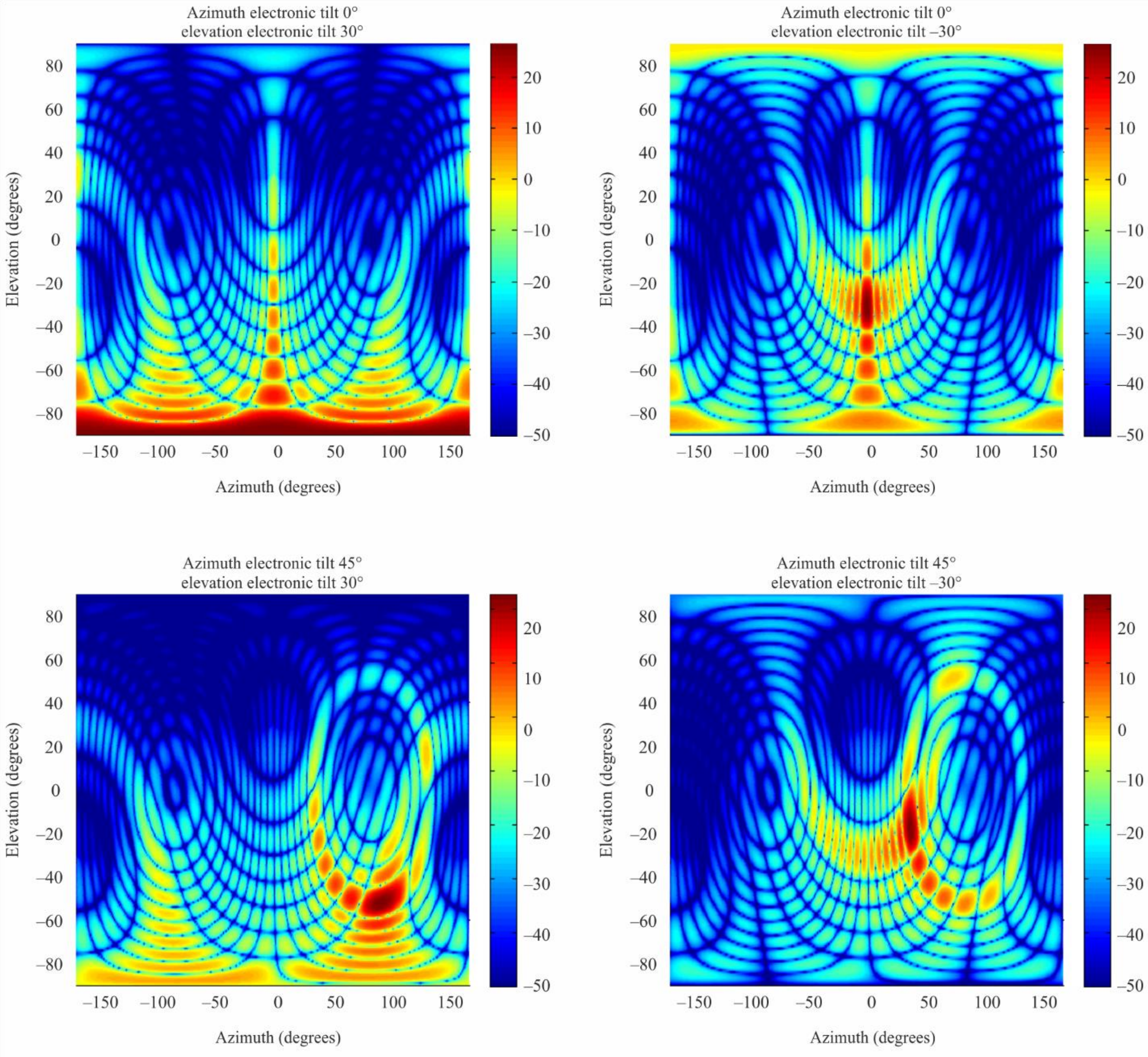
Figure 8 below, presents the HAPS antenna patterns for a down tilt of 60 degrees, an electronic elevation tilt of respectively 30 degrees and -30 degrees (edge of the HAPS coverage area) and finally an electronic azimuth tilt of 0 degrees.

FIGURE 8

HAPS antenna patterns for a mechanical down tilt of 60°



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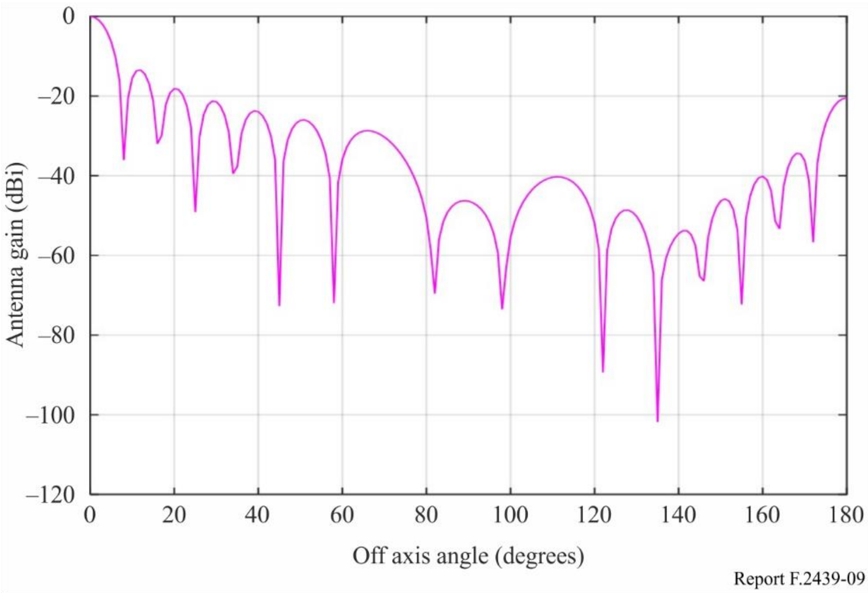
2 HAPS Antenna characteristics (HAPS System 5 CPE beam)

The HAPS antenna characteristics outlined below are applicable where directed by the Table in Annex 1 above (HAPS System 5 antenna characteristics CPE beam).

Figure 9 shows the antenna characteristics of the 5-facet panel AESA system, which is deployed on HAPS for HAPS <-> CPE link.

FIGURE 9

AESA antenna pattern



Both azimuth electronic tilt and elevation electronic tilt are 0 degree in the Figure.

The −3 dB beam width is about 7 degrees, and the antenna gain of 1st side lobe is 13 dB lower than that of the main lobe.

Annex 3

Example of link budget in 28/31 GHz band

Link budget of System 5

Option	**1**				**2**				**3**			
	CPEs→GWs		**GWs→CPEs**		**CPEs→GWs**		**GWs→CPEs**		**CPEs→GWs**		**GWs→CPEs**	
	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
Frequency (GHz)	31	28	31	28	31	28	31	28	31	28	31	28
Bandwidth (MHz)	9.4	35	247	65.6	9.4	35	247	65.6	9.4	35	247	65.6
Tx power (dBW)	–2	–12	5	4	–2	–12	5	4	–2	–12	5	4
Tx antenna gain (dBi)	36.8	35.3	53	24	41.5	35.3	53	24	47.5	35.3	53	24
Nominal e.i.r.p. (dBW)	34.8	23.3	58	28	39.5	23.3	58	28	45.5	23.3	58	28
Slant range* (km)	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4
Free space path loss (dB)	157.30	156.42	157.30	156.42	157.30	156.42	157.30	156.42	157.30	156.42	157.30	156.42
Rain attenuation (dB)	12	12	12	12	12	12	12	12	12	12	12	12
Receiver noise temperature (K)	800	550	800	550	800	550	800	550	800	550	800	550
Receiver *G/T* (dB/K)	–4.3	24.8	6.3	9.4	–4.3	24.8	6.3	14.1	–4.3	24.8	6.3	20.1
RX and TX losses (dB)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Rx antenna gain	24.7	52.2	35.3	36.8	24.7	52.2	35.3	41.5	24.7	52.2	35.3	47.5
Boltzmann’s constant (dB(W/K*Hz))	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6	–228.6
Required *C/(N+I)* (dB)	14.5	19.0	19.0	14.5	19.0	19.0	19.0	19.0	19	19.0	19.0	19.0
C/N UP (dB)	18.04		37.64		22.74		37.64		28.74		37.64	
C/N down (dB)		30.84		17.41		30.84		22.11		30.84		28.11
Margin (dB)	**3.54**	**11.84**	**18.64**	**2.91**	**3.74**	**11.84**	**18.64**	**3.11**	**9.74**	**11.84**	**18.64**	**9.11**

* Note: investigation are ongoing to see if this slant range could be extended for gateways.

Annex 4

Automatic Transmitting Power Control

This Annex aims at providing explanation on the Automatic Transmit Power Control (ATPC) that is used to compensate the rain attenuation and how it is used in the sharing studies under WRC-19 agenda item 1.14.

ATPC is a method to allow the emitter to compensate the attenuation due to rainy weather conditions.

1 Definition

$EIRP_{nominal}$: Maximum e.i.r.p. at which the HAPS system operates under clear sky condition

$EIRP_{max}$: Maximum e.i.r.p. that will never be exceeded

ATPC: Automatic transmit power control is the increase of the EIRP to compensate the rain attenuation

$ATPC_{max}$: Maximum ATPC that will never be exceeded

$$EIRP_{max} = EIRP_{nominal} + ATPC_{max}$$

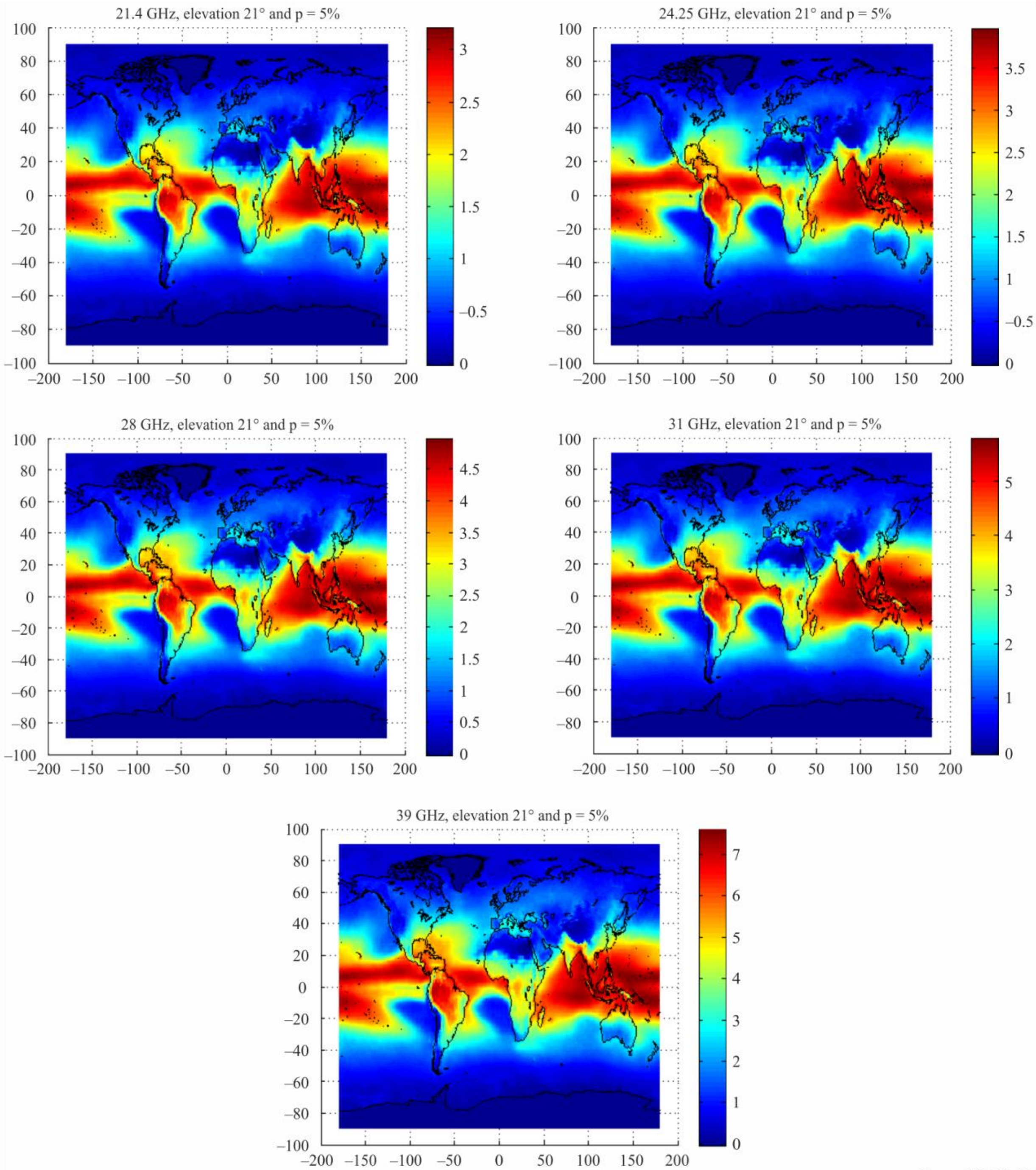
2 Clear sky condition

The clear sky conditions can be defined by the percentage of an average year when the rain attenuations can be considered negligible. Recommendation ITU-R P.618-12 provides the estimated attenuation to be exceeded for a percentage of an average year p in the range 0.001% to 5%. Figure 10 provides the rain attenuations for p = 5% of the time and for an elevation angle of 21 degrees corresponding to the HAPS edge of coverage.

For p = 20%, the attenuation should be lower than the above results and can be considered negligible. Therefore, for p = 20% the conditions should be very close to the clear sky conditions.

FIGURE 10

Rain attenuation using Recommendation ITU-R P.618-12



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3 Elements to illustrate ATPC cumulative distribution function (CDF) over an average year

A HAPS or a HAPS ground station will transmit a nominal e.i.r.p. under clear sky condition.

During raining conditions, those stations will increase their transmit e.i.r.p. to compensate the rain attenuation. Three areas of the rain attenuation CDF can be defined:

– the clear sky condition area: raining attenuation close to 0 dB for p = 100% to p = 20%;

– the raining condition area: raining attenuation within the range of Recommendation ITU-R P.618-12 (p = 5% to p = 0.001%);

– the raining condition area outside the range of Recommendation ITU-R P.618-12; (p = 20% to p = 5%): for this area there is no ITU-R Recommendation and it is proposed to interpolate Recommendation ITU-R P.618-12.

During raining conditions, HAPS stations will limit the increase of their transmit EIRP to a maximum value EIRPmax which is the nominal e.i.r.p. plus the maximum ATPC. This maximum ATPC value is often linked to the required link availability.

$$EIRP = \min(EIRP_{nominal} + ATPC, EIRP_{nominal} + ATPC_{max})$$

Figure 11 is a representation of the above.

FIGURE 11

Link between weather, raining attenuation and EIRP level

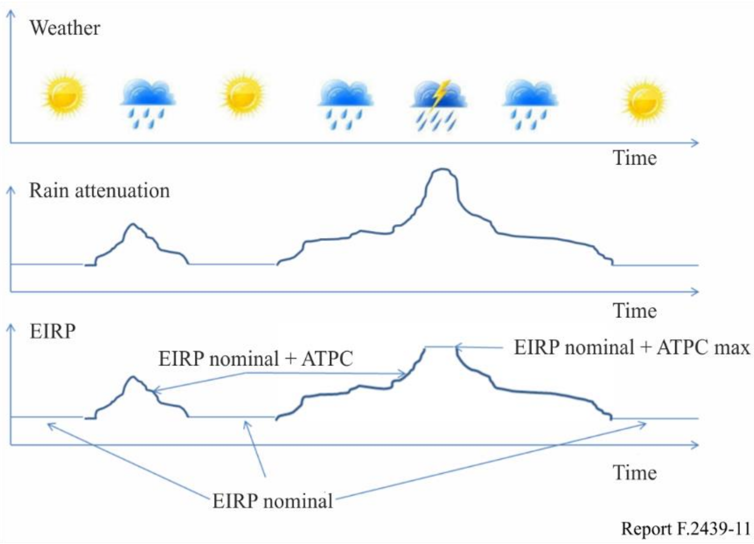
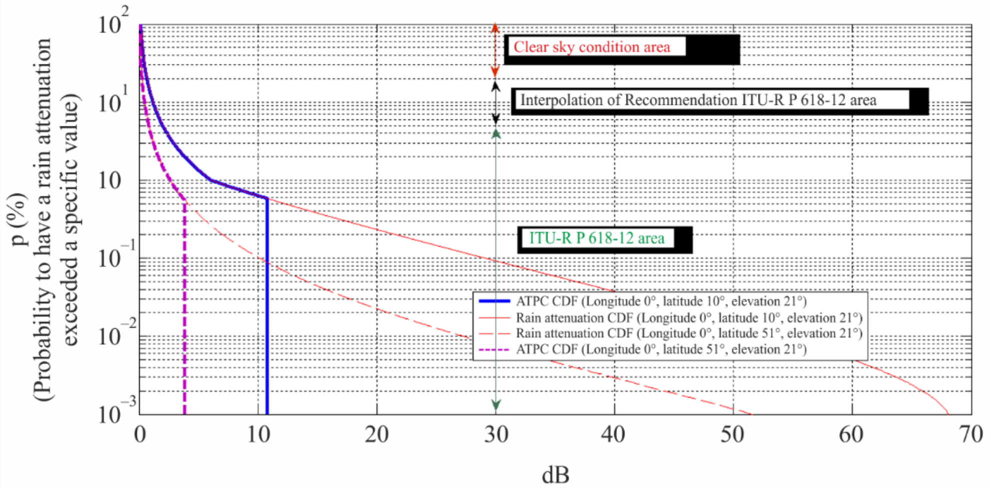


Figure 12 provides an example of the rain attenuation CDF and the ATPC level CDF when the HAPS station is located at longitude 0 degree and latitude 10 degrees, the elevation angle is 21 degrees (edge of the HAPS coverage), a maximum ATPC of 10.8 dB and the frequency at 24.25 GHz. The same computation can be performed when the HAPS beam is not pointing toward the HAPS edge of coverage. In this case the rain attenuation CDF will be lower.

FIGURE 12

Rain attenuation CDF and ATPC CDF



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