Radiocommunication Study Groups

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Annex 4.21 to
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Annex 4.21 to Working Party 5D Chairman's Report

WORKING DOCUMENT TOWARDS SHARING AND COMPATIBILITY STUDIES OF HIBS UNDER WRC-23 AGENDA ITEM 1.4

Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) on WRC-23 agenda item 1.4

[*Editor's note: As guidance for future input contributions, below is an example of structure for each study provided:*

1.1 Study A

1.1.1 Technical characteristics

[This section provides the specific parameters used in the included study/studies.]

1.1.2 Propagation models

[This section provides specific propagation models and related parameters for sharing/interference analyses used in the study.]

1.1.3 Methodology

[This section provides the methodology used in this study.]

1.1.4 Study results

[This section provides the sharing and compatibility study results of this study.]

1.1.5 Summary and analysis of the results of Study A

[This section provides the summary and analysis of the results of this study.]]

1 Introduction

This document provides the sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in the 694-960 MHz, 1 710-1 885 MHz, 1 885-1 980 MHz, 2 010-2 025 MHz, 2 110-2 170 MHz, and 2 500-2 690 MHz frequency ranges with other services and systems referenced under resolves to invite ITU-R 2 in Resolution **247 (WRC-19)**, to ensure the protection of services, without imposing any additional technical or regulatory constraints in their deployment, to which the frequency band is allocated on a primary basis, including other IMT uses, existing systems and the planned development of primary allocated services, and adjacent services, as appropriate, for certain frequency bands below 2.7 GHz, or portions thereof, globally or regionally harmonized for IMT.

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2 Allocation information

The relevant allocation information is contained in the RR Article **5**, in the Tables for the frequency ranges 460-890 MHz, 890-1 300 MHz, 1 710-2 170 MHz, 2 170-2 520 MHz, and 2 520-2 700 MHz.

3 Propagation models and technical and operational characteristics

3.1 Technical and operational characteristics of HIBS

The technical and operational characteristics of HIBS are contained in the working document towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS] (see Annex 4.19 to Working Party 5D Chairman's Report, Document 5D/716).

3.2 Propagation models and technical and operational characteristics of other services and systems

Source	Services/Applications/Models	Information available at
WP 5D	IMT parameters	5D/716 (Annex 4.4)
WPs 3J, 3K and 3M	Propagation models	5D/243, 723
WP 4A	Broadcasting satellite (BSS) Fixed satellite (FSS)	5D/385, 732
WP 4C	Mobile satellite (MSS) Radiodetermination satellite (RDSS)	5D/376, 731
WP 5A	Mobile (MS)	5D/401
WP 5B	Aeronautical mobile (AMS) Aeronautical radionavigation Meteorological radars Radiodetermination	5D/241, 711
WP 5C	Fixed (FS)	5D/234
WP 6A	Broadcasting (BS)	5D/363, 554
WP 7B	Earth exploration satellite (EESS) Meteorological satellite (MetSat) Space operation (SOS) Space research (SRS)	5D/149, 351, 558, 751
WP 7C	Earth exploration satellite (EESS (passive)) Space research (SRS (passive))	5D/152, 354, 566
WP 7D	Radio astronomy (RAS)	5D/261

4 Sharing and compatibility studies

The sharing and compatibility studies are contained in the Annexes to this document.

5 Summary and analysis of the results of studies

[*Editor's note: This section includes the summary of all the studies between HIBS and existing services, which should be transposed to the Section 3 of the Draft CPM text for WRC-23 agenda item 1.4. It may also include possible mitigation measures, as applicable.*]

[*Editor's note: In case of more than one study, need to separate as Study A, Study B, etc. Highlight in each study only the characteristics used that are not already described in Section 3.*]

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Annex 1: Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in the 694-960 MHz frequency range

Annex 2: Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in the 1 710-1 885 MHz frequency range

Annex 3: Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in the 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

Annex 4: Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in the 2 500-2 690 MHz frequency range

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ANNEX 1

Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS)in the 694-960 MHz frequency range

A1.1 Sharing studies between land mobile service excluding IMT and HIBS operating in the 694-960 MHz frequency range

The applications of the land mobile service in the 694-960 MHz frequency range include:

- Trunk systems in the 869-960 MHz range;
- Public Protection and Disaster Relief Operations (PPDR) in the 694-894 MHz range;
- Digital dispatch systems in different bands in the 746-940 MHz range;
- Systems for public mobile communications with aircraft in Region 2 in the 849-851 MHz and 894-896 MHz frequency ranges.

It is important to note that several of these frequency ranges would fall in the proposed HIBS uplink arrangement (i.e., 698-748 MHz, 824-862 MHz, and 880-915 MHz), and thus the sharing and compatibility would not differ from the existing conditions for terrestrial IMT networks.

For example, the PPDR broadband applications in the sub-ranges 694-791 MHz and 791-862 MHz in Region 1, and 703-803 MHz in Region 2 are mostly aligned with the channel arrangements proposed for IMT in Recommendation ITU-R M.1036, which would therefore align with the proposed channel arrangements for HIBS in the same geographical area. In this case, the operation of HIBS and PPDR in the same geographical is equivalent to that of terrestrial IMT and PPDR, including in its capabilities to support such applications. As such, the HIBS base stations transmission will not be different than terrestrial IMT base stations in terms of compatibility with broadband PPDR in this range. The channel arrangements for PDDR in the frequency range 806-869 MHz in Region 2 does not coincide with that of IMT, and thus does not coincide with that of HIBS in the same Region.

A1.2 Sharing studies between the ground component of IMT and HIBS operating in the 694-960 MHz frequency range

A1.2.1 Study A

A1.2.1.1 Technical characteristics

A1.2.1.1.1 Technical and operational characteristics of HIBS systems operating in the frequency band 694-960 MHz

This section provides the characteristics of HIBS systems, according to the PDNR ITU-R M.[HIBS-CHARACTERISTICS] (Annex 4.19 to Working Party 5D Chairman's Report, Doc. 5D/716). Table A1.2.1.1 provides the specification-related parameters to be used in this analysis for HIBS.

TABLE A1.2.1.1

Specification related parameters of HIBS (Base Station)

No.	Parameter	Band 1 (694-960 MHz)
1	Duplex Method	FDD
2	Channel bandwidth (MHz)	20 MHz

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3	Signal bandwidth (MHz)	18 MHz
4	Power dynamic range (dB)	0 dB conducted BS output power
5	Spurious emissions	−13 dBm/100 kHz

Table A1.2.1.2 shows deployment-related parameters used in this analysis for HIBS and the associated UEs.

TABLE A1.2.1.2

Deployment related parameters of HIBS and the UE associated to HIBS

No.	Parameter	Band 1 (694-960 MHz)
1	**Network topology and characteristics**	
1.1	BS density or ISD	1 BS/HIBS area
1.2	HIBS area radius	100 km
1.3	HIBS network configuration (Duplex Mode)	FDD
2	**Base station characteristics/Cell Structure**	
2.1	HIBS Platform Altitude	20
2.2	Number of cells/HIBS	7
2.3	Frequency reuse	1
2.5	HIBS Platform Antenna pattern	Recommendation ITU-R M.2101
	Element gain	8 dBi
	Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V
	Horizontal/vertical front-to-back ratio	30 dB for both H/V
	Antenna polarization	Linear/±45 degrees
	Antenna array configuration (Row × Column)	2 × 2 elements (1st layer cell), 4 × 2 elements per cell (2nd layer cell)
	Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
	Ohmic losses	2 dB
2.6	HIBS Platform Antenna tilt	90º (1st layer cell), 33º (2nd layer cell)
2.7	HIBS Conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
2.8	HIBS Platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)
2.9	HIBS Platform e.i.r.p. Spectral Density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)
3	**UE characteristics**	
3.1	UE density for equipment that are transmitting simultaneously	3 UEs per cell
3.2	UE height	1.5 m
3.3	Body loss	4 dB
3.4	Typical antenna gain for UE	-3 dBi

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3.5	Transmit power control model	Refer to Recommendation ITU-R M.2101
3.6	Maximum UE transmitter output power	23 dBm

A1.2.1.1.2 Technical and operational characteristics of the ground component of IMT operating in the frequency band 694-960 MHz

This section provides the characteristics of IMT systems, according to *Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23* (Annex 4.4 to Working Party 5D Chairman's Report, 5D/716).

Tables A1.2.1.3 and A1.2.1.4 provide the deployment-related parameters of IMT systems for the frequency bands below 1 GHz. In these frequency bands, implementation of AAS is not considered in IMT base and mobile stations.

TABLE A1.2.1.3

Deployment-related parameters for bands below 1 GHz

	Urban/suburban macro	**Rural macro**
Base station characteristics/Cell structure		
Cell radius	urban macro: 1.5 km suburban macro: 3 km	8 km
Antenna height	30 m	30 m
Sectorization	3 sectors	3 sectors
Downtilt	3 degrees	3 degrees
Frequency reuse	1	1
Antenna pattern	Recommendation ITU-R F.1336 (*recommends* 3.1) $k_a = 0.7$ $k_p = 0.7$ $k_h = 0.7$ $k_v = 0.3$ Horizontal 3 dB beam width: 65 degrees Vertical 3 dB beam width: determined from the horizontal beam width by equations in Recommendation ITU-R F.1336. Vertical beam widths of actual antennas may also be used when available.	
Antenna polarization	Linear/±45 degrees	Linear/±45 degrees
Below rooftop base station antenna deployment	Urban: 20% Suburban: 0%	0%
Feeder loss	3 dB	3 dB
Typical channel bandwidth	10 MHz	10 MHz
Maximum base station output power (Report ITU-R M.2292)	46 dBm in 10 MHz	46 dBm in 10 MHz
Maximum base station antenna gain (Report ITU-R M.2292)	15 dBi	15 dBi
Maximum base station output power/sector (e.i.r.p.)	58 dBm in 10 MHz	58 dBm in 10 MHz
Network loading factor (base station load probability X%)	50%	50%

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	Urban/suburban macro	Rural macro
TDD / FDD / SDL	FDD	FDD

TABLE A1.2.1.4

UE parameters for bands below 1 GHz

	Urban/suburban macro	Rural macro
User terminal characteristics		
Indoor user terminal usage (Report ITU-R M.2292)	70%	50%
Indoor user terminal penetration loss	Rec. ITU-R P.2109	Rec. ITU-R P.2109
User equipment density for terminals that are transmitting simultaneously	3 UEs per sector	3 UEs per sector
UE height	1.5 m	1.5 m
Average user terminal output power	Use transmit power control	Use transmit power control
Typical antenna gain for user terminals	−3 dBi	−3 dBi
Body loss	4 dB	4 dB
Transmit power control		
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1	
Maximum user terminal output power, PCMAX	23 dBm	23 dBm
Power (dBm) target value per RB, P0_PUSCH	−92.2	−92.2
Path loss compensation factor, α (same as "balancing factor" mentioned in Rec. ITU-R M.2101)	0.8	0.8

Table A1.2.1.5 provides the protection criterion for IMT systems (irrespective of the number of cells and independent of the number of interferers). This criterion has been developed without considering any percentage of time related to it.

TABLE A1.2.1.5

Protection criterion for IMT

Protection criterion (*I/N*)	−6 dB

A1.2.1.2 Propagation models for sharing and compatibility studies in the frequency band 694-960 MHz

According to the liaison statement from ITU-R SG 3 (Doc. 5D/723), Recommendation ITU-R P.528-4 is used to model the basic transmission loss between HIBS BS and UEs in the ground.

In urban and suburban scenarios, according to the liaison statement 5D/723, Document 3K/178 (Annex 6 to Working Party 3K Chairman's Report) is used to calculate clutter loss.

When the user equipment of the ground component of IMT system is indoors, building entry loss shall be considered according to Recommendation ITU-R P.2109-1.

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A1.2.1.3 Methodology

This section describes the methodology of modelling HIBS BS interference into IMT UE. Main steps of the simulation are as follows:

Step 1: Determine evaluation area and the deployment of HIBS and the ground component of IMT system.

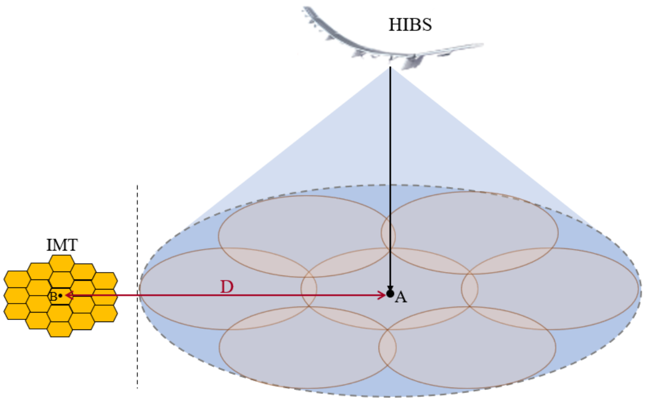
Step 1.1: Determine evaluation area.

According to the PDNR ITU-R M.[HIBS CHARACTERISTICS], the potential usage scenarios for HIBS are coverage enhancement for rural and remote areas, safety and security, internet of things, and event services. To cover all kinds of border areas, the deployment scenarios for the ground component of IMT system are assumed to contain urban, suburban and rural areas.

The coexistence scenario for HIBS and IMT system is shown in Figure A1.2.1.1. In this figure, point A represents the subpoint of HIBS base station, point B represents the centre cell of the IMT system, the letter D represents the distance between point A and point B. HIBS and the ground component of IMT system are assumed to be deployed in different areas.

FIGURE A1.2.1.1

Coexistence scenario of HIBS and the ground component of IMT system



Step 1.2: Determine the deployment of HIBS and the ground component of IMT system.

The HIBS base stations is assumed to be deployed at the altitude of 20 km, with the structure of 7 cells. The IMT system is composed of 19 cells, with the structure of 3 sectors per cell. HIBS system and the ground component of IMT system are assumed to use the same frequency band to transmit or receive, in the FDD duplex mode.

Step 2: Calculate aggregate interference from HIBS system.

Step 2.1: Calculate the interference from HIBS BS sector to each IMT UE.

In HIBS downlink transmission, the interference power from HIBS BS sector to the IMT UE could be calculated by equation (1) as below.

$$I_n = P_{tx} + G_{tx} - PL + G_{rx} \quad (1)$$

where:

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I_n : interference power from the n-th HIBS base station sector to the IMT UE, dBm/20 MHz;

P_{tx} : HIBS base station transmit power in the reference bandwidth, dBm/20 MHz;

G_{tx}: The antenna gain of the n-th HIBS base station sector in direction of the IMT UE, dBi;

PL: propagation loss including free space transmission loss, atmospheric attenuation and clutter loss as appropriate, dB;

G_{rx}: the maximum antenna gain of the IMT UE, dBi.

Step 2.2: Calculate aggregate interference from HIBS BS.

The aggregate interference is calculated by equation (2) as follows.

$$I_{total} = 10\log\left(\sum_{n=1}^{n=N} 10^{I_n/10}\right) \quad (2)$$

where:

I_{total}: received aggregate interference for IMT UE, dBm/20 MHz;

n: index of the HIBS BS sectors;

I_n: received interference power from the n-th HIBS BS sector (dBm/20 MHz);

N: the total number of HIBS BS sectors.

Step 3: Compare the defined *I/N* protection criterion and analyse the simulation results.

A1.2.1.4 Study results

A1.2.1.4.1 HIBS antenna patterns

The antenna patterns for HIBS base station are shown in following figures, in accordance with Recommendation ITU-R M.2101. In the frequency band 694-960 MHz, HIBS system uses Non-Advanced Antenna System (Non-AAS).

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FIGURE A1.2.1.2

HIBS antenna pattern for 1st layer cell (2×2 elements)

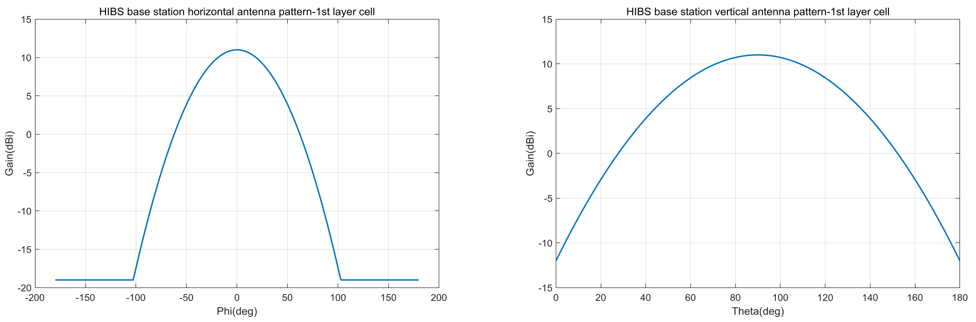
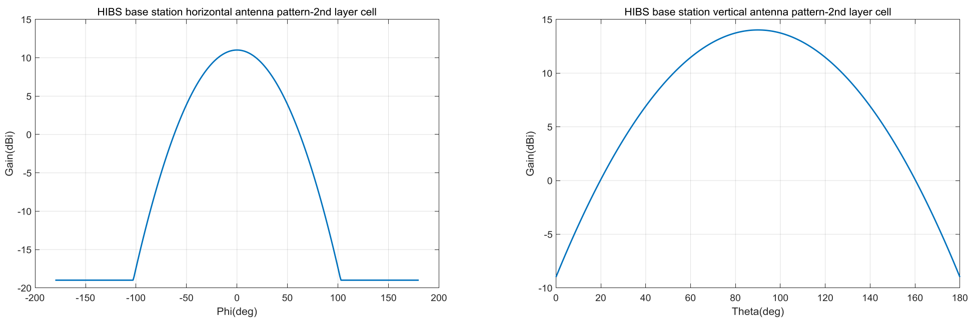


FIGURE A1.2.1.3

HIBS antenna pattern for 2nd layer cell (4×2 elements)



A1.2.1.4.2 Propagation loss

The Cumulative Distribution Function of propagation loss between HIBS base station and HIBS UE is shown in Figure A1.2.1.4, where HIBS UEs are randomly distributed in the coverage area. The simulations were done with 700 snapshots.

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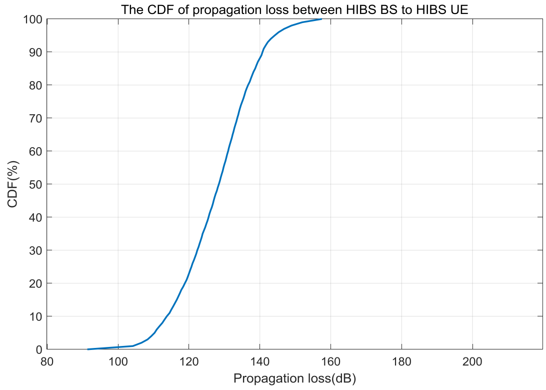
FIGURE A1.2.1.4

The CDF of propagation loss in urban areas



A1.2.1.4.3 HIBS interference

A1.2.1.5 Summary and analysis of the results of Study A

[*Editor's note: This section provides the summary and analysis of the results of this study.*]

A1.3 Sharing studies between aeronautical radionavigation service and HIBS operating in the 694-960 MHz frequency range

[*TBD*]

A1.4 Sharing and compatibility studies between broadcasting services in the 470-960 MHz band and HIBS operating in the 694-960 MHz frequency range

The use of the frequency band 698-748 MHz by HIBS would be in the uplink direction, consistent with Recommendation ITU-R M.1036 and based exclusively on FDD duplex mode (no use of TDD duplex mode). Since a HIBS base station will not transmit in the band adjacent to the broadcasting service in the 470-698 MHz band, it could be considered that interference from HIBS in the uplink direction to broadcasting receivers operating in adjacent frequency band is unlikely to be a problem.

In terms of sharing conditions between HIBS and broadcasting services in the 694-960 MHz frequency, the high altitude of the HIBS base stations gives them a potential of interference over a very large area As they may operate in co-channel with broadcasting services in neighbouring countries, co-channel sharing and compatibility studies between terrestrial broadcasting service and HIBS downlinks operating in the 694-960 MHz frequency range are needed to determine the size of the area over which an existing receiving installation of the terrestrial broadcasting service might be affected.

A1.5 Compatibility studies between aeronautical radionavigation service in the adjacent frequency band and HIBS operating in the 694-960 MHz frequency range

[*TBD*]

A1.6 Compatibility studies between aeronautical mobile (route) service in the adjacent frequency band and HIBS operating in the 694-960 MHz frequency range

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[A1.7 Compatibility studies between radio astronomy service 1 610.6-1 613.8 MHz and HIBS BS operating in the 694-960 MHz frequency range

[*Editor's Note: With regards to 2nd harmonics, this issue and related studies have not fully discussed, nor concluded, and nor agreed to by WP 5D.*]

A1.7.1 General description

The frequency band 1 610.6-1 613.8 MHz is allocated to the radio astronomy service on a primary basis. Owing to the increased likelihood of line-of-sight conditions and main-beam to main-beam coupling, RAS stations may receive harmful interference from spurious emissions of HIBS operating in the frequency range 804.3-806.9 MHz. According to RR Article **1**, No. **1.145**, *"[...] Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products[…]".*

Harmonic emissions are a physical consequence of electronic circuits, only a perfectly linear system (an ideal device) would not produce any harmonic emissions. Normally, harmonics are not an issue for compatibility studies due to their relatively low level with respect to in-band signals. Nevertheless, the high sensitivity of radio telescopes and the fact that HIBS transmissions would be attenuated almost exclusively by free space propagation, require specific attention to second harmonics as presented in this study.

According to Report ITU-R SM.2421 (Section 5.3), one of the measured LTE800 UE devices produced second harmonics in the 1 700 MHz band, with broad-band emissions of -31.3 dBm/MHz just slightly below the regulatory limit for this type of device, which is -30 dBm/MHz. It is difficult to rule out that other IMT equipment could produce similar features in the RAS band considered in this study. The regulatory limits for spurious emissions are usually much higher than real emissions at most frequencies, but at particular frequencies the actual emissions can come close to the spectrum mask values, owing to intermodulation products, harmonics, etc.

This study is conducted using parameters from relevant references as described in Tables A1.7.1 – A1.7.4. One HIBS system is assumed to consist of two layers, with 1 central and 6 surrounding cells as described in WDPDN REPORT ITU-R M.[HIBS-CHARACTERISTICS], with base stations (BS) using the frequency arrangement A3 or A6 (see Table A1.7.2) of which the second harmonic falls into the 1 610.6-1 613.8 MHz RAS band, from a platform at nominal altitude 20 km. The study calculates the mean power flux density (pfd) of spurious emissions arriving at a radio telescope in the frequency band 1 610.6-1 613.8 MHz, varying the nadir distance to the HIBS platform in a spherical Earth geometry.

A1.7.2 Characteristics and protection criteria

A1.7.2.1 HIBS characteristics

To calculate the eirp level in the RAS band arising from the second harmonics of HIBS BS, the spurious emissions level for HIBS BS is given in Table 2 of WDPDN REPORT ITU-R M.[HIBS-CHARACTERISTICS] as -13 dBm/MHz or -30 dBm/MHz[1]. Throughout this study, the -13 dBm/MHz spurious level is considered, the effect of a lower spurious level is discussed in section A1.7.7. To obtain the eirp from one BS, the spurious emissions are affected by the single element antenna pattern as described in Recommendation ITU-R M.2101 Section 5.

[1] Note 1: The choice between the two spurious emissions values of −13 dBm/–30 dBm should take into consideration specific national requirements and the studies with other services and applications, as the results of such studies may indicate which value is more appropriate to achieve compatibility.

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TABLE A1.7.1

Platform operating characteristics

HAPS Parameters	Value	Reference
Altitude (nominal)	20 km	RR. 1.66A
Horizontal circulation radius (1)	5 km	Rep. ITU-R F.2439
Altitude deviation (1)	+5 km (20 – 25 km)	Rep. ITU-R F.2439

(1) Not considered at this point in the study

TABLE A1.7.2

HIBS operational characteristics

HIBS/BS Parameters	Value or Description	Reference in WDPDN Report ITU-R M.[HIBS-CHARACTERISTICS]
Frequency band	A3 or A6	Table 2
Spectrum mask per beam	-13 dBm/MHz or -30 dBm/MHz (1)	Table 2
Single element maximum gain	8 dBi	Table 2 and Rec. ITU-R M.2101
Ohmic losses	2 dB	Table 2
Antenna pattern	Single element as per Rec. ITU-R M.2070	Parameters from Table 5
Beams considered	1x1st layer toward nadir 6x2nd layer 67^{o} off-nadir	Section 6.1.3.2 2nd layer offset +/- 30^{o}, 90^{o}, 150^{o} in azimuth relative to the RAS antenna

(1) The -30 dBm/MHz value is considered in section A1.7.7

A1.7.2.2 RAS Characteristics

Radio telescopes are sited in remote locations having a clear horizon down to a few degrees elevation, rendering HIBS in line of sight at large distances. Site characteristics have little influence on the study results but, for definiteness, this study took as an example a radio telescope operating at an elevation of 7000 feet (Table A1.7.1) like the Karl Jansky Very Large Array (VLA) in New Mexico, USA.

The characteristics and protection thresholds for radio astronomy are reproduced in Table A1.7.3 from the relevant recommendations.

TABLE A1.7.3

RAS operating characteristics and protection threshold

RAS Parameters	Value	Reference
PFD threshold	-251 dB W/m^2/Hz	Rec. ITU-R RA.769, Table 1
Antenna gain	0 dBi	Rec. ITU-R RA.769
Site altitude	2.13 km (7000’)	Karl Jansky VLA (USA)
Max data loss from HIBS	2%	Rec. ITU-R RA.1513
Allocated Frequency Band	1 610.6-1 613.8 MHz	RR Vol 1 Article **5**

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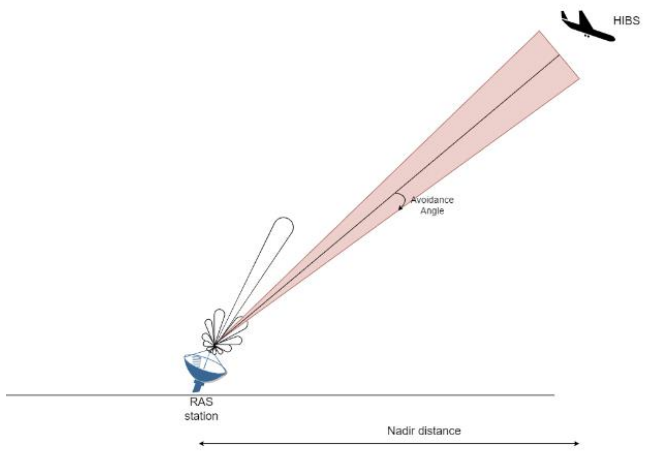
Antenna pattern considered for avoidance angle		Rec ITU-R SA.509
Separation angle for 2% data loss	11.5 degrees (for one HIBS in line of sight)	

The protection thresholds in the tables of Recommendation ITU-R RA.769 are calculated for 0 dBi RAS gain, and, as noted in Rec. ITU-R RA.1513, ensuring 0 dBi gain requires an off-axis angle (avoidance angle) from a persistent interferer like a HIBS that remains in direct line of sight of a radio telescope. The size of such angular offset will define how much of the sky in not available for RAS observations at 1 610.6-1 613.8 MHz resulting in data loss.

FIGURE A1.7.1

Avoidance angle for an RAS station



For only one HAPS in line of sight, the maximum permitted sky loss is of 2%, representing an avoidance angle of 11.5°. The gain for an RAS antenna as defined in Rec. ITU-R SA.509, irrespective of antenna diameter, for this off-axis angle is 5.5 dBi.

A1.7.3 Geometry: HIBS – RAS distance

The geometry of the study is illustrated in Figure A1.7.2 where it is shown that the line between the platform and the radio astronomy station, defining the nadir distance, passes between two outer-layer HIBS BS cells/beams and is not aligned with any one of them.

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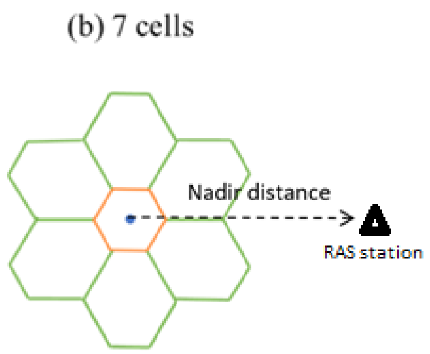
FIGURE A1.7.2

Geometrical configuration of the study.



A1.7.4 Propagation model

TABLE A1.7.4

Propagation characteristics

Propagation loss	Value or Description	Reference
Free space loss	Inverse square law	P.619
Atmospheric attenuation (1)	Numerical integration of 0.006 dB/km * exp (-h/6 km) at height h along path to RAS	P.619, P.676, P.835
Ducting, Scintillation	Negligible	P.619, P.676, P.835
Clutter loss	None	See Section A1.X.4.1

(1) Atmospheric attenuation is not included in the study

A1.7.4.1 Clutter loss

Over the range of nadir distances shown in Figures A1.X.3 and A1X.4, the line of sight between the HIBS and the VLA does not pass low enough to encounter ground clutter except in the very immediate vicinity of the telescope where the only “clutter” is other antennas that by design do not obstruct each other.

A1.7.5 Study results

A1.7.5.1 Harmonics level at -13 dBm/MHz

Shown in Figure A1.X.3 at left is the pfd received from HIBS transmissions aboard one platform as a function of the platform’s nadir distance to the radio astronomy station (the total BS on board the HIBS and only the nadir pointing one). The threshold level defined in Rec. ITU-R RA.769 is denoted by a dashed horizontal line. At larger separation the contribution from the outer layer is enhanced by the 67^{o} upward tilt from nadir of the radiating elements. Shown at right is the apparent elevation of the HIBS above the horizon at the telescope.

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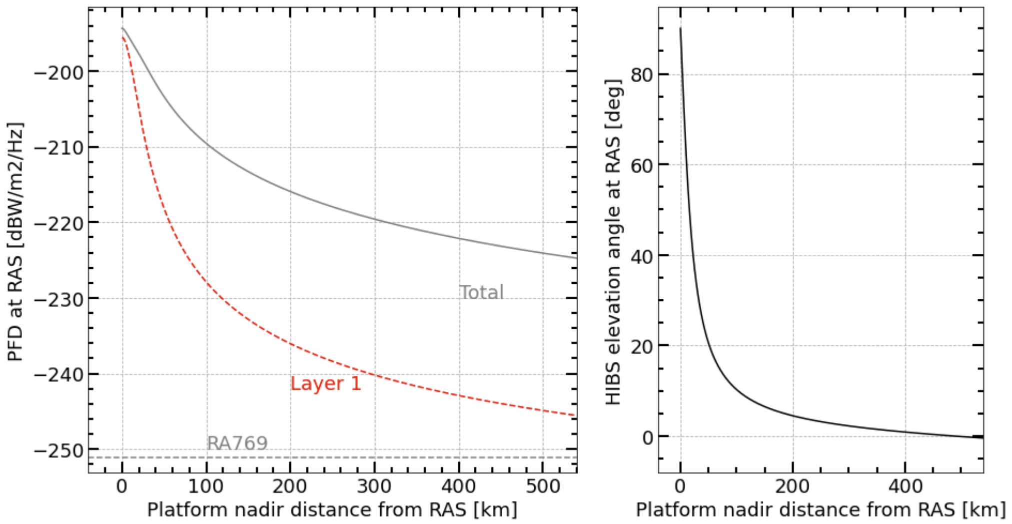
FIGURE A1.7.3

Left: Received power flux density vs. HIBS platform nadir distance. The total pfd and the contribution of the nadir-pointing central antenna element are shown. The horizontal dashed line at bottom left represents the protection threshold -251 dB W/m^2/Hz in Table 1 of Rec. ITU-R RA.769 at 1 612 MHz. Right: Elevation angle of the HIBS at the RAS station.



As a check, note that the pfd at 0 nadir distance arising from the nadir-pointing BS is just that for a conducted power of -13 dBm/MHz affected by the maximum element gain and the ohmic losses at 18 km line of sight distance, resulting in -195.57 dBW/m^2/Hz. The effect of the individual antenna element beam pattern is evident in Figure A1.7.3 because the incident pfd from the central BS drops much faster than the inverse square law distance dependence as the platform nadir distance increases away from the origin. By contrast, the upward tilt of the outer layer BS is more nearly oriented toward the telescope at larger nadir distance, compensating for increased spreading loss.

A1.7.5.1.1 Incident PFD compared with the protection threshold in Recommendation ITU-R RA. 769

The total incident pfd exceeds the Rec. ITU-R RA.769-2 threshold at all separations by 52 to 22 dB (see Figure A1.7.4 in the blue line). In this case, added attenuation of the unwanted emissions of whatever kind (see A1.7.6) would be required to operate compatibly with radio astronomy. The added attenuation that will lower the incident pfd to the RA.769 threshold will be denoted X_{block}. Once that is added and the threshold pfd in RA.769 is met, compatibility becomes a question of sky blockage, as explained in A1.7.2.2.

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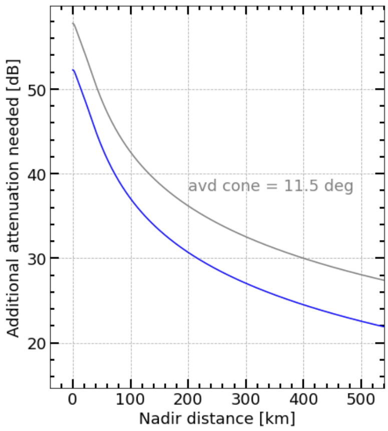
FIGURE A1.7.4

Additional attenuation X_{block} needed to reach the RA769 levels for 0 dBi RAS antenna gain and for an 11.5° avoidance cone where X_{block} is increased by 5.5 dB.



In the case of multiple HIBS deployment, calculation of the size of the angular regions of avoidance and the value of X_{block} is complex because to maintain the 2% data loss, each additional HIBS in line of sight reduces the required size of all cones of avoidance, implying higher RAS gain and increased X_{block}. This could greatly complicate compatibility if several HIBS in line of sight to the same radio telescope are deployed by different operators or in different administrations.

As an example, in previous studies of a full HAPS network buildout, compatibility with RAS operations at 23.6-24 GHz required X_{block} = 30 dB in the direction of radio astronomy stations as discussed in Rep. ITU-R F.2472-0. This allowed the cones of avoidance to have radii $\theta = 3^o$ and to occupy 2% of the sky in the aggregate.

A1.7.7.1 Harmonics –30 dBm/MHz

In the case that the spurious level from BS is the lower option in Table A1.7.2 (-30 dBm/MHz), the pfd level at the RAS site and the needed Xblock are shown in Figure A1.7.5.

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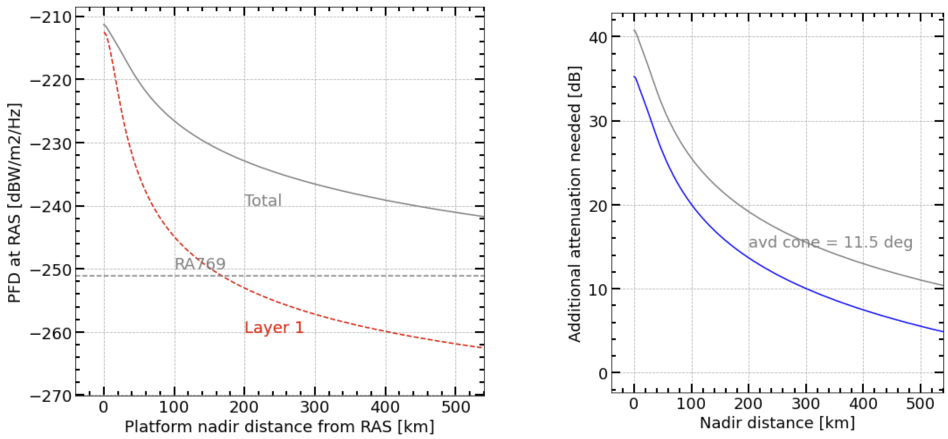
FIGURE A1.7.5

Left: Received power flux density vs. HIBS platform nadir distance with -30dBm/MHz spurious emissions. The total pfd and the contribution of the nadir-pointing central antenna element are shown. The horizontal dashed line at bottom left represents the protection threshold -251 dB W/m^2/Hz in Table 1 of Rec. ITU-R RA.769 at 1 612 MHz. Right: Additional attenuation X_{block} needed to reach the RA769 levels



A1.7.6 Summary

It should be noted that studies on the effects of second harmonics are not usually performed as part of sharing and compatibility studies, and are not included in the invites of Resolution **247 (WRC-19)**. Furthermore, when considering the FDD arrangements of Recommendation ITU-R M.1036 (A4-A11), most of the possible harmonics listed to fall under RAS frequency bands would come from the HIBS uplink in the 700 MHz band. As such, considering that the UE from HIBS and ground-based IMT networks are the same, no studies would be necessary in this case. In the case when the FDD arrangement A3 (also known as 800 MHz band) is used, which has a reverse duplexer (BS in the lower part, UE in the upper part), there could be a possibility that the second harmonics of this arrangement would fall into the RAS frequency band 1 610.6-1 613.8 MHz. For this specific case, this study has provided the following summary.

With the parameters considered in this study, for a single HIBS and a RAS station, and the deployment scenario considered, achieving compatibility requires further measures.

To achieve compatibility of a single HIBS using a frequency arrangement as A3 or A6 (791-821 or 698-806 respectively) and a RAS station operating in the 1 610.6-1 613.8 MHz band, the following measures can be considered:

To avoid receiving harmful interference an RAS station would have to avoid pointing to a HIBS, with the angular separation dependent on the HIBS 2nd harmonics emissions level. The dynamic movement of the HIBS (vertically and horizontally) may be an important consideration in this avoidance.

A combination of the following measures could be employed by the HIBS:

a) As assumed in this study, avoid the situation where HIBS BS are oriented in azimuth directly towards RAS station.

b) Filter or otherwise attenuate 2^{nd} harmonics emissions in the direction of the RAS station. According to Figure A1.7.3, the required additional attenuation for one HIBS

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(in a 2-layer 7 cell HIBS system) at 100 km nadir distance from a RAS station is X_{block} = 42 dB, (see Section A1.7.4 and A.1.7.6) including the additional 5.5 dB attenuation that limits the fractional sky blockage of the region of avoidance about the HIBS to 2%.

c) Geographic separation.]

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ANNEX 2

Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in the 1 710-1 885 MHz frequency range

A2.1 Sharing studies between land mobile service excluding IMT and HIBS operating in the 1 710-1 885 MHz frequency range

The applications of the land mobile service in the 1 710-1 885 MHz frequency range include digital dispatch systems in the 1 785-1 805 MHz and 1 850-1 910 MHz frequency bands. The 1 710-1 885 MHz frequency range would fall in the proposed HIBS uplink arrangement, and thus the sharing and compatibility conditions between HIBS and the applications of the land mobile service do not differ from the existing conditions for ground-based terrestrial IMT networks.

A2.2 Sharing studies between the ground component of IMT and HIBS operating in the 1 710-1 885 MHz frequency range

A2.2.1 Study A

A2.2.1.1 Technical characteristics

[*Editor's note: This section provides the specific parameters used in the included study/studies.*]

A2.2.1.1.1 Technical and operational characteristics of HIBS systems operating in the frequency band 1 710-1 885 MHz

This section provides the characteristics of HIBS systems, according to the PDNR ITU-R M.[HIBS-CHARACTERISTICS] (Annex 4.19 to Working Party 5D Chairman's Report, Doc. 5D/716). Table A2.2.1.1 provides the specification-related parameters to be used in this analysis for HIBS.

TABLE A2.2.1.1

Specification related parameters of HIBS (Base Station)

No.	Parameter	Band 2 (1 710-1 980 MHz 2 010-2 025 MHz 2 110-2 170 MHz)
1	Duplex Method	FDD
2	Channel bandwidth (MHz)	20 MHz
3	Signal bandwidth (MHz)	18 MHz
4	Power dynamic range (dB)	0 dB conducted BS output power
5	Spurious emissions	−13 dBm/ MHz

Table A2.2.1.2 shows deployment-related parameters used in this analysis for HIBS and the associated UEs.

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TABLE A2.2.1.2

Deployment related parameters of HIBS and the UE associated to HIBS

No.	Parameter	Band 2 (1 710-1 980 MHz 2 010-2 025 MHz 2 110-2 170 MHz)
1	**Network topology and characteristics**	
1.1	BS density or ISD	1 BS/HIBS area
1.2	HIBS area radius	100 km
1.3	HIBS Network Configuration (Duplex Mode)(1)	FDD
2	**Base station characteristics/Cell Structure**	
2.1	HIBS Platform Altitude	20 km
2.2	Number of cells/HIBS	7
2.3	Frequency reuse	1
2.5	HIBS Platform Antenna pattern	Recommendation ITU-R M.2101
	Element gain	8 dBi
	Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V
	Horizontal/vertical front-to-back ratio	30 dB for both H/V
	Antenna polarization	Linear/±45 degrees
	Antenna array configuration (Row × Column)	2 × 2 elements (1st layer cell), 4 × 2 elements per cell (2nd layer cell)
	Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
	Ohmic losses	2 dB
2.6	HIBS Platform Antenna tilt	90º (1st layer cell), 23º (2nd layer cell)
2.7	HIBS Conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
2.8	HIBS Platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)
2.9	HIBS Platform e.i.r.p. Spectral Density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)
3	**UE characteristics**	
3.1	UE density for equipment that are transmitting simultaneously	3 UEs per cell
3.2	UE height	1.5 m
3.3	Body loss	4 dB
3.4	Typical antenna gain for UE	−3 dBi
3.5	Transmit power control model	Refer to Recommendation ITU-R M.2101
3.6	Maximum UE transmitter output power	23 dBm

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A2.2.1.1.2 Technical and operational characteristics of the ground component of IMT operating in the frequency band 1 710-1 885 MHz

This section provides the characteristics of IMT systems, according to the *Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23* (Annex 4.4 to Working Party 5D Chairman's Report, 5D/716).

Tables A2.2.1.3 and A2.2.1.4 provide the deployment-related parameters of IMT systems for the frequency bands between 1 and 3 GHz. AAS is implementable in IMT base stations in the frequency bands above about 1 710 MHz, and for these bands both AAS and antenna characteristics in Recommendation ITU-R F.1336 are considered for IMT base stations. Implementation of AAS is not considered in IMT user equipment / mobile stations.

TABLE A2.2.1.3

Deployment-related parameters for bands between 1 and 3 GHz

	Rural macro	**Urban/suburban macro**
Cell radius / Deployment density (for bands between 1 and 2 GHz) (Report ITU-R M.2292)	5 km	urban macro 0.5 km suburban macro 1 km
Cell radius / Deployment density (for bands between 2 and 3 GHz) (Report ITU-R M.2292)	4 km	urban macro 0.4 km suburban macro 0.8 km
Antenna height (Report ITU-R M.2292)	30 m	25 m urban / 30 m suburban
Sectorization	3 sectors	3 sectors
Frequency reuse	1	1
Below rooftop base station antenna deployment (Report ITU-R M.2292)	0%	Urban: 30% Suburban: 0%
Typical channel bandwidth	10 or 20 MHz	10 or 20 MHz
Network loading factor (base station load probability X%) (see section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6)	50%	50%
TDD / FDD	FDD	FDD

TABLE A2.2.1.4

UE parameters for bands between 1 and 3 GHz

	Rural macro	**Urban/suburban macro**
User terminal characteristics		
Indoor user terminal usage (Report ITU-R M.2292)	50%	70%
Indoor user terminal penetration loss	Rec. ITU-R P.2109	Rec. ITU-R P.2109

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User equipment density for terminals that are transmitting simultaneously	3 UEs per sector	3 UEs per sector
UE height	1.5 m	1.5 m
Average user terminal output power	Use transmit power control	Use transmit power control
Typical antenna gain for user terminals	−3 dBi	−3 dBi
Body loss	4 dB	4 dB
UE TDD activity factor	25%	25%
Transmit power control		
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1	
Maximum user terminal output power, PCMAX	23 dBm	23 dBm
Power (dBm) target value per RB, P0_PUSCH	−92.2	−92.2
Path loss compensation factor, α (same as "balancing factor" mentioned in Rec. ITU-R M.2101)	0.8	0.8

Antenna characteristics for AAS base stations (for frequency bands above 1 710 MHz) are provided in *Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23*.

Table A2.2.1.5 provides the protection criterion for IMT systems (irrespective of the number of cells and independent of the number of interferers). This criterion has been developed without considering any percentage of time related to it.

TABLE A2.2.1.5

Protection criterion for IMT

Protection criterion (I/N)	-6 dB

A2.2.1.2 Propagation models for sharing and compatibility studies in the frequency band 1 710-1 885 MHz

According to the liaison statement from ITU-R SG3 (5D/723), Recommendation ITU-R P.528-4 is used to model the basic transmission loss between HIBS BS and UEs in the ground. In urban and suburban scenarios, according to the liaison statement 5D/723, the document 3K/178 (Annex 6 to Working Party 3K Chairman's report) is used to calculate clutter loss. When the user equipment of the ground component of IMT system is indoors, building entry loss shall be considered according to Recommendation ITU-R P.2109-1.

A2.2.1.3 Methodology

This section describes the methodology of modelling HIBS BS interference into IMT UE. Main steps of the simulation are as follows:

Step 1: Determine evaluation area and the deployment of HIBS and the ground component of IMT system.

Step 1.1: Determine evaluation area.

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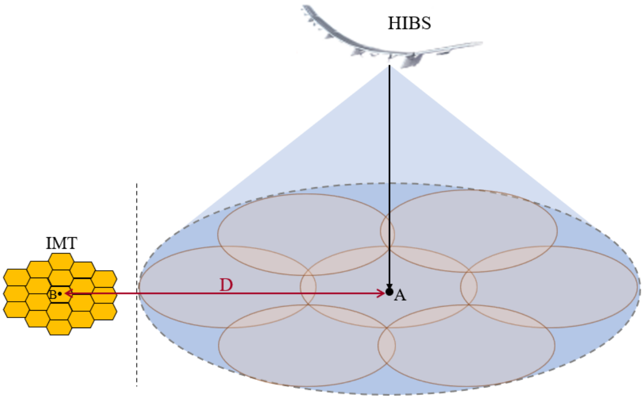
According to the PDNR ITU-R M.[HIBS CHARACTERISTICS], the potential usage scenarios for HIBS are coverage enhancement for rural and remote areas, safety and security, internet of things, and event services. To cover all kinds of border areas, the deployment scenarios for the ground component of IMT system are assumed to contain urban, suburban and rural areas.

The coexistence scenario for HIBS and IMT system is shown in Figure A2.2.1.1. In this figure, point A represents the subpoint of HIBS base station, point B represents the centre cell of the IMT system, the letter D represents the distance between point A and point B. HIBS and the ground component of IMT system are assumed to be deployed in different areas.

FIGURE A2.2.1.1

Coexistence scenario of HIBS and the ground component of IMT system



Step 1.2: Determine the deployment of HIBS and the ground component of IMT system.

The HIBS base stations is assumed to be deployed at the altitude of 20 km, with the structure of 7 cells. The IMT system is composed of 19 cells, with the structure of 3 sectors per cell. HIBS system and the ground component of IMT system are assumed to use the same frequency band to transmit or receive, in the FDD duplex mode.

Step 2: Calculate aggregate interference from HIBS system.

Step 2.1: Calculate the interference from HIBS BS sector to each IMT UE.

In HIBS downlink transmission, the interference power from HIBS BS sector to the IMT UE could be calculated by equation (1) as below.

$$I_n = P_{tx} + G_{tx} - PL + G_{rx} \quad (1)$$

where:

I_n : Interference power from the n-th HIBS base station sector to the IMT UE, dBm/20 MHz;

P_{tx} : HIBS base station transmit power in the reference bandwidth , dBm/20 MHz;

G_{tx}: The antenna gain of the HIBS base station sector in direction of the IMT UE, dBi;

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PL: Propagation loss including free space transmission loss, atmospheric attenuation and clutter loss as appropriate, dB;

G_{rx}: the maximum antenna gain of the IMT UE, dBi.

Step 2.2: Calculate aggregate interference from HIBS BS.

The aggregate interference is calculated by equation (2) as follows:

$$I_{total} = 10\log\left(\sum_{n=1}^{n=N} 10^{I_n/10}\right) \quad (2)$$

where:

I_{total}: Received aggregate interference for the IMT UE, dBm/20 MHz;

n: Index of the HIBS BS sectors;

I_n: Received interference power from the n-th HIBS BS sector (dBm/20 MHz);

N: The total number of HIBS BS sectors.

Step 3: Compare the defined *I/N* protection criterion and analyse the simulation results.

A2.2.1.4 Study results

A2.2.1.4.1 HIBS antenna patterns

The antenna patterns for HIBS base station are shown in following figures, in accordance with Recommendation ITU-R M.2101. In the frequency band 1 710-1 885 MHz, HIBS system uses Advanced Antenna System (AAS).

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FIGURE A2.2.1.2

HIBS antenna pattern for 1st layer cell (2×2 elements)

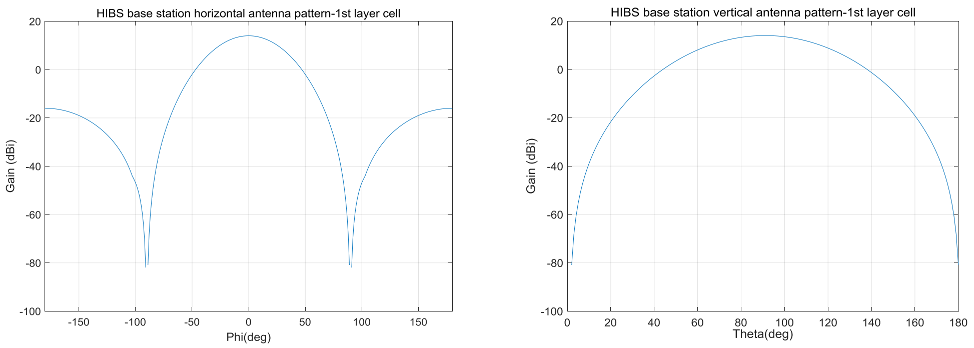
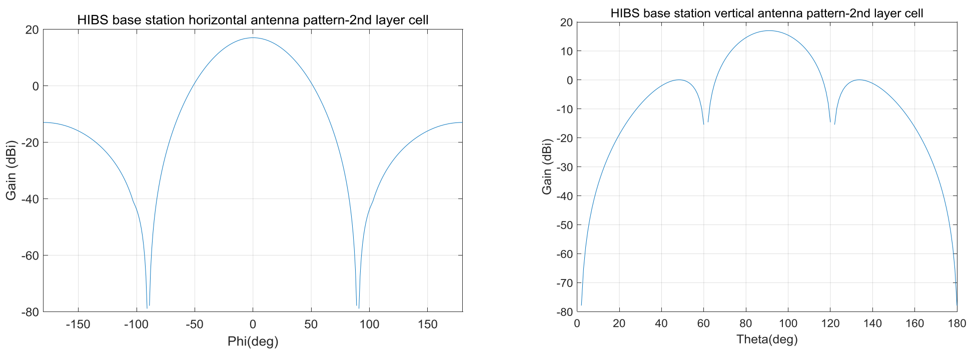


FIGURE A2.2.1.3

HIBS antenna pattern for 2nd layer cell (4×2 elements)



A2.2.1.4.2 Propagation loss

The Cumulative Distribution Function of propagation loss between HIBS base station and HIBS UE is shown in Figure A2.2.1.4, where HIBS UEs are randomly distributed in the coverage area. The simulations were done with 700 snapshots.

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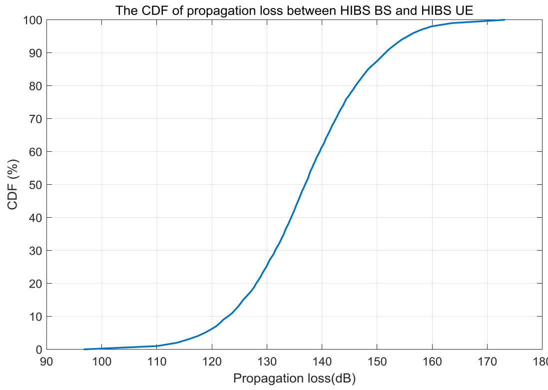
FIGURE A1.2.1.4

The CDF of propagation loss in urban areas



A2.2.1.4.3 HIBS interference

A2.2.1.5 Summary and analysis of the results of Study A

[*Editor's note: This section provides the summary and analysis of the results of this study.*]

A2.3 Sharing studies between fixed service and HIBS operating in the 1 710-1 885 MHz frequency range

See Section A3.3.

A2.4 Sharing studies between space research service (Earth-to-space) and space operation service (Earth-to-space) in the 1 750-1 850 MHz band and HIBS operating in the 1 710-1 885 MHz frequency range

The frequency band 1 750-1 850 MHz is allocated to the space operation (Earth-to-space) and space research (Earth-to-space) services in Region 2 (except in Mexico), in Australia, Guam, India, Indonesia and Japan on a primary basis, subject to agreement obtained under RR No. **9.21**, having particular regard to troposcatter systems, as identified under RR No. **5.386**.

[As shown in the Appendix, since the interference level from HIBS to space stations is much lower than that from ground-based IMT base stations, any HIBS specific mitigation measures to protect the space stations would not be necessary.]

A2.5 Sharing studies between aeronautical mobile service and HIBS operating in the 1 780-1 850 MHz frequency range

A2.5.1 Study A

This study is for interference from a high-altitude platform station as IMT base station (HIBS) to aeronautical mobile service stations operating in 1 780-1 850 MHz frequency range.

A2.5.1.1 Technical and operational characteristics of HIBS operating in the 1 710-1 850 MHz frequency band

The technical and operational characteristics of a high-altitude platform station as IMT base station (HIBS) are based on the working documents towards a preliminary draft new Report ITU-R

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M.[HIBS-CHARACTERISTICS] (Annex 4.19 of 5D/716) and summarized in this section. The following Table A2.5.1.1 provides the HIBS frequency arrangements in 1 710-1 850 MHz band. The interference from HIBS will be calculated for the analysis.

TABLE A2.5.1.1

HIBS Frequency arrangements in 1 710-1 850 MHz band

No.	Frequency band		Duplex mode
	Mobile station transmitter	Base station transmitter	
	(MHz)	(MHz)	
B2	1 710-1 785	1 805-1 880	FDD
B4	1 710-1 785	1 805-1 880	FDD

The deployment related parameters for HIBS for use in sharing studies are given in following Table A2.5.1.2.

TABLE A2.5.1.2

Deployment related parameters in 1 710-1 850 MHz frequency band

Parameter	Band 2
	(1 710-1 980 MHz)
Network topology and characteristics	
BS density or ISD	1 BS/HIBS area
HIBS area radius	100 km
HIBS Network Configuration	FDD
Base station characteristics/Cell Structure	
HIBS Platform Altitude	20-50 km
Number of cells/HIBS	7
Frequency reuse	1
HIBS Platform Antenna pattern	Recommendation ITU-R M.2101
Element gain	8 dBi
Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V
Horizontal/vertical front-to-back ratio	30 dB for both H/V
Antenna polarization	Linear/±45 degrees
Antenna array configuration (Row × Column)	2 x 2 elements (1st layer cell),
	4 x 2 elements per cell (2nd layer cell)

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Parameter	Band 2 (1 710-1 980 MHz)
Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
Ohmic losses	2 dB
Channel Bandwidth	20 MHz
HIBS Platform Antenna tilt	90º (1st layer cell), 23º (2nd layer cell)
HIBS Conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
HIBS Platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)
HIBS Platform e.i.r.p. Spectral Density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)
UE characteristics	
UE density for equipment that are transmitting simultaneously	3 UEs per cell
UE height	1.5 m
Body loss	4 dB
Typical antenna gain for UE	-3 dBi
Transmit power control model	Refer to Recommendation ITU-R M.2101
Maximum UE transmitter output power	23 dBm

A2.5.1.2 Technical and operational characteristics of aeronautical mobile services (AMS) operating in the 1 780-1 850 MHz frequency band

Data links operating in the aeronautical mobile service includes transmission from and to, either aircraft stations or a ground terminal considered as an aeronautical station. These transmissions could use bidirectional air-to-ground links. Table 3 below provides the typical technical characteristics of representative systems operating in aeronautical mobile service in the frequency range 1 780-1 850 MHz. WP 5B has finalized the characteristics for AMS systems in frequency bands of 1 780-1 850 MHz which are provided in Chairman's report (Annex 23 of 5D/355). The system characteristics for 3 AMS systems to be used for sharing studies are given in below Table A2.5.1.3.

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TABLE A2.5.1.3

Typical technical characteristics of representative systems operating in aeronautical mobile service in the frequency range 1 780-1 850 MHz

Parameter	Units	System 1 Airborne	System 1 Ground			System 2 Airborne		System 2 Ground		System 3 Airborne	System 3 Ground	
Tuning range	MHz	1 780-1 850	1 780-1 850			1 780-1 850		1 780-1 850		1 780-1 850	1 780-1 850	
IF Selectivity (3 dB)	MHz	6	6			0.2		0.2		1	1	
Noise figure	dB	3.5	3			2.5		2.5		3	3	
Antenna type		Omni-directional	Omni-directional	Directional		Omni-directional	Directional	Omni-directional	Directional	Omni-directional	Omni-directional	Omni-directional
Antenna gain	dBi	3	6	19	31	3.5	16	3	30	3	3	13
1st sidelobe	dBi	Not applicable	Not applicable	6	11	Not applicable	9	Not applicable	17	Not applicable	Not applicable	6
Antenna pattern		Omni	Omni	Rec ITU-R M.1851 Uniform distribution	Rec ITU-R M.1851 Uniform distribution	Omni	Rec ITU-R M.1851 Uniform distribution	Omni	Rec ITU-R M.1851 Uniform distribution	Omni	Omni	Biconical dipole (Rec. ITU-R F.1336)
Horizontal beamwidth	Degrees	360	360	16	3.3	360	33	360	4.4	360	360	360
Vertical beamwidth	Degrees	90	90	16	3.3	35	33	40	4.4	180	180	10
Antenna height	Meters	20 000	10	10	10	20 000	20 000	10	10	15 000	10	10
I/N protection criteria	dB	−6	−6	−6	−6	−6	−6	−6	−6	−6	−6	−6

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A2.5.1.3 Propagation model

Recommendation ITU-R P.1409, indicates that Recommendation ITU-R P.528 should be used for studies of frequency sharing between high-altitude platform networks and other aeronautical stations.

A2.5.1.4 Methodology

The following Figures A2.5.1.1 and A2.5.1.2 show the interference scenarios from a high-altitude platform station as IMT base station (HIBS) to AMS stations. Figure A2.5.1.1 represent the scenario in which HIBS interfere the aircraft terminal and aeronautical station on ground. The second scenario is when aircraft to aircraft are communicating, and interference affects the receivers of aircraft stations being used for aeronautical mobile services.

FIGURE A2.5.1.1

Interference from a high-altitude platform station as IMT base station (HIBS) to aircraft station and aeronautical station

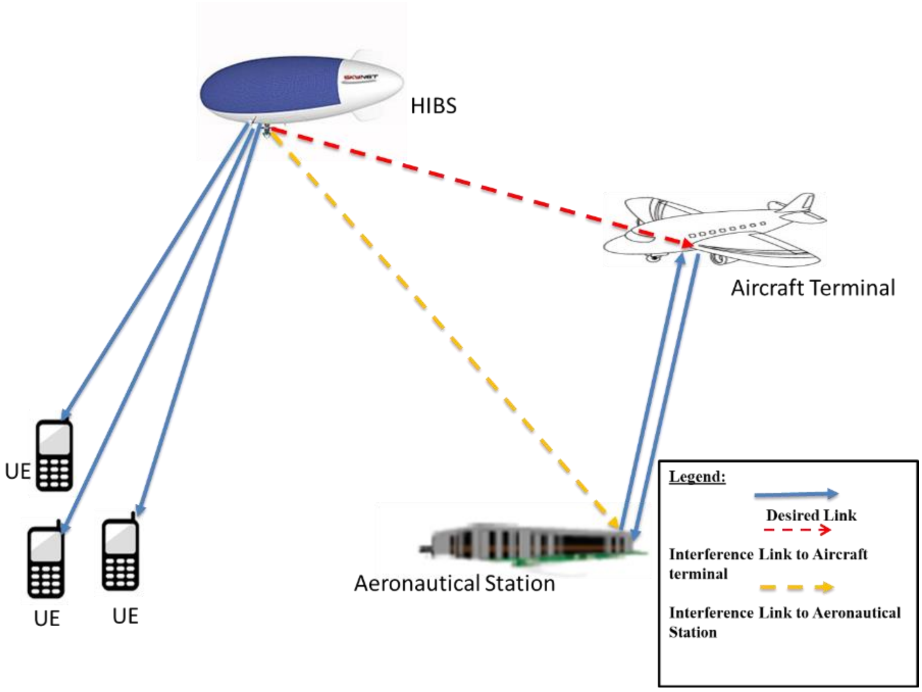

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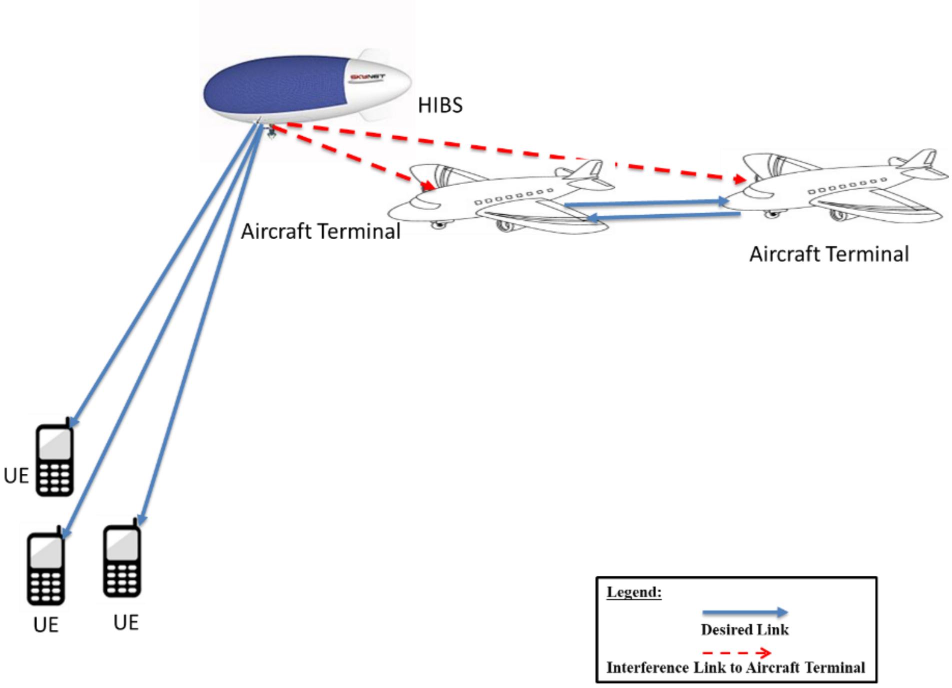
FIGURE A2.5.1.2

Interference from a high-altitude platform station as IMT base station (HIBS) to aircraft stations



[*Editor's Note: Further details for methodology will be added later on.*]

A2.5.1.5 Scenarios and results of the study

[*TBD*]

A2.5.1.6 Summary and analysis of the results of Study A

[*TBD*]

A2.6 Compatibility studies between meteorological satellite service in the adjacent 1 670-1 710 MHz frequency band and HIBS operating in the 1 710-1 885 MHz frequency range

As HIBS are intended to be used as a part of, and complement to, terrestrial IMT networks, they will use the same frequency bands as ground-based IMT base stations. Since *resolves* 1 of Resolution **223 (Rev.WRC-19)** invites administration for implementation of IMT above 1 GHz to consider "the benefits of harmonized utilization of the spectrum for the terrestrial component of IMT, taking into account the services to which the frequency band is currently allocated", it would be expected that administrations who deploy HIBS in 1 710-1 885 MHz are likely to employ the same band plans (i.e. Recommendation ITU-R M.1036) as those used by ground-based IMT networks. Furthermore, section 5 of Recommendation ITU-R M.1036 provides only the uplink directions of frequency arrangements based on FDD duplex mode in the frequency band 1 710-1 785 MHz.

It should also be noted that development of new frequency arrangements would be outside the scope of WRC-23 agenda item 1.4 based on *invites WRC-23* of Resolution **247 (WRC-19)** so as to avoid any technical and operational changes to existing IMT identifications.

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Based on the above considerations, HIBS would only use the frequency band 1 710-1 785 MHz in the uplink direction. As a HIBS base station will not transmit in the band adjacent to meteorological satellite (MetSat) operations in 1 670-1 710 MHz band, it could be considered that interference is unlikely to be from HIBS in the uplink direction to MetSat Earth stations operating in adjacent frequency band. However, it is noted that the limitation of HIBS in the uplink direction is not based on regulatory conditions but only on Recommendation ITU-R M.1036. It would be valuable to consider regulatory matters on how such uplink limitation could be ensured or on how MetSat protection in the 1 670-1 710 MHz band would be ensured if the 1 710-1 785 MHz band in the future will be proposed for usage by HIBS in the downlink direction or for TDD duplex mode.

[*Editor's note: It would be valuable to provide in this section elements of understanding on how protection of MetSat in the 1 670-1 710 MHz would be ensured from technical point of view.*]

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ANNEX 3

Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

A3.1 Sharing studies between land mobile service excluding IMT and HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

The applications of the land mobile service in the 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges include digital dispatch systems in the 1 850-1 910/1 930-1 990 MHz and 1 920-1 980/2 110-2 170 MHz frequency bands. Currently, HIBS may use the bands 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz as per RR No. **5.388A**, and in accordance with Resolution **221 (Rev.WRC-07)**, which does not include any additional regulatory or technical measures in relation to the land mobile service.

A3.2 Sharing studies between the ground component of IMT and HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

A3.2.1 Study A

A3.2.1.1 Technical characteristics

[*Editor's note: This section provides the specific parameters used in the included study/studies.*]

A3.2.1.1.1 Technical and operational characteristics of HIBS systems operating in the frequency band 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz

This section provides the characteristics of HIBS systems, according to the PDNR ITU-R M.[HIBS-CHARACTERISTICS] (Annex 4.19 to Working Party 5D Chairman's Report, Doc. 5D/716). Table A3.2.1.1 provides the specification-related parameters to be used in this analysis for HIBS.

TABLE A3.2.1.1

Specification related parameters of HIBS (Base Station)

No.	Parameter	Band 2 (1 710-1 980 MHz 2 010-2 025 MHz 2 110-2 170 MHz)
1	Duplex Method	FDD
2	Channel bandwidth (MHz)	20 MHz
3	Signal bandwidth (MHz)	18 MHz
4	Power dynamic range (dB)	0 dB conducted BS output power
5	Spurious emissions	−13 dBm/ MHz

Table A3.2.1.2 shows deployment-related HIBS parameters for this analysis.

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TABLE A3.2.1.2

Deployment related parameters of HIBS and the UE associated to HIBS

No.	Parameter	Band 2 (1 710-1 980 MHz 2 010-2 025 MHz 2 110-2 170 MHz)
1	**Network topology and characteristics**	
1.1	BS density or ISD	1 BS/HIBS area
1.2	HIBS area radius	100 km
1.3	HIBS Network Configuration (Duplex Mode)(1)	FDD
2	**Base station characteristics/Cell Structure**	
2.1	HIBS Platform Altitude	20 km
2.2	Number of cells/HIBS	7
2.3	Frequency reuse	1
2.5	HIBS Platform Antenna pattern	Recommendation ITU-R M.2101
	Element gain	8 dBi
	Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V
	Horizontal/vertical front-to-back ratio	30 dB for both H/V
	Antenna polarization	Linear/±45 degrees
	Antenna array configuration (Row × Column)	2 × 2 elements (1st layer cell), 4 × 2 elements per cell (2nd layer cell)
	Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
	Ohmic losses	2 dB
2.6	HIBS Platform Antenna tilt	90º (1st layer cell), 23º (2nd layer cell)
2.7	HIBS Conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
2.8	HIBS Platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)
2.9	HIBS Platform e.i.r.p. Spectral Density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)
3	**UE characteristics**	
3.1	UE density for equipment that are transmitting simultaneously	3 UEs per cell
3.2	UE height	1.5 m
3.3	Body loss	4 dB
3.4	Typical antenna gain for UE	−3 dBi
3.5	Transmit power control model	Refer to Recommendation ITU-R M.2101
3.6	Maximum UE transmitter output power	23 dBm

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A3.2.1.1.2 Technical and operational characteristics of the ground component of IMT operating in the frequency band 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz

This section provides the characteristics of IMT systems, according to *the Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23* (Annex 4.4 to Working Party 5D Chairman's Report, 5D/716).

Tables A3.2.1.3 and A3.2.1.4 provide the deployment-related parameters of IMT systems for the frequency bands between 1 and 3 GHz. AAS is implementable in IMT base stations in the frequency bands above about 1 710 MHz, and for these bands both AAS and antenna characteristics in Recommendation ITU-R F.1336 are considered for IMT base stations. Implementation of AAS is not considered in IMT user equipment / mobile stations.

Antenna characteristics for AAS base stations (for frequency bands above 1 710 MHz) are provided in Annex 4.4 to Working Party 5D Chairman's Report.

TABLE A3.2.1.3

BS Deployment-related parameters for bands between 1 and 3 GHz

	Rural macro	**Urban/suburban macro**
Cell radius / Deployment density (for bands between 1 and 2 GHz) (Report ITU-R M.2292)	5 km	urban macro 0.5 km suburban macro 1 km
Cell radius / Deployment density (for bands between 2 and 3 GHz) (Report ITU-R M.2292)	4 km	urban macro 0.4 km suburban macro 0.8 km
Antenna height (Report ITU-R M.2292)	30 m	25 m urban / 30 m suburban (1-2 GHz) 20 m urban / 25 m suburban (2-3 GHz)
Sectorization	3 sectors	3 sectors
Frequency reuse	1	1
Below rooftop base station antenna deployment (Report ITU-R M.2292)	0%	Urban: 30% (1-2 GHz), 50% (2-3 GHz) Suburban: 0%
Typical channel bandwidth	10 or 20 MHz	10 or 20 MHz
Network loading factor (base station load probability X%) (see section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6)	50%	50%
TDD / FDD	FDD	FDD

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TABLE A3.2.1.4

UE parameters for bands between 1 and 3 GHz

	Rural macro	**Urban/suburban macro**
User terminal characteristics		
Indoor user terminal usage (Report ITU-R M.2292)	50%	70%
Indoor user terminal penetration loss	Rec. ITU-R P.2109	Rec. ITU-R P.2109
User equipment density for terminals that are transmitting simultaneously	3 UEs per sector	3 UEs per sector
UE height	1.5 m	1.5 m
Average user terminal output power	Use transmit power control	Use transmit power control
Typical antenna gain for user terminals	−3 dBi	−3 dBi
Body loss	4 dB	4 dB
UE TDD activity factor	25%	25%
Transmit power control		
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1	
Maximum user terminal output power, PCMAX	23 dBm	23 dBm
Power (dBm) target value per RB, P0_PUSCH	−92.2	−92.2
Path loss compensation factor, α (same as "balancing factor" mentioned in Rec. ITU-R M.2101)	0.8	0.8

Table A3.2.1.5 provides the protection criterion for IMT systems (irrespective of the number of cells and independent of the number of interferers). This criterion has been developed without considering any percentage of time related to it.

TABLE A3.2.1.5

Protection criterion for IMT

Protection criterion (I/N)	−6 dB

A3.2.1.2 Propagation models for sharing and compatibility studies in the frequency band 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz

According to the liaison statement from ITU-R SG 3 (Doc. 5D/723), Recommendation ITU-R P.528-4 is used to model the basic transmission loss between HIBS BS and UEs in the ground. In urban and suburban scenarios, according to the liaison statement 5D/723, Document 3K/178 (Annex 6 to Working Party 3K Chairman's report) is used to calculate clutter loss. When the user equipment of the ground component of IMT system is indoors, building entry loss shall be considered according to Recommendation ITU-R P.2109-1.

A3.2.1.3 Methodology

This section describes the methodology of modelling HIBS BS interference into IMT UE. Main steps of the simulation are as follows:

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Step 1: Determine evaluation area and the deployment of HIBS and the ground component of IMT system.

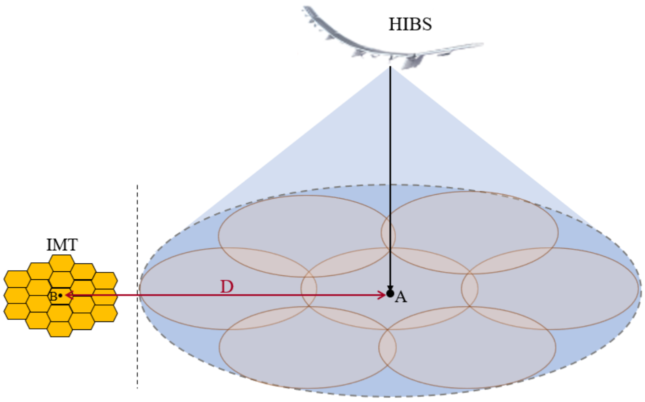
Step 1.1: Determine evaluation area.

According to the PDNR ITU-R M.[HIBS CHARACTERISTICS], the potential usage scenarios for HIBS are coverage enhancement for rural and remote areas, safety and security, internet of things, and event services. To cover all kinds of border areas, the deployment scenarios for the ground component of IMT system are assumed to contain urban, suburban and rural areas.

The coexistence scenario for HIBS and IMT system is shown in Figure A3.2.1.1. In this figure, point A represents the subpoint of HIBS base station, point B represents the centre cell of the IMT system, the letter D represents the distance between point A and point B. HIBS and the ground component of IMT system are assumed to be deployed in different areas.

FIGURE A3.2.1.1

Coexistence scenario of HIBS and the ground component of IMT system



Step 1.2: Determine the deployment of HIBS and the ground component of IMT system.

The HIBS base stations is assumed to be deployed at the altitude of 20 km, with the structure of 7 cells. The IMT system is composed of 19 cells, with the structure of 3 sectors per cell. HIBS system and the ground component of IMT system are assumed to use the same frequency band to transmit or receive, in the FDD duplex mode.

Step 2: Calculate aggregate interference from HIBS system.

Step 2.1: Calculate the interference from HIBS BS sector to each IMT UE.

In HIBS downlink transmission, the interference power from HIBS BS sector to IMT UE could be calculated by equation (1) as below:

$$I_n = P_{tx} + G_{tx} - PL + G_{rx} \quad (1)$$

where:

I_n: interference power from the n-th HIBS base station sector to the IMT UE, dBm/20 MHz;

P_{tx} : HIBS base station transmit power in the reference bandwidth , dBm/20 MHz;

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G_{tx}: The antenna gain of HIBS base station sector in direction of the IMT UE, dBi;

PL: propagation loss including free space transmission loss, atmospheric attenuation and clutter loss as appropriate, dB;

G_{rx}: the maximum antenna gain of the IMT UE, dBi.

Step 2.2: Calculate aggregate interference from HIBS BS.

The aggregate interference is calculated by equation (2) as follows.

$$I_{total} = 10\log\left(\sum_{n=1}^{n=N} 10^{I_n/10}\right) \quad (2)$$

where:

I_{total}: received aggregate interference for the IMT UE, dBm/20 MHz;

n: index of the HIBS BS sectors

I_n: received interference power from the n-th HIBS BS sector to the IMT UE (dBm/20 MHz);

N: the total number of HIBS BS sectors.

Step 3: Compare the defined I/N protection criterion and analyse the simulation results.

A3.2.1.4 Study results

A3.2.1.4.1 HIBS antenna patterns

The antenna patterns for HIBS base station are shown in following figures, in accordance with Recommendation ITU-R M.2101. In the frequency band 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz, HIBS system uses Advanced Antenna System (AAS).

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FIGURE A A3.2.1.2

HIBS antenna pattern for 1st layer cell (2 × 2 elements)

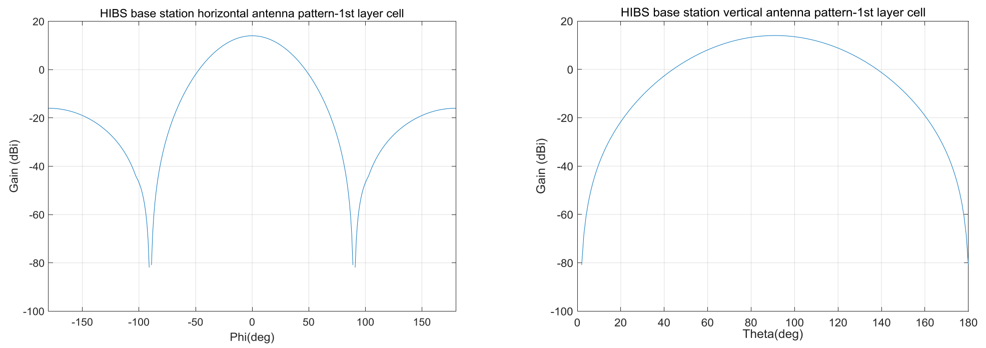
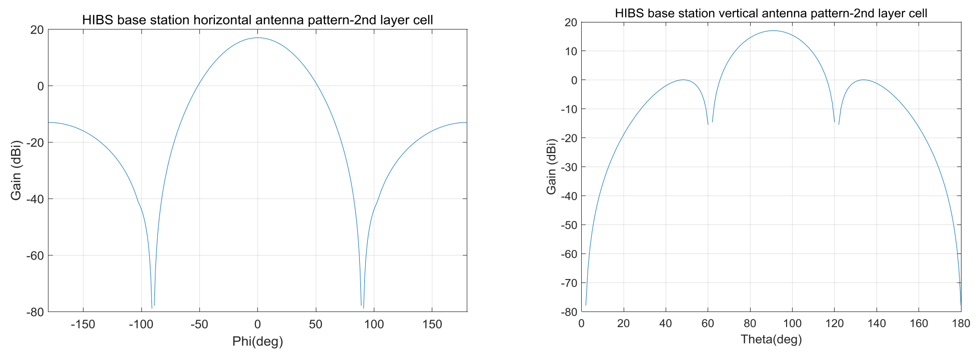


FIGURE A3.2.1.3

HIBS antenna pattern for 2nd layer cell (4 × 2 elements)



A3.2.1.4.2 Propagation loss

The Cumulative Distribution Function of propagation loss between HIBS base station and HIBS UE is shown in Figure A3.2.1.4, where HIBS UEs are randomly distributed in the coverage area. The simulations were done with 700 snapshots.

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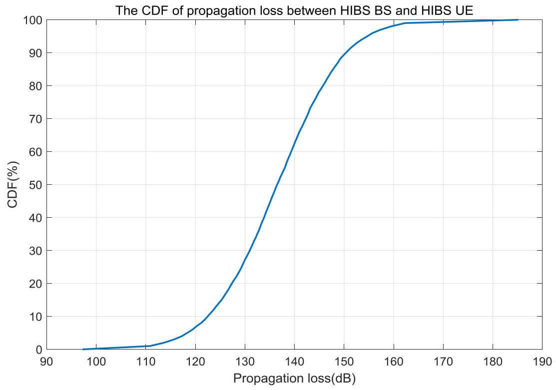
FIGURE A3.2.1.4

The CDF of propagation loss in urban areas



A3.2.1.4.3 HIBS interference

A3.2.1.5 Summary and analysis of the results of Study A

[*Editor's note: This section provides the summary and analysis of the results of this study.*]

A3.3 Sharing studies between fixed service and HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

A3.3.1 Study A

A3.3.1.1 Technical and operational characteristics of HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz frequency ranges

The technical and operational characteristics of HIBS are those for Band 2 from the working document towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS], including Table 2, Table 2-A, Table 3, and Table 5. It should be emphasized that the analysis is needed only with the HIBS (BS), as the user equipment is the same as the IMT ground-based network.

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FIGURE A3.3.1.1

HIBS antenna pointing and network topology

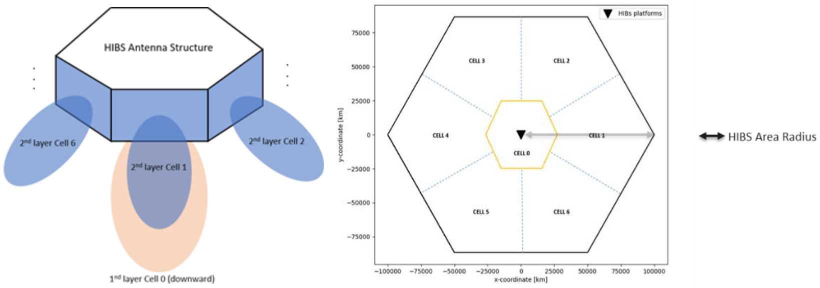
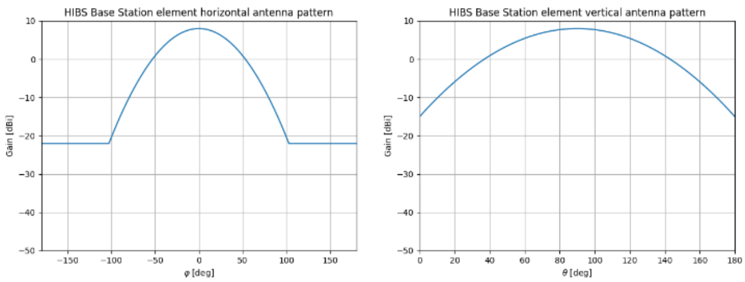
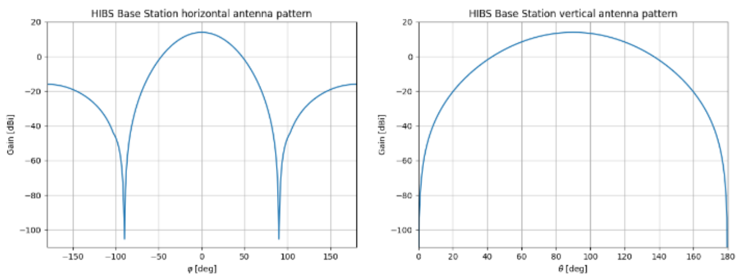


FIGURE A3.3.1.2

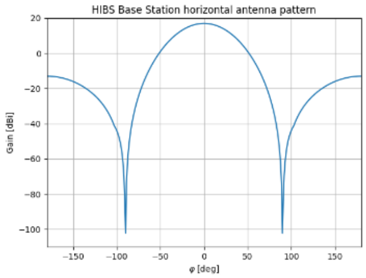
HIBS antenna pattern (Recommendation ITU-R M.2101)
(a) Single element (for adjacent case)

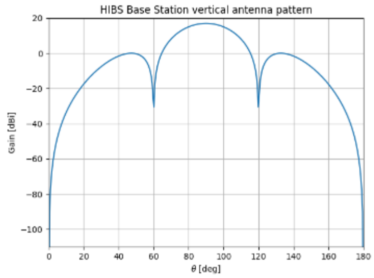


(b) 1st layer (2 × 2)



(c) 2nd layer (4 × 2)





A3.3.1.2 Technical and operational characteristics of fixed service operating in the 1 885-1980 MHz and 2 010-2 170 MHz frequency ranges

[*Editor's Note: The characteristic of the FS antenna pattern given in the table below and used in the study needs to be updated for the next meeting, taking into account Note 2 of Recommendation ITU-R F.1245, which references item 3 of the Recommendation ITU-R F.699 for antenna diameter calculation based on the maximum gain information.*]

The characteristics for the fixed service (FS) for point-to-point (PP) systems are based on the information contained in the Recommendation ITU-R F.758, Table 16, as summarized below.

TABLE A3.3.1.1

Characteristics of the FS (PP) systems

Parameter	Value
Band of operation	1 900-2 300 MHz
Reference for the band of operation	Recommendation ITU-R F.1098
Modulation format	256-QAM
Bandwidth	14 MHz
Receiver noise figure	3.5 dB
Antenna height	30 m
Antenna pattern	Recommendation ITU-R F.1245
Antenna gain	35 dBi
Antenna beamwidth	2.58^0
Diameter of the antenna	4 m
Protection criteria (I/N)	−6 dB

For FS (PP), in cases of analysis consisting of many interference entries, as it is the case with the HIBS multiple cells, using a peak envelope radiation pattern would result in aggregate interference values that are greater than values that would be experienced in practice. In this case, it is more appropriate to use an antenna pattern in accordance with Recommendation ITU-R F.1245, representing average sidelobe levels.

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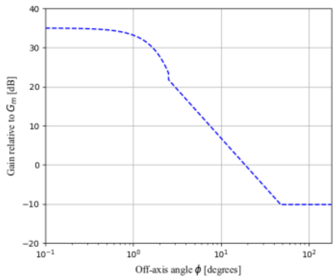
FIGURE A3.3.1.3

FS (PP) antenna pattern (Recommendation ITU-R F.1245)



A3.3.1.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at −15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. Finally, the HIBS visible horizon when deployed at 18 km and 20 km of altitude is approximately 478 km and 500 km, respectively, from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A3.3.1.4 Methodology

The SHARC open-source simulation tool is used, which is a coexistence static system-level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa. In this study the interference-to-noise ratio is calculated and compared with the protection criteria for their specific frequency range.

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A3.3.1.5 Scenarios and results of the study

The study was implemented in accordance with the scenarios described in Figure A3.3.1.4, with the FS stations positioned at different distances from the HIBS nadir, as described in Table A3.3.1.2. The simulations were done with 10 000 snapshots.

FIGURE A3.3.1.4

HIBS-FS (PP) simulation scenario

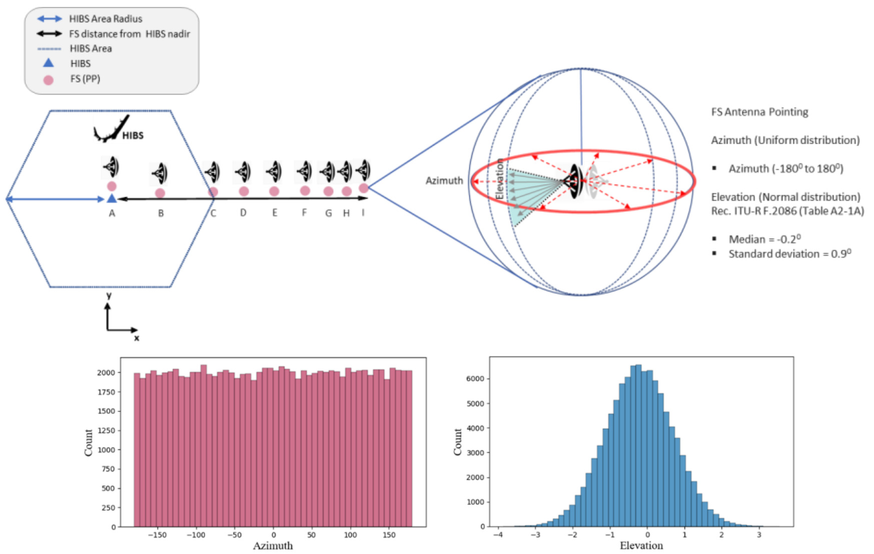

TABLE A3.3.1.2

Geographical coordinates of the FS (PP) stations in the simulation

Position	Distance from point A	Latitude	Longitude
A[(1)]	–	−15.809422°	−47.866732°
B	50 km	−15.356298°	−47.866732°
C	100 km	−14.901080°	−47.866732°
D	150 km	−14.458172°	−47.866732°
E	250 km	−13.560102°	−47.866732°
F	350 km	−12.660001°	−47.866732°
G	450 km	−11.760120°	−47.866732°
H	478 km	−11.510010°	−47.866732°
I	500 km	−11.310301°	−47.866732°

[(1)] HIBS nadir.

The simulation for co-channel sharing analysis was done considering both HIBS and FS (PP) central frequency at 2 017.5 MHz, as shown in Figure A3.3.1.5. For HIBS, the maximum available bandwidth of 15 MHz in this range was used. For FS (PP), the bandwidth of 14 MHz was used.

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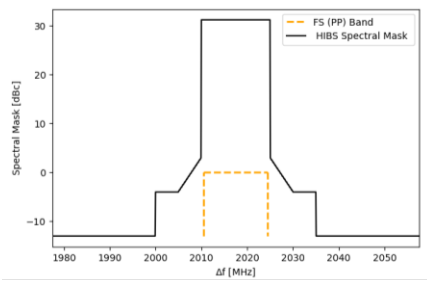
FIGURE A3.3.1.5

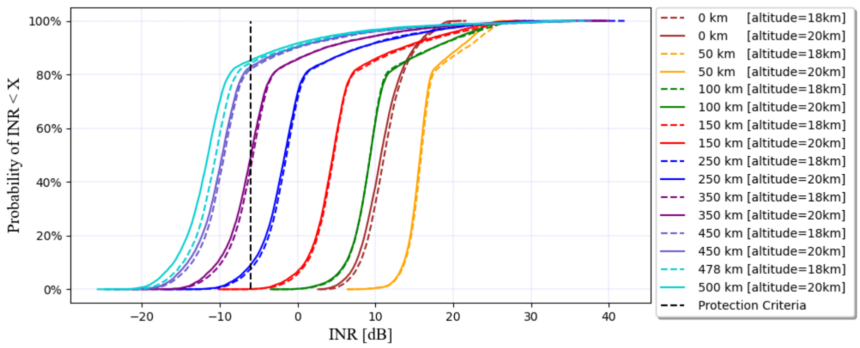
HIBS-FS (PP) co-channel analysis



The results of the simulations, as shown in Figure A3.3.1.6, indicates the probability of the achieved protection criteria (*I/N*) for each of the distances described above. At each snapshot, the FS (PP) station elevation angle varied following a normal distribution with a median of −0.2º and standard deviation of 0.9º, according to the Recommendation ITU-R F.2086 (Table A2-1A), and the azimuth varied from −180º to 180º in a uniform distribution. Furthermore, a sensitivity analysis was performed considering HIBS at an altitude of 18 km.

FIGURE A3.3.1.6

HIBS-FS (PP) co-channel simulation results



In case no additional measures are implemented for the HIBS station, the results show that the achieved *I/N* will not meet the FS (PP) protection criteria of -6 dB. It should be noted that, for this frequency range, Resolution **221 (Rev.WRC-07)** currently defines values of power flux-density (pfd) at the Earth's surface for the operation of the HIBS stations in order to protect the FS systems.

As such, an analysis was done to verify what the appropriate pfd values for the HIBS station would be to protect the FS systems, in calculating pfd levels as the following:

$$Thermal\ noise_{(\text{dBm/MHz})} = 10 \times \log\left(Boltzmann\ constant\ \times Receiver\ Noise\ figure_{Kelvin} \times 1000\right) + 10 \times \log(Bandwidth)$$

$$INR_{(dB)} = Interference\ level_{dBm} - Thermal\ noise_{dBm}$$

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$$PFD_{dB(\mathrm{m}/(m^2*\mathrm{MHz}))} = 10 \times log\left(\frac{10^{\frac{Interference\ level_{dBm}}{10}}}{Effective\ area \times 10^{\frac{G_\theta}{10}} \times Bandwidth}\right)$$

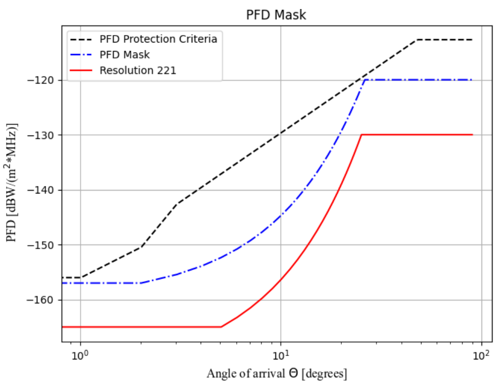
$$PFD_{dB(\mathrm{W}/(m^2*\mathrm{MHz}))} = PFD_{dB(\mathrm{m}/(m^2*\mathrm{MHz}))} - 10 \times log(1000)$$

Where G_θ = antenna gain at each angle of arrival.

As shown in Figure A3.3.1.7, the results indicate that while a pfd limit is still required for the HIBS station, the current values in Resolution **221 (Rev.WRC-07)** could be reviewed. As such, considering all the possible cases, it is possible to achieve the FS (PP) protection criteria (*I/N*) always lower than −6 dB when implementing the HIBS pfd mask in blue.

FIGURE A3.6.1.7

HIBS pfd mask for FS (PP) co-channel feasibility



A3.3.1.6 Summary and analysis of the results of Study A

The results of this study show that for HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz frequency ranges the sharing with FS co-channel is only feasible if additional measures are implemented for the HIBS stations. In reviewing the existing values in Resolution **221 (Rev.WRC-07)**, the results indicate that they could be updated. As such, HIBS, in order to protect fixed stations from co-channel interference, shall not exceed the following limits of a co channel power flux-density (pfd) at the Earth's surface:

– −157 dB(W/(m^2 · MHz)) for angles of arrival (θ) less than 2° above the horizontal plane;

– −157 + 1.55 (θ − 2) dB(W/(m^2 · MHz)) for angles of arrival between 2° and 25° above the horizontal plane; and

– −120 dB(W/(m^2 · MHz)) for angles of arrival between 25° and 90° above the horizontal plane.

A3.4 Sharing studies between space research service (deep space) (Earth-to-space) in the 2 110-2 120 MHz band and HIBS operating in the 2 110-2 170 MHz frequency range

Currently, HIBS may use the bands 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz as per RR No. **5.388A**, and in accordance with Resolution **221 (Rev.WRC-07)**, which does not

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include any additional regulatory or technical measures in relation to the space research service in the 2 110-2 120 MHz frequency range.

[Furthermore, as shown in the Appendix, since the interference level from HIBS to space stations is much lower than that from ground-based IMT base stations, any HIBS specific mitigation measures to protect the space stations would not be necessary.]

A3.5 Compatibility studies between mobile satellite service (space-to-Earth) in the adjacent 2 170-2 200 MHz frequency band and HIBS operating in the 2 110-2 170 MHz frequency range

A3.5.1 Study A

This study conducted the calculations of the pfd values for the protection of MSS (s-E) from HIBS based on the technical and operational characteristics of MSS (s-E) and HIBS and the comparison between those values and the existing pfd limit in *resolves* 3.2 of Resolution **221 (Rev.WRC-07)**.

A3.5.1.1 Technical and operational characteristics of HIBS in the 2 110-2 160/2 170 MHz frequency range

This study used technical and operational characteristics of HIBS in Band 2 (1 710-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges) contained in section 6.1.3 of the working document towards a PDN Report ITU-R M.[HIBS-CHARACTERISTICS]. The single element antenna pattern of Recommendation ITU-R M.2101 was used for this adjacent compatibility study. With regard to Platform Altitude, this study considers at 18 km and 20 km in order to perform the sensitivity analysis on the interference from HIBS operating at altitude below 20 km.

A3.5.1.2 Technical and operational characteristics of MSS (s-E) in the 2 160/2 170-2 200 MHz frequency range

Tables A3.5.1.1 summarized the technical and operational characteristics of MSS (s-E) for this study, which are included in Recommendation ITU-R M.1184.

TABLE A3.5.1.1

Technical and operational characteristics of MSS (s-E) in 2.1/2.2 GHz frequency bands

Parameters	Units	GSO System E	Non-GSO System F	Non-GSO System R
Frequency bands of service link	GHz	2.2	2.2	2.1
Beam carrier bandwidth	kHz	4	4	4
Maximum MES antenna discrimination towards the horizon	dBi	1	2	0
User G/T	dB(K^{-1})	−23	−24	−18

It is noted that currently there are no ITU-R Recommendations for the protection criteria for MSS (s-E) in the 2 160/2 170-2 200 MHz frequency range.

Furthermore, pfd limit for the protection of mobile earth stations (MES) in the 2 160/2 170-2 200 MHz frequency range from HIBS in the 2 100-2 160/2 170 MHz frequency range is stipulated in *resolves* 3.2 of Resolution **221 (Rev.WRC-07)** as follows.

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3.2 for the purpose of protecting mobile earth stations within the satellite component of IMT from interference, a HAPS operating as an IMT base station, shall not exceed an out-of-band pfd of −165 dB(W/(m^2 · 4 kHz)) at the Earth's surface in the bands 2 160-2 200 MHz in Region 2 and 2 170-2 200 MHz in Regions 1 and 3.

A3.5.1.3 Propagation model

Free space and depolarization loss from Recommendation ITU-R P.619 were used as the baseline propagation model based on section 2.1 of the draft revision of Recommendation ITU-R P.1409-1. Diffraction loss due to a spherical earth was also considered.

A3.5.1.4 Methodology and results of the study

In this study, the pfd values for single-entry interference from HIBS based on the technical and operational characteristics of MSS (s-E) in section A3.5.1.4.1. Then, multiple HIBS effects were calculated and added to pfd values for single-entry interference in order to find pfd values for the aggregated interference to protect MSS (s-E) in section A3.5.1.4.2. Section A3.5.1.4.2 also compared those values with the existing pfd limit in resolves 3.2 of Resolution **221 (Rev.WRC-07)**.

A3.5.1.4.1 pfd calculation for single-entry interference

The pfd calculation for single-entry interference from HIBS to protect MSS (s-E) is provided in Table A3.5.1.2. Since currently there are no ITU-R Recommendations for the protection criteria for MSS (s-E) in this frequency range as section A3.5.2.1, this study used "*I/N* = −6/−10/−12.2 dB" as the MSS protection criteria.

TABLE A3.5.1.2

Calculation results of pfd values for HIBS to protect MSS (s-E)

Parameters	**Units**	**GSO System E**			**Non-GSO System F**		
Frequency	MHz	2 170			2 170		
10log(λ^2/4π)	m^2	−28.2			−28.2		
Beam carrier bandwidth	kHz	4			4		
User G/T	dB(K^{-1})	−23			−24		
Maximum MES antenna discrimination towards the horizon	dBi	1			2		
Thermal noise	dBK	24			26		
Noise spectrum density	dBW/4 kHz	−168.6			−166.6		
MES protection criteria (*I/N*)	dB	−6	−10	−12.2	−6	−10	−12.2
Interferences level to satisfy the protection criterion	dBW/4 kHz	−174.6	−178.6	−180.8	−172.6	−176.6	−178.8
Antenna discrimination loss	dB	0			0		
Depolarization loss (See section 2.2 of Recommendation ITU-R P.619)	dB	3			3		
pfd value	dBW/m^2/4 kHz	−144.4	−148.4	−150.6	−143.4	−147.4	−149.6

Parameters	Units	NGSO System R		
Frequency	MHz	2 170		
$10\log(\lambda^2/4\pi)$	m^2	−28.2		
Beam carrier bandwidth	kHz	4		
User G/T	$dB(K^{-1})$	−18		
Maximum MES antenna discrimination towards the horizon	dBi	0		
Thermal noise	dBK	18		
Noise spectrum density	dBW/4 kHz	−174.6		
MES protection criteria (*I/N*)	dB	−6	−10	−12.2
Interferences level to satisfy the protection criterion	dBW/4 kHz	−180.6	−184.6	−186.8
Antenna discrimination loss	dB	0		
Depolarization loss (See section 2.2 of Recommendation ITU-R P.619)	dB	3		
pfd value	$dBW/m^2/4$ kHz	−149.4	−153.4	−155.6

Note to the Table
The pfd calculation formula is listed as follows:
pfd (dB(W/m²·MHz)) = Noise spectrum density (dB(W/4 kHz)) + I/N (dB) - Maximum MES antenna discrimination towards the horizon (dBi) + Antenna discrimination loss (dB) + Depolarization loss (dB) - $10\log(\lambda^2/4\pi)$.

Since the values of non-GSO system R are the most stringent as Table A3.5.1.2, those values were used for the calculations in the following sections.

A3.5.1.4.2 Analysis on the multiple HIBS effect

To analyse the multiple HIBS effect, the horizontal separation distances (worst case) to satisfy pfd value in the previous section were calculated, reflecting the interference power increment in multiple HIBS deployment scenario. This analysis was conducted based on the technical and operational characteristics of HIBS in section A3.5.1.1.

A3.5.1.4.2.1 HIBS deployments and interference scenario

Figure A3.5.1.1 shows single and twelve (12) HIBS deployments and the relative relation between HIBS and an interfered station. The horizontal separation distance D_h is defined as the distance from the nadir of the nearest HIBS (HIBS1-1) to the interfered station. When the horizontal separation distance exceeds 500 km, the elevation angle (θ) between HIBS and the interfered station becomes 0° or less, which is out of visible range. In the case of that interfered stations are deployed outside the visible area of HIBS, the interference from HIBS would be negligible due to the heavy attenuation. Therefore, this study assumed the number of multiple HIBS as twelve (12), the maximum number of HIBS deployed within the visible area of HIBS from the interfered station.

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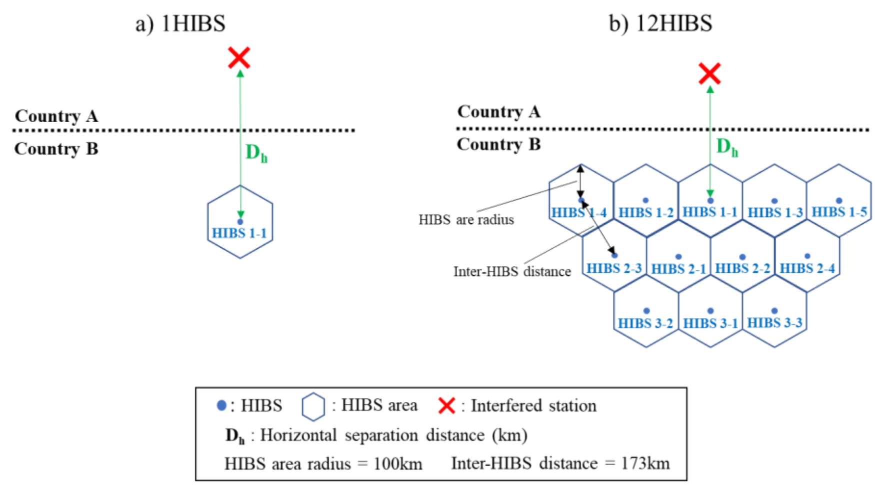
FIGURE A3.5.1.1

Relative relations between HIBS and interfered station



A3.5.1.4.2.2 Calculation method of horizontal separation distance

The separation distance *D* between HIBS and the interfered station for calculating pfd value at the receiving point is calculated by the horizontal separation distance D_h (see also Figure A3.5.1.2) as follows:

$$D = \sqrt{R^2 + (R+H)^2 - 2R(R+H)\cos(\frac{D_h}{R})} \quad \text{(km)}$$

where:

R: Earth radius = 6 378 km;

H: Platform Altitude = 18/20 km.

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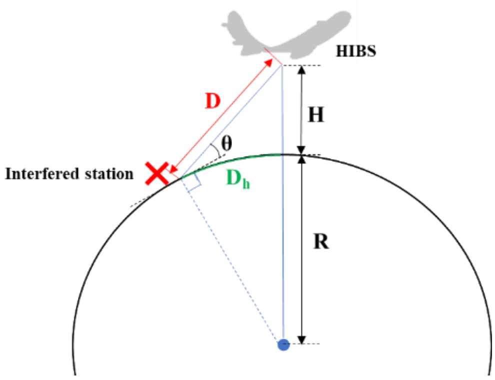
FIGURE A3.5.1.2

Separation distance from HIBS to Interfered station



A3.5.1.4.2.3 pfd calculation for aggregate interference

Aggregated pfd values (PFD_{agg}) from multiple HIBS is computed using the following equation:

$$PFD_{agg} = 10\log(\sum_m \sum_n EIRP_{m,n}/ADL_{m,n}/4\pi D_m^2) \quad (\text{dBW/m}^2\cdot\text{MHz})$$

where:

$EIRP_{m,n}$: transmit e.i.r.p of Cell_n in HIBS_m (W/MHz);

$ADL_{m,n}$: angular discrimination of Cell_n in HIBS_m;

D_m: separation distance between HIBS_m and the interfered station (m).

The calculation result of aggregated pfd values is shown in Figure A3.5.1.3.

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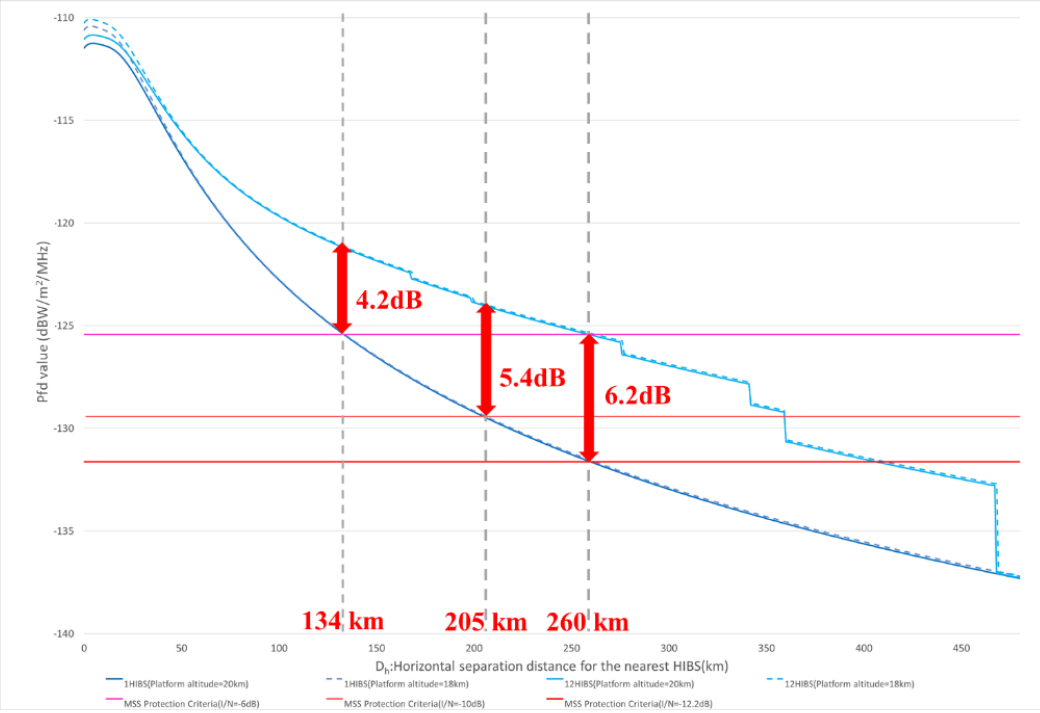
FIGURE A3.5.1.3

Calculation results of aggregated pfd values



Based on the calculation result, the horizontal separation distance D_h to satisfy pfd values of non-GSO System R in Table A3.5.1.1 were 134 km (*I/N*=−6 dB), 205 km (*I/N*=−10 dB) and 260 km (*I/N*=−12.2 dB) in the single HIBS deployment scenario with both 18 km and 20 km of HIBS platform altitude.

At those horizontal separation distances, the interference power increment relating to the increase of HIBS number (12 HIBS) were 4.2 dB (*I/N*=−6 dB), 5.4 dB (*I/N*=−10 dB) and 6.2 dB (*I/N*=−12.2 dB). It can be seen that the increment is comparatively limited since the interference from the nearest HIBS of the interfered station is dominant. In addition, although the increment rises toward far side of the horizontal separation distance, pfd value is satisfied to protect the interfered station and no interference occur in such area. Moreover, when the HIBS number is increased to more than 12, it is expected that those HIBS would not contribute the increment of aggregate interference as section A3.5.1.4.2.1 indicated. Based on the above analysis, it was considered that those values are sufficient as the aggregate effect of the multiple HIBS deployment.

The pfd values which consider the aggregate effect on the single-entry pfd values of non-GSO System R in Table A3.5.1.1 are −153.6 dBW/m^2/4 kHz (*I/N*=−6 dB), −158.8 dBW/m^2/4 kHz (*I/N*=−10 dB) and −161.8 dBW/m^2/4 kHz (*I/N*=−12.2 dB). The current pfd limits (−165 dBW/m^2/4 kHz) in *resolves* 3.2 of Resolution **221 (Rev.WRC-07)** are more stringent than all of those pfd values.

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A3.5.1.5 Summary and analysis of the results of Study A

Based on the results of study A, the pfd values of −153.6 dBW/m²/4 kHz for horizontal separation distance between HIBS and MSS earth station 134 km (*I/N*=−6 dB), −158.8 dBW/m²/4 kHz for horizontal separation distance HIBS and MSS earth station 205 km (*I/N*=−10 dB) and −161.8 dBW/m²/4 kHz for horizontal separation distance HIBS and MSS earth station 260 km (*I/N*=−12.2 dB) were derived for the protection of MSS (s-E) in the 2 160/2 170-2 200 MHz frequency range from the interference of HIBS in the 2 110-2 160/2 170 MHz frequency range. It should be noted that the shape of the country border was taken as a line and therefore aggregate affect was calculated from 12 HIBS that may be not sufficient. With understanding that MES in 2GHz has omni-directional antennas, the shape of the country border as a part of a circle could have more serious aggregate affect. On the other hand, it should also be noted that the aggregate effect may be evaluated excessively since Network loading factor of HIBS and clutter loss were not considered in this study. The current pfd limit (−165 dBW/m²/4 kHz) in *resolves* 3.2 of Resolution **221 (Rev.WRC-07)** are more stringent than all of those pfd values.

A3.6 Compatibility studies between fixed service in the adjacent 1 885-1980 MHz and 2 010-2 170 MHz frequency bands and HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz frequency ranges

A3.6.1 Study A

A3.6.1.1 Technical and operational characteristics of HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

The technical and operational characteristics of HIBS are based on the working documents towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS], and summarized in this section. It should be emphasized that the analysis is needed only with the HIBS (BS), as the user equipment is the same as the IMT ground-based network.

TABLE A3.6.1.1

Specification related parameters of HIBS (Base Station)

		HIBS (BS)
No.	**Parameter**	**Band 2** **(1 710-1 980 MHz / 2 010-2 025 MHz / 2 110-2 170 MHz)**
1	Duplex Method	FDD/TDD
2	Channel bandwidth (MHz)	20 MHz[(1)]
4	Transmitter characteristics	
4.4	Spurious emissions	-13 dBm / MHz
5	Receiver characteristics	
5.1	Noise figure	5 dB

[(1)] In the case of the 2 010-2 025 MHz range, the maximum bandwidth of 15 MHz is used.

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TABLE A3.6.1.1-A

Spectrum mask - HIBS (BS)

Frequency offset from "edge of transmission" Δ*f*	**Emission limit**	**Measurement bandwidth**
0 MHz ≤ Δf < 5 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < 10 MHz	-14 dBm	100 kHz
10 MHz ≤ Δf	-13 dBm	1 MHz

TABLE A3.6.1.2

Deployment related parameters of HIBS and the UE associated to HIBS

No.	**Parameter**	**Band 2 (1 710-1 980 MHz / 2 010-2 025 MHz / 2 110-2 170 MHz)**
1	Network topology and characteristics	
1.1	BS density or ISD	1 BS/HIBS area
1.2	HIBS area radius	100 km
2	Base station characteristics/Cell Structure	
2.1	Platform Altitude	20 km
2.2	Number of cells/HIBS	7
2.3	Frequency reuse	1
2.4	Network loading factor	100%
2.5	Platform Antenna pattern	Recommendation ITU-R M.2101
	Element gain	8 dBi
	Antenna array configuration (Row × Column)	2 x 2 elements (1st layer cell), 4 x 2 elements per cell (2nd layer cell)
2.6	Platform Antenna tilt	90º (1st layer cell), 23º (2nd layer cell)
2.7	Conducted power per antenna element	37 dBm (1st layer cell) 34 dBm (2nd layer cell)
3	UE characteristics	
3.1	UE density for equipment that are transmitting simultaneously	3 UEs per cell
3.2	UE height	1.5 m
3.3	Body loss	4 dB
3.4	Typical antenna gain for UE	-3 dBi

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FIGURE A3.6.1.1

HIBS antenna pointing and network topology

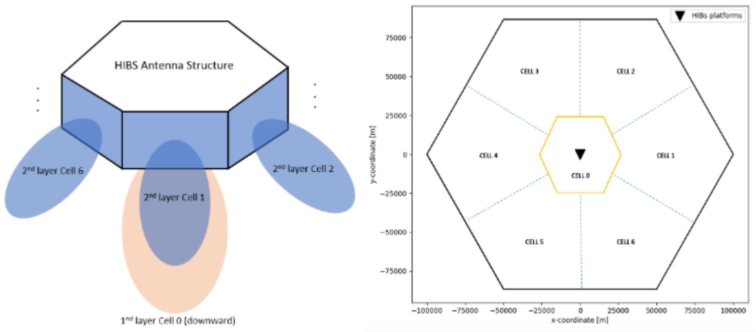
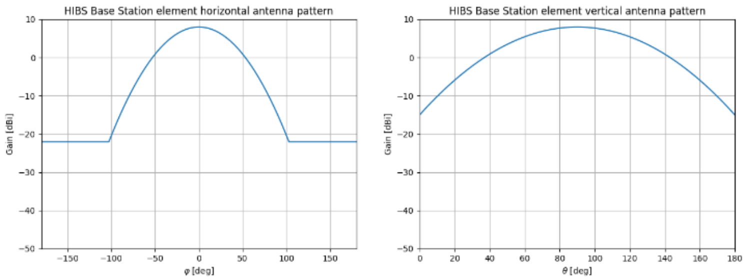


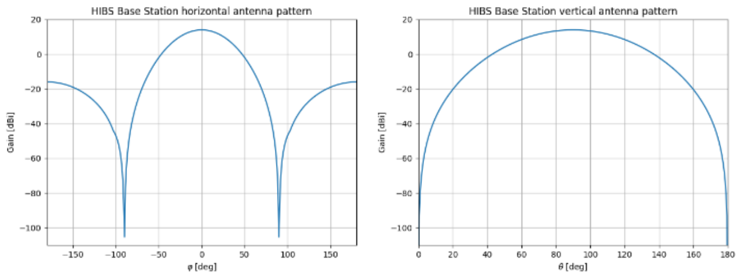
FIGURE A3.6.1.2

HIBS antenna pattern (Recommendation ITU-R M.2101)

(a) Single element (for adjacent case)



(b) 1st layer (2 x 2)



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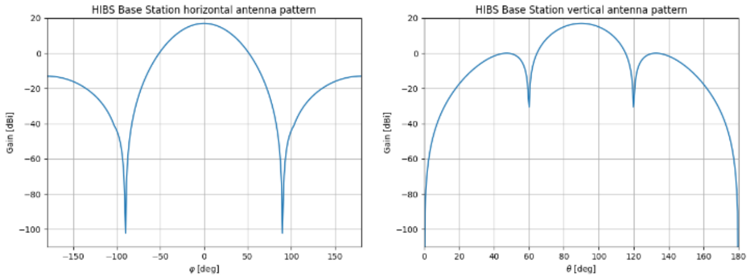
(c) 2nd layer (4 x 2)



A3.6.1.2 Technical and operational characteristics of fixed service operating in the 1 885-1980 MHz and 2 010-2 170 MHz frequency ranges

The characteristics for the fixed service (FS), for both point-to-multipoint (PMP) and point-to-point (PP) systems are based on the information contained in the Recommendation ITU-R F.758, especially those contained in its Tables 16 and 19, and summarized in this section.

TABLE A3.6.1.3

Characteristics of the FS (PMP) systems

Parameter	Value
Band of operation	1 350-2 690 MHz
Reference	Recommendation ITU-R F.701
Modulation format	QPSK
Bandwidth	3.5 MHz
Receiver noise figure	4 dB
Antenna height	30 m
Antenna pattern	Recommendation ITU-R F.1336
Antenna gain	13 dBi (omni)
Protection criteria (I/N)	-6 dB

TABLE A3.6.1.4

Characteristics of the FS (PP) systems

Parameter	Value
Band of operation	1 900-2 300 MHz
Reference	Recommendation ITU-R F.1098
Modulation format	256-QAM
Bandwidth	14 MHz
Receiver noise figure	3.5 dB
Antenna height	30 m
Antenna pattern	Recommendation ITU-R F.1245

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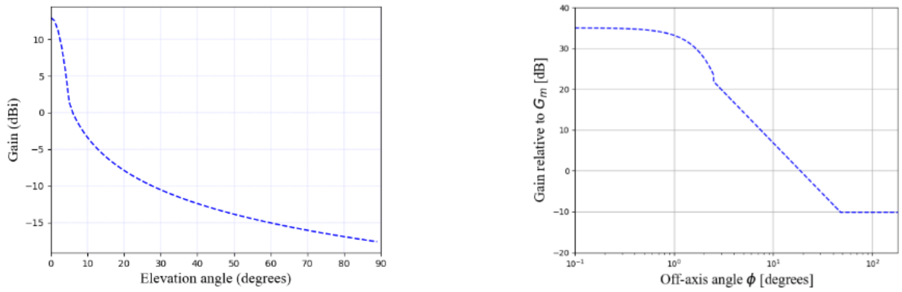
Parameter	Value
Antenna gain	35 dBi
Antenna beamwidth	2.56⁰
Diameter of the antenna	4 m
Protection criteria (I/N)	-6 dB

FIGURE A3.6.1.3

FS antenna pattern

(a) PMP (Recommendation ITU-R F.1336) **(b) PP (Recommendation ITU-R F.1245)**



For FS (PP), it should be highlighted that in cases of analysis consisting of many interference entries, as with the HIBS multiple cells, using a peak envelope radiation pattern would result in aggregate interference values that are greater than values that would be experienced in practice. In this case, it is more appropriate to use an antenna pattern in accordance with Recommendation ITU-R F.1245, representing average sidelobe levels.

A3.6.1.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at -15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. Finally, the HIBS visible horizon when deployed at 18 km and 20 km of altitude is approximately 478 km and 500 km, respectively, from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A3.6.1.4 Methodology

The Brazilian administration continues to use and develop, in cooperation with partners in the industry and academia, an open-source simulation tool, named SHARC, to support Sharing and Compatibility studies between IMT and other radio communication systems, according to the framework proposed by Recommendation ITU-R M.2101. SHARC is a coexistence static system-

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level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa. In this contribution, a FS system is considered. The interference-to-noise ratio is calculated and compared with the FS protection criteria for their specific frequency range.

A3.6.1.5 Scenarios and results of the study

The study was implemented in accordance with the scenarios described in Figures A3.6.1.4 and A3.6.1.5, with the FS stations positioned at different distances from the HIBS nadir, as described in Tables A3.6.1.5 and A3.6.1.6. For the FS (PMP) simulations, the only variance is the distance. However, for the FS (PP) case, for each distance, the elevation and azimuth of the FS antenna varied according to the statistical distributions presented in Figure A3.6.1.5. The simulations were done with 10 000 snapshots.

FIGURE A3.6.1.4

HIBS-FS (PMP) simulation scenario

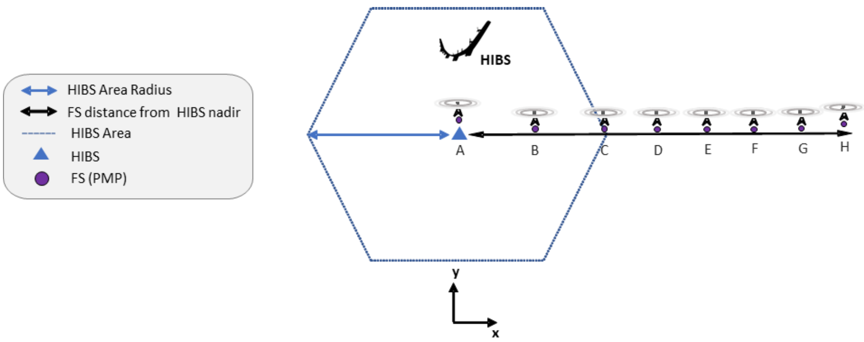

TABLE A3.6.1.5

Geographical coordinates of the FS (PMP) stations in the simulation

Position	Distance from point A	Latitude	Longitude
A(1)	-	-15.809422°	-47.866732°
B	50 km	-15.356298°	-47.866732°
C	100 km	-14.901080°	-47.866732°

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Position	Distance from point A	Latitude	Longitude
D	150 km	-14.458172°	-47.866732°
E	250 km	-13.560102°	-47.866732°
F	350 km	-12.660001°	-47.866732°
G	450 km	-11.760120°	-47.866732°
H	500 km	-11.310301°	-47.866732°

(1) HIBS nadir.

FIGURE A3.6.1.5

HIBS-FS (PP) simulation scenario

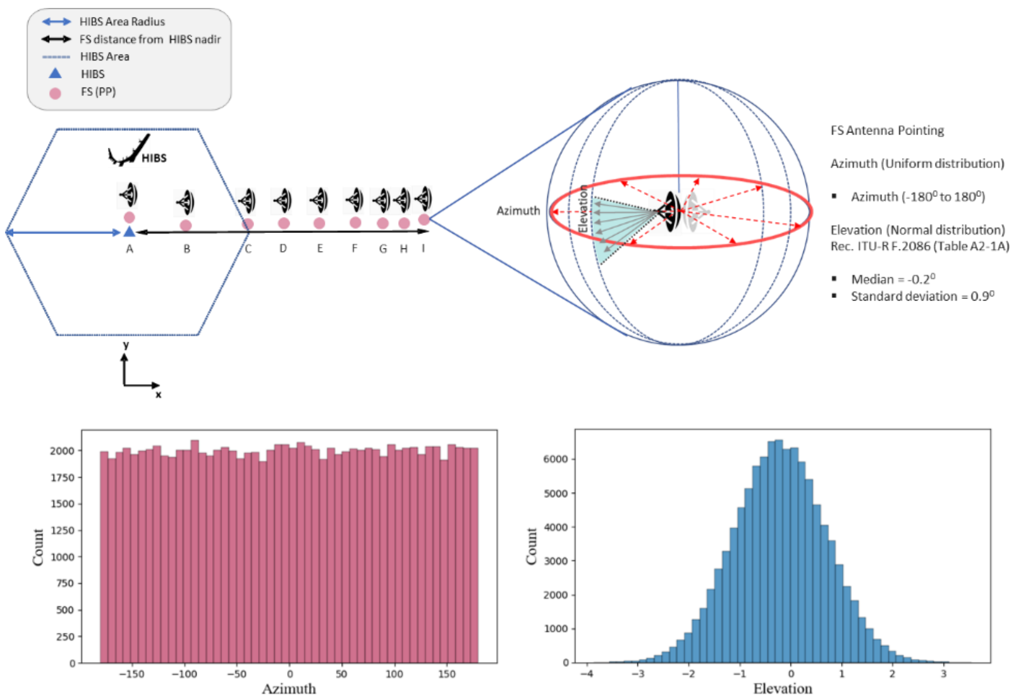

TABLE A3.6.1.6

Geographical coordinates of the FS (PP) stations in the simulation

Position	Distance from point A	Latitude	Longitude
A(1)	-	-15.809422°	-47.866732°
B	50 km	-15.356298°-	-47.866732°
C	100 km	-14.901080°	-47.866732°
D	150 km	-14.458172°	-47.866732°
E	250 km	-13.560102°	-47.866732°

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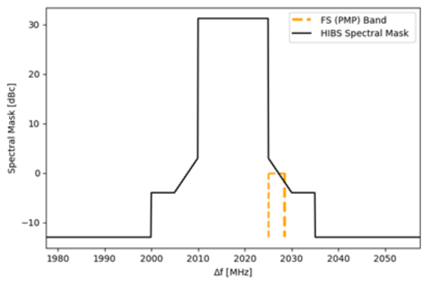
Position	Distance from point A	Latitude	Longitude
F	350 km	-12.660001°	-47.866732°
G	450 km	-11.760120°	-47.866732°
H	478 km	-11.510010°	-47.866732°
I	500 km	-11.310301°	-47.866732°

(1) HIBS nadir.

The simulations for adjacent channel compatibility analysis were done considering HIBS central frequency at 2 017.5 MHz, and FS (PMP) central frequency at 2 026.75 MHz, as shown in Figure A3.6.1.6.

FIGURE A3.6.1.6

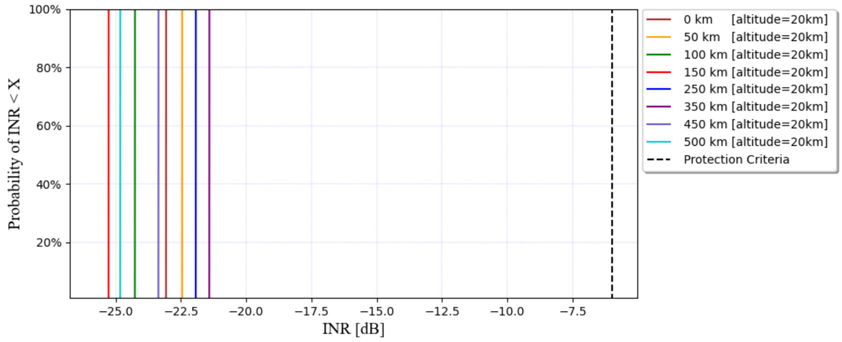
HIBS-FS (PMP) adjacent channel analysis



The results of the simulations, as shown in Figure A3.6.1.7, indicates the probability of the achieved protection criteria (*I/N*) for each of the distances described above. In all cases, the achieved *I/N* is always lower than -21 dB.

FIGURE A3.6.1.7

HIBS-FS (PMP) adjacent channel simulation results



Additionally, the simulations for adjacent channel compatibility analysis were done considering HIBS central frequency at 2 017.5 MHz, and FS (PP) central frequency at 2 032 MHz, as shown in Figure A3.6.1.8.

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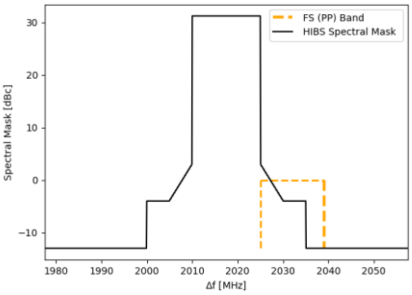
FIGURE A3.6.1.8

HIBS-FS (PP) adjacent channel analysis

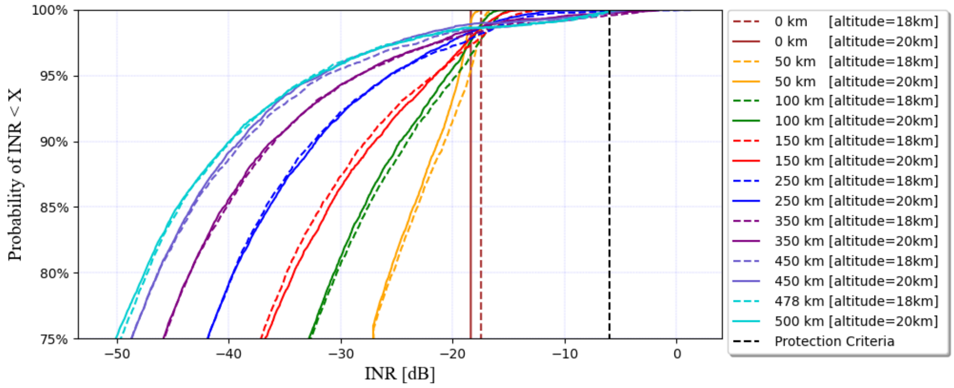


The results of the simulations are shown in Figure A3.6.1.9. At each snapshot, the FS (PP) station elevation angle varied following a normal distribution with a median of -0.2º and standard deviation of 0.9º, according to the Recommendation ITU-R F.2086 (Table A2-1A), and the azimuth varied from -180º to 180º in a uniform distribution. Furthermore, a sensitivity analysis was performed considering HIBS at an altitude of 18 km.

For all cases at nadir, the achieved *I/N* is lower than -17.5 dB. For the probability of 80% of the cases, the achieved *I/N* varies from -25.5 dB (50 km), -30.5 dB (100 km), to -47.5 dB (500 km). For the probability of 90% of the cases, the achieved *I/N* varies from -20.8 dB (50 km), -24.2 dB (100 km), to -40.5 dB (500 km). And for the probability of 95% of the cases, the achieved *I/N* varies from -18.5 dB (50 km), -19.7 dB (100 km), to -33.3 dB (500 km). Finally, considering all the possible cases, the achieved I/N is always lower than -6 dB.

FIGURE A3.6.1.9

HIBS-FS (PP) adjacent channel simulation results



A3.6.1.6 Summary and analysis of the results of Study A

The results of this study show that for HIBS operating in the 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz frequency ranges the compatibility with FS in the adjacent channel is feasible. In the case of FS (PMP), the results indicate a margin of more than 15 dB in comparison with the FS protection criteria. In the case of FS (PP), for the probability of 95% of the cases or

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lower, the results indicate a margin of at least 11 dB in comparison with the FS protection criteria, as well as that in all the possible cases the protection criteria is met. Additionally, the sensitivity analysis of varying the altitude of the HIBS platform from 20 km to 18 km has shown that the FS protection criteria continues to be met.

A3.7 Compatibility studies between space operation service (Earth-to-space) (space-to-space), Earth exploration-satellite service (Earth-to-space)(space-to-space), and space research service (Earth-to-space) (space-to-space) in the adjacent 2 025-2 110 MHz frequency band and HIBS operating in the 2 010-2 025 MHz and 2 110-2 170 MHz frequency ranges

Currently, HIBS may use the bands 1 885-1 980 MHz, 2 010-2 025 MHz, and 2 110-2 170 MHz as per RR No. **5.388A**, and in accordance with Resolution **221 (Rev.WRC-07)**, which does not include any additional regulatory or technical measures in relation to the space operation service, Earth exploration-satellite service, and space research service in the adjacent bands.

[Furthermore, as shown in the Appendix, since the interference level from HIBS to space stations is much lower than that from ground-based IMT base stations, any HIBS specific mitigation measures to protect the space stations would not be necessary.]

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ANNEX 4

Sharing and compatibility studies of high-altitude platform stations as IMT base stations (HIBS) in 2 500-2 690 MHz frequency range

A4.1 Sharing studies between the ground component of IMT and HIBS operating in the 2 500-2 690 MHz frequency range

A4.1.1 Study A

This study is for cross-border interference scenario from HIBS to ground-based IMT base station in the border of neighbouring administration. Two main factors for cross-border interference coordination are presented: i) the minimum separation distance between the HIBS nadir and the border of neighbouring administration to meet the IMT protection criterion, and ii) the amount of interference reduction required for meeting the IMT protection criterion.

A4.1.1.1 Technical characteristics

A4.1.1.1.1 Technical and operational characteristics of HIBS operating in the 2 500-2 690 MHz frequency range

The technical and operational characteristics of HIBS are based on Document 5D/716 Chapter 4 Annex 4.19 "Working documents towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS]". This study is conducted to evaluate the potential interference of the HIBS operating in the Band 3 (2 500-2 690 MHz). The HIBS user equipment are not considered as a source of interference.

Under the frequency arrangement presented in Table A4.1.1.2, TDD HIBS operating in the 2 500-2 570 MHz (2 535- 2 570 in Region 3) could interfere with a ground-based IMT base station in neighboring administrations in the FDD uplink band 2 500- 2 570 MHz (2 535- 2 570 in Region 3).

TABLE A4.1.1.1

Deployment related parameters of HIBS (Base Station)

No.	Parameter	Band 3 (2 500-2 690 MHz)
1	**Network topology and characteristics**	
1.1	BS density or ISD	1 BS/HIBS area
1.2	HIBS area radius	90 km
1.3	HIBS network configuration (Duplex Mode)	TDD(1)
2	**Base station characteristics/Cell structure**	
2.1	HIBS Platform Altitude	20 km
2.2	Number of cells/HIBS	7
2.3	Frequency reuse	1
2.4	HIBS Platform Antenna pattern	Recommendation ITU-R M.2101
	Element gain	8 dBi
	Horizontal/vertical 3 dB beamwidth of single element	65° for both H/V
	Horizontal/vertical front-to-back ratio	30 dB for both H/V

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No.	Parameter	Band 3 (2 500-2 690 MHz)
	Antenna polarization	Linear/±45 degrees
	Antenna array configuration (Row × Column)	2 × 2 elements (1st layer cell), 4 × 2 elements per cell (2nd layer cell)?
	Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
	Ohmic losses	2 dB
2.5	HIBS platform antenna tilt	90º (1st layer cell), 23º (2nd layer cell)
2.6	HIBS conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
2.7	HIBS platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)

(3) See Table A4.1.1.2 for the 2 500-2 690 MHz band for the specific Duplex mode applicable to the scenario under study, noting that the 2 500-2 535 MHz range is to be used for only uplink in Region 3, and that the 2 655-2 690 MHz range is not to be used in Region 3.

TABLE A4.1.1.2

**Possible examples of HIBS frequency arrangements in 2 500-2 690 MHz
(see also Section 7 in Recommendation ITU-R M.1036)**

No.	Frequency band		Duplex mode
	Mobile station transmitter (MHz)	Base station transmitter (MHz)	
C1	2 500-2 570	2 620-2 690	FDD
	2 570-2 620		TDD
C2	3 500-2 570 External	3 620-2 690 2 570-2 620	FDD
C3	2 500-2 690		Flexible FDD/TDD

A4.1.1.1.2 Technical and operational characteristics of the ground component of IMT operating in the 2 500-2 690 MHz frequency range

The technical and operational characteristics of the ground component of IMT are based on Document 5D/716 Chapter 4 Annex 4.4 "Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23". Tables A4.1.1.3 and A4.1.1.4 list the deployment-related and specification-related parameters of Non AAS IMT BS for the frequency bands including the 2 500-2 690 MHz. Table 3 presents the protection criterion for IMT, which is also found in the aforementioned Document.

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TABLE A4.1.1.3

IMT-2020 specification related parameters in 470-4 990 MHz

Parameter	Base station (non-AAS)
Noise figure (dB)	5 dB (Macro cell scenario) 10 dB (Micro cell scenario) 13 dB (Indoor small cell scenario)

TABLE A4.1.1.4

Deployment-related parameters for bands between 1 and 3 GHz

	Urban/suburban macro	Rural macro
Antenna height (Report ITU-R M.2292)	25 m urban / 30 m suburban (1-2 GHz) 20 m urban / 25 m suburban (2-3 GHz)	30 m
Sectorization	3 sectors	3 sectors
Non-AAS BS downtilt (Report ITU-R M.2292)	10 degrees urban / 6 degrees suburban	3 degrees
Non-AAS BS antenna pattern	Recommendation ITU-R F.1336 (*recommends* 3.1) ka = 0.7 kp = 0.7 kh = 0.7 kv = 0.3 Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. Vertical beamwidths of actual antennas may also be used when available.	
Non-AAS BS antenna polarization	Linear/±45 degrees	Linear/±45 degrees
Indoor base station deployment	n.a.	n.a.
Typical channel bandwidth	10 or 20 MHz	10 or 20 MHz
Maximum Non-AAS BS antenna gain (Report ITU-R M.2292) (Note 1)	16 dBi	18 dBi

TABLE A4.1.1.5

Protection criterion for IMT

Protection criterion (I/N)	–6 dB

A4.1.1.2 Propagation models

The propagation model used is contained in Recommendation ITU-R P.619 "Propagation data required for the evaluation of interference between stations in space and those on the surface of the Earth". The propagation loss consists of free space basic transmission loss, depolarization

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attenuation, attenuation due to atmospheric gases and beam spreading. According to a liaison statement from ITU-R Working Party 3J, 3K and 3M in Document 5D/723, Recommendation ITU-R P.1409 has been updated to include guidance to the sharing and compatibility studies of HIBS under WRC-23 agenda item 1.4. Recommendation ITU-R P.1409 indicates that Recommendation ITU-R P.619 or ITU-R P.528 should be used for the interference scenario/path between HIBS and stations on the surface of the Earth, as appropriate. Future revision may include Recommendation ITU-R P.528 “A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands” and Recommendation ITU-R P.2108 “prediction of clutter loss”.

A4.1.1.3 Methodology

A methodology for assessing the cross-border interference from HIBS to the ground-based IMT base station are presented. Two interference scenarios, single HIBS and multiple HIBSs are considered.

A4.1.1.4 Deployment Scenario

For inference assessment, two HIBS deployment scenarios are considered: a single HIBS and the HIBS networks consisting of seven HIBSs as shown in Figures A4.1.1.1 and A4.1.1.2. The single HIBS or HIBS network interferes with a ground-based IMT base station at the border of a neighbouring country. The HIBS area radius and the inter-HIBS distance is 90 km and 155.9 km, respectively. As noted in Table 4, indoor base station is not considered.

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FIGURE A4.1.1.1

Single HIBS Interference Scenario

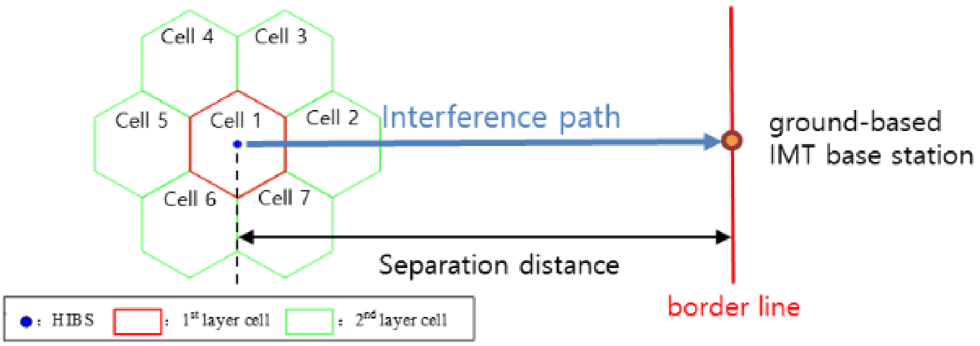
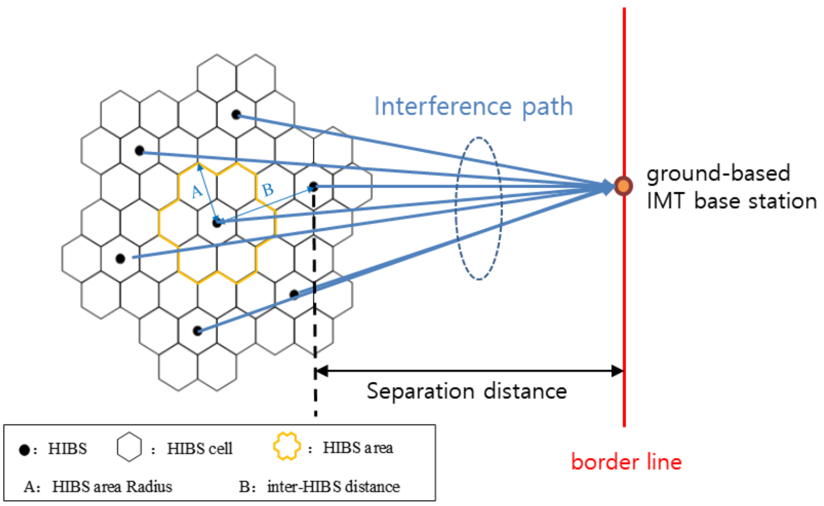


FIGURE A4.1.1.2

Multiple HIBS Interference Scenario



A4.1.1.5 Assumptions for Interference Calculation

HIBS adopts AAS with a radiation pattern defined in Recommendation ITU-R M.2101 and seven antenna-arrays, each of which conducts beamforming in a direction perpendicular to array antenna aperture; that is, fixed beams are assumed. In the single HIBS scenario, the main beam of HIBS for the cell 2 azimuthally points the ground-based IMT base station. In the multiple HIBS scenario, the main beam of the nearest HIBS for the cell 2 azimuthally points the ground-based IMT base station.

Ground-based IMT base station is not equipped with AAS, but typical three-sectoral antenna with a radiation pattern defined in Recommendation ITU-R F.1336. The ground-based IMT base station antenna azimuthally points the HIBS in the single HIBS scenario, or the nearest HIBS in the multiple HIBS scenario.

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Center frequency of HIBS and ground-based IMT base station is 2 545 MHz. The channel bandwidth of both systems is 20 MHz.

The ground-based IMT base station for macro cell is deployed in urban, suburban, or rural.

As shown in Figure 1, in the single HIBS scenario, the separation distance is defined as a distance between the HIBS nadir and the ground-based IMT base station at the border line between two different countries. In the multiple HIBS scenario, the separation distance is defined as a distance between the HIBS nadir and the ground-based IMT base station at the border line between two difference countries.

A4.1.1.6 Study results

For protection of a ground-based IMT base station receiver, Table A4.1.1.6 shows the required separation distances are from 189 km to 222 km in the single HIBS interference scenario, and from 219 km to 273 km in multiple HIBS interference scenario.

For protection of a ground-based IMT base station receiver with a separation distance from 50 km to 200 km, Table A4.1.1.7 shows the required interference reductions are from18.72 dB to 0 dB in the single HIBS interference scenario, and from 18.88 dB to 1.03 dB in multiple HIBS interference scenario.

TABLE A4.1.1.6

Minimum separation distance

Interference Scenario	Separation distance (km) between IMT BS and HIBS nadir		
	Urban macro	Suburban macro	Rural macro
Single HIBS	189	196	222
Multiple HIBS	219	231	273

TABLE A4.1.1.7

Required inference reduction at a given separation distance

Interference Scenario	Separation distance (km)	Required interference reduction (dB)		
		Urban macro	Suburban macro	Rural macro
Single HIBS	50	16.91	17.14	18.72
	100	8.99	9.35	10.98
	150	3.28	3.71	5.41
	200	-	-	1.42
Multiple HIBS	50	17.06	17.29	18.88
	100	9.54	9.92	11.57
	150	4.47	4.94	6.67
	200	1.03	1.58	3.38

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A4.1.2 Study B

A4.1.2.1 Technical and operational characteristics of HIBS operating 2 500-2 690 MHz frequency range

The technical and operational characteristics of HIBS are those for Band 3 from the working document towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS], including Table 2, Table 2-A, Table 3, and Table 5. It should be emphasized that the analysis is needed only with the HIBS (BS), as the user equipment is the same as the IMT ground-based network.

FIGURE A4.1.2.1

HIBS antenna pointing and network topology

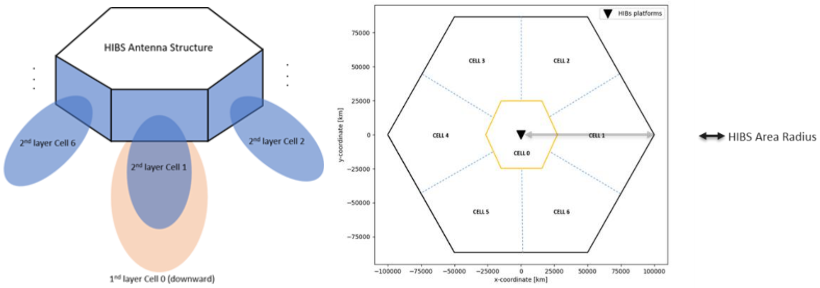
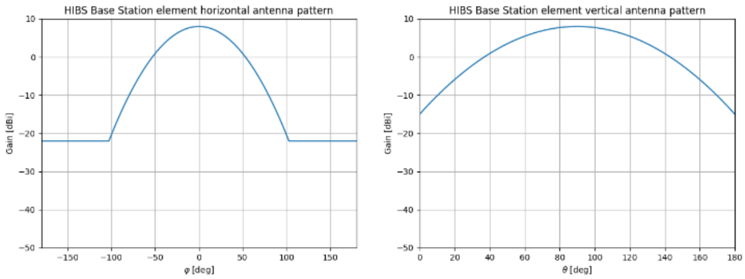


FIGURE A4.1.2.2

HIBS antenna pattern (Recommendation ITU-R M.2101)
(a) Single element (for adjacent case)



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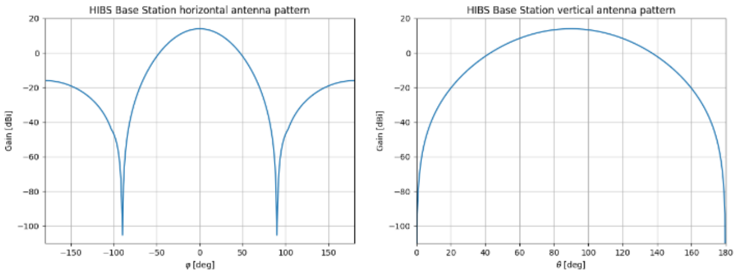
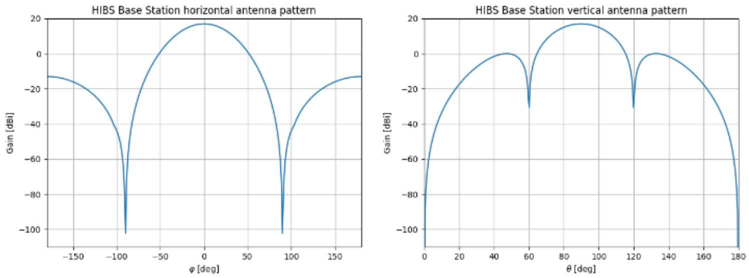
(b) 1st layer (2 x 2)



(c) 2nd layer (4 x 2)



A4.1.2.2 Technical and operational characteristics of IMT operating in the 2 500-2 690 MHz frequency range

The characteristics for IMT are those contained in the document with the characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23 (Annex 4.4 to Document 5D/716), Tables 5-1 and 9, and summarized below. It should be noted that for IMT base stations, AAS should be considered in the frequency bands above 1 710 MHz. Also, as HIBS is envisioned to complement the coverage of existing IMT networks in areas not covered by the terrestrial IMT networks, a suburban macro scenario is more adequate for the cross-border analysis.

TABLE A4.1.2.1

IMT deployment characteristics for bands between 2 and 3 GHz

	Suburban macro
Cell radius / deployment density (for bands between 2 and 3 GHz) (Report ITU-R M.2292)	0.4-2.5 km suburban (typical value to be used in sharing studies for suburban macro 0.8 km)
Antenna height (Report ITU-R M.2292)	25 m suburban (2-3 GHz)
Sectorization	3 sectors
Frequency reuse	1
Below rooftop base station antenna deployment (Report ITU-R M.2292)	Suburban: 0%
Typical channel bandwidth	20 MHz

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	Suburban macro
Network loading factor (base station load probability X%) (see section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6)	20%, 50%
BS TDD activity factor	75%

TABLE A4.1.2.2

UE parameters for bands between 1 and 3 GHz

	Urban/suburban macro
Indoor user terminal usage (Report ITU-R M.2292)	70%
Indoor user terminal penetration loss	Rec. ITU-R P.2109
User equipment density for terminals that are transmitting simultaneously [1]	3 UEs per sector
UE height [2]	1.5 m
Average user terminal output power	Use transmit power control
Typical antenna gain for user terminals	−3 dBi
Body loss	4 dB
UE TDD activity factor	25%
Transmit power control	
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1
Maximum user terminal output power, PCMAX	23 dBm
Power (dBm) target value per RB, P0_PUSCH [3]	−92.2
Path loss compensation factor, α (same as "balancing factor" mentioned in Rec. ITU-R M.2101)	0.8

[1]: UEs share equally the channel bandwidth, i.e. each UE is allocated 1/3 of the channel bandwidth (see Rec. ITU-R M.2101, Section 3.4.1, item 1e-f.). In sharing studies, it is assumed that the AAS BS beamforms towards each UE using the entire array.

[2]: In principle, indoor UEs are distributed over different floors of the building. It should be noted that the number of floors of buildings vary within the environment and among the countries. Moreover, the number of floors of buildings is not related to Macro BS antenna height (parameter given in the Table). In particular in small cities, sub-urban and rural areas, many or most of antennas are installed on masts. Therefore, for outdoor BSs, indoor UEs are assumed to be modelled on the ground floor for the sharing study.

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[3]: The target power is defined per Resource Block (RB), considering 180 kHz RB bandwidth corresponding to 15 kHz subcarrier spacing

A4.1.2.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at -15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. In addition, for the analysis between HIBS and IMT user equipment, the human shield loss was added in accordance with the revision of Recommendation ITU-R P.1409-1. The human shield loss includes the contribution of multi-paths, such as reflections or diffractions caused by the surrounding environments, in different cases in which the user equipment antenna can be at the height of the head or chest of the user. It considers different elements such as the frequency of operation, elevation of Earth-space path, average building height, azimuth angle between the direction of the HIBS to the user, and percentage of angles.

Finally, the HIBS visible horizon when deployed at 18 km and 20 km of altitude is approximately 478 km and 500 km, respectively, from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A4.1.2.4 Methodology

The SHARC open-source simulation tool is used, which is a coexistence static system-level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa.

A4.1.2.5 Scenarios and results of the study

The study was implemented in accordance with the scenario described in Figure A4.1.2.3, in which the HIBS and IMT networks are from different operators located at the border of two countries. The network topology of each system is as such that their respective coverage areas are next to each other, representing a worst-case scenario of both networks operating in suburban areas next to their country border. The IMT network topology is based on 19 macro cells, whereas HIBS topology is based on 7 cells. The simulations were done with 10 000 snapshots.

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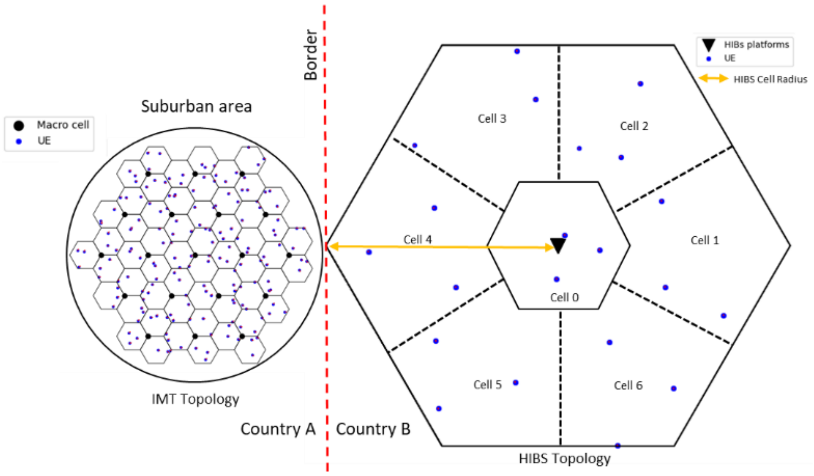
FIGURE A4.1.2.3

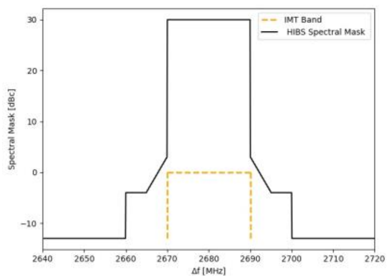
HIBS-IMT simulation scenario



The simulation for co-channel sharing analysis was done considering both HIBS and IMT central frequency at 2 680 MHz, as shown in Figure A4.1.2.4.

FIGURE A4.1.2.4

HIBS-IMT co-channel analysis



[*Editor's note: The results of the Study A will be provided later*.]

A4.1.1.6 Summary and analysis of the results of Study B

[*Editor's note: The summary and analysis of Study A will be provided later.*]

A4.1.3 Study C

This study evaluates sharing and compatibility between the ground component of IMT and high-altitude platform stations as IMT base stations (HIBS) operating in the 2 500-2 690 MHz frequency range. Characteristics and operation of the IMT User Equipment (UE), e.g. its association to the network (HIBS or terrestrial IMT) that offers the best connection condition, make the interference due to IMT UEs associated to the HIBS network similar to conventional inter-cell interference in

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the terrestrial IMT network. Therefore, the study considers only interference due to transmissions of HIBS base stations into the terrestrial IMT network, as this is the relevant case.

A4.1.3.1 Technical characteristics

This section provides the specific parameters used in this study for HIBS and terrestrial IMT, as provided by ITU-R WP 5D.

A4.1.3.1.1 Technical and operational characteristics of HIBS operating in the 2 500-2 690 MHz frequency range

Table A4.1.3.1 summarizes the main HIBS parameters and values used in the conducted study. HIBS parameters not listed in Table A4.1.3.1 are used as described in Document 5D/716 (WP 5D Chairman's Report), Annex 4.19 – "Working document towards a preliminary draft new report ITU-R M.[HIBS-CHARACTERISTICS]/Working document related to WRC-23 agenda item 1.4".

TABLE A4.1.3.1

Main HIBS system parameters.

Parameter	Base Station	UE
Network topology, cell structure and characteristics		
Centre frequency	2.6 GHz	
Channel bandwidth	20 MHz	
HIBS Network Configuration (Duplex Mode)	TDD	
Number of nodes	1 BS/HIBS area	3 UEs per cell
HIBS area radius	90 km	N.A.
Number of cells/HIBS	7	N.A.
Frequency reuse	1	N.A.
Height above ground	20 km	1.5 m
Antenna characteristics		
Antenna pattern model	Rec. ITU-R M.2101	Isotropic, -3 dBi gain
Element gain	8 dBi	N.A.
Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V	N.A.
Horizontal/vertical front-to-back ratio	30 dB for both H/V	N.A.
Antenna polarization	Linear/±45 degrees	N.A.
Antenna array configuration (Row × Column)	2 x 2 elements (1st layer cell), 4 x 2 elements per cell (2nd layer cell)	N.A.
Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V	N.A.
Ohmic losses	2 dB	N.A.
HIBS Platform Antenna tilt	90º (1st layer cell), 33º (2nd layer cell)	N.A.
HIBS Conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)	N.A.
HIBS Platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)	N.A.

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Parameter	Base Station	UE
HIBS Platform e.i.r.p. Spectral Density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)	N.A.
Others		
Body loss	N.A.	4 dB
Transmit power control model	N.A.	Rec. ITU-R M.2101
Maximum UE output power	N.A.	23 dBm
ACLR	45 dB	30 dB

AAS antenna radiation at adjacent channel

AAS antennas have their antenna elements correlated to generate radiation beams in the operating frequency bands. Antenna elements are expected to gradually lose the correlation observed in-band with the increase of the frequency offset from the operating band.

For the specific compatibility case of HIBS operating in the frequency band 2 500-2 690 MHz and the ground component of IMT operating in an adjacent band, it is technically reasonable to consider that HIBS base station antennas will keep the same level of correlation between their elements for such a small frequency offset. This is the assumption adopted in this study.

A4.1.3.1.2 Technical and operational characteristics of the ground component of IMT operating in the 2 500-2 690 MHz frequency range

Table A4.1.3.2 summarizes the main parameters and values used in the conducted study to model the ground component of IMT. Parameters not listed in Table A4.1.3.2 are used as described in Document 5D/716 (WP 5D Chairman's Report), Annex 4.4 – "Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23".

TABLE A4.1.3.2

Main system parameters for the ground component of IMT.

Parameter	Base Station	UE
Network topology, cell structure and characteristics		
Centre frequency	2.6 GHz (co-channel with HIBS) 2.62 GHz (first adjacent channel to HIBS)	
Channel bandwidth	20 MHz	
Network Configuration (Duplex Mode)	TDD	
Cell radius	0.8 km (suburban macro)	N.A.
Antenna height	25 m	1.5 m
Sectorization	3 sectors	N.A.
User equipment density for terminals that are transmitting simultaneously	N.A.	3 UEs per sector
Frequency reuse	1	N.A.
Indoor user terminal usage	N.A.	70%
Antenna characteristics		
Antenna pattern model	Extended AAS model in Table A of Annex 3 of Doc 5D/716,	Isotropic, -3 dBi gain

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Parameter	Base Station	UE
	Annex 4.4.	
Element gain **(Note 1)**	6.4 dBi	N.A.
Horizontal/vertical 3 dB beamwidth of single element	90º for H 65º for V	N.A.
Horizontal/vertical front-to-back ratio	30 dB for both H/V	N.A.
Antenna polarization	Linear/±45 degrees	N.A.
Antenna array configuration (Row × Column)	4 x 8 elements	N.A.
Horizontal/Vertical radiating element/sub-array spacing	0.5 of wavelength for H, 2.1 of wavelength for V	N.A.
Number of element rows in sub-array	3	N.A.
Vertical radiating element spacing in sub-array	0.7 of wavelength of V	N.A.
Pre-set sub-array down-tilt	3º	N.A.
Array ohmic loss **(Note 1)**	2 dB	N.A.
Conducted power (before Ohmic loss) per antenna element/sub-array	28 dBm	N.A.
Base station horizontal coverage range	±60º	N.A.
Base station vertical coverage range	90º -100º	N.A.
Mechanical downtilt	6º	N.A.
Maximum base station output power/sector (e.i.r.p.)	72.28 dBm	N.A.
Others		
Body loss	N.A.	4 dB
Transmit power control model	N.A.	Rec. ITU-R M.2101
Maximum UE output power	N.A.	23 dBm
ACS	37.6 dB	27 dB
Noise figure	5 dB	9 dB

Note 1: The element gain includes the ohmic loss. Therefore, ohmic loss is not needed for the calculation of the BS composite antenna gain and e.i.r.p.

Correlation of AAS antenna elements outside the operating band:

The assumption of HIBS base station antenna keeping the same level of correlation between their elements for a small frequency offset is also made for the ground component of IMT.

A4.1.3.2 Propagation models

The application of propagation models in this study is based on the guidance given by ITU-R WPs 3J, 3K, 3M in Document 5D/723. For interference paths between HIBS base station and the ground component of IMT, Rec. ITU-R P.528 is applied.

The statistical clutter loss model (Rec. ITU-R P.2108, Section 3.3) and the building entry loss model (Rec. ITU-R P.2109) are also applied, the latter in case of IMT UEs located indoors (i.e. 70% of UEs associated to the ground component of IMT network). The entire distribution of loss from these statistical models is used to select different loss samples in the Monte Carlo simulation.

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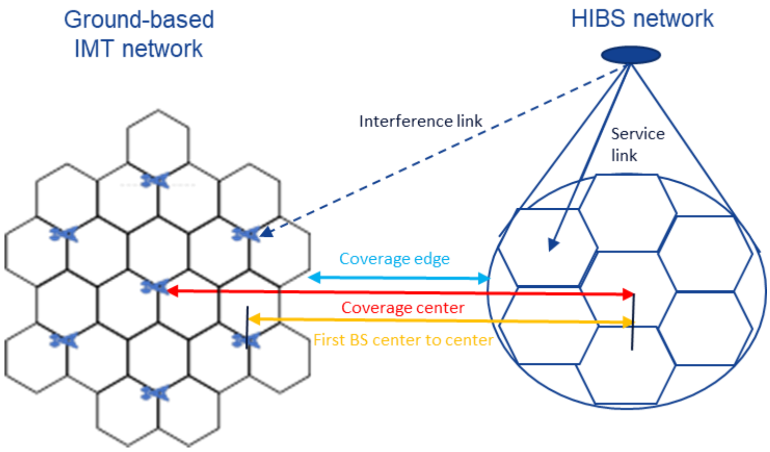
For intra-system propagation between BS and UE in the ground component of IMT network, the Urban Macro (UMa) model from Document 3GPP TR 38.901 is used. For HIBS intra-system propagation, free-space path loss and clutter loss model (Rec. ITU-R P.2108, Section 3.3) are used.

A4.1.3.3 Methodology

The HIBS network is modeled as indicated in Section 1.1, with a 7-cell network topology. The methodology to simulate the ground component of IMT follows Rec. ITU-R M.2101. A cell grid with 21 sectors (7 tri-sectorized cells) with characteristics provided in Section 1.2 is considered in the study. Figure A4.1.3.1 illustrates the network topology of both systems. It also shows different aspects of the simulation scenario, such as the distance between the coverage edge of the two networks, the distance between their coverage centers, and the distance between the closest bases station of the ground-based IMT network and the HIBS network coverage center.

FIGURE A4.1.3.1

Topology of HIBS and ground-based IMT networks for simulation



For the evaluation of interference into the ground-based IMT network due to HIBS base station transmissions, this study considers the distance between the coverage centers of the two networks, namely the **Inter-Network Distance (IND)**. Given that the coverage area of the HIBS network has a radius of 90 km and the ground-based IMT cell/sector radius is 0.8 km (inter-site distance 1.2 km) for the assumed suburban environment, one can easily derive the other mentioned distances from the IND.

Studies for co-channel and adjacent channel operations are provided. For adjacent channel studies, the HIBS base station Adjacent Channel Leakage Ratio (ACLR) and the Adjacent Channel Selectivity (ACS) of base station and UE in the ground-based IMT network are used to derive the resulting interference level at the receiver.

The interference scenarios considered in this study refer to interference into the ground-based IMT network due to HIBS base station transmissions. As illustrated in Figure A4.1.3.2, HIBS base station can cause interference to the UE connected to the ground-based IMT network, shown as downlink to downlink (DL) interference, and/or to the ground-based IMT base station, shown as

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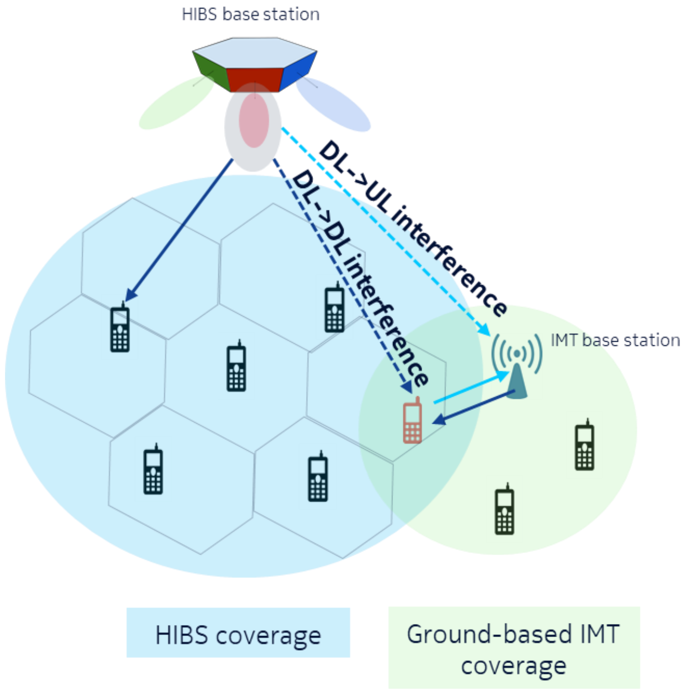
downlink to uplink (UL) interference. Both interference cases are evaluated for the co-channel and the adjacent channel scenarios.

FIGURE A4.1.3.2

Interference scenarios: HIBS base station interference into the ground-based IMT network



Results are presented in this study as cumulative distribution of interference-to-noise ratio (I/N) for different IND. The I/N distribution curves can then be checked against the IMT protection level of I/N = -6 dB. As additional analysis, the study also presents the observed throughput degradation of the ground-based IMT network due to interference from HIBS base station transmissions.

A4.1.3.4 Study results

In the following, simulation results are provided separately for the co-channel and the adjacent channel scenarios.

A4.1.3.4.1 Co-channel operation of HIBS and the ground component of IMT

A4.1.3.4.1.1 HIBS base station interference into ground-based IMT base stations

Figure A4.1.3.3 presents simulation results of interference at the ground-based IMT base stations due to HIBS base station transmissions. This is the scenario shown in Figure A4.1.3.2 as DL to UL interference, which is representative of a fully unsynchronized operation of the two networks. Results are presented as curves of cumulative distribution of *I/N* for Inter-Network Distance (IND)

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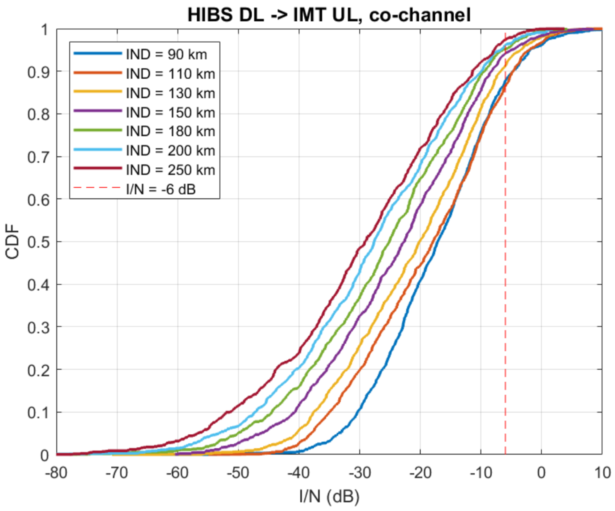
varying from 90 km to 250 km, where IND = 90 km means that the centre of the simulated ground-based IMT network is placed at the edge of the HIBS coverage area.

FIGURE A4.1.3.3

Co-channel interference at IMT base stations due to HIBS base station transmissions



As observed in Figure A4.1.3.3, the protection level for the ground component of IMT, i.e. *I/N* = -6 dB, is crossed even for the largest IND considered, i.e. 250 km. However, additional assessment of the impact of HIBS base station interference into the ground-based IMT base stations shows limited degradation of the average UL throughput, as described in Table A4.1.3.3. The average UL throughput degradation due to HIBS base station interference is less than 1% even for IND = 90 km.

TABLE A4.1.3.3

Degradation of the average UL throughput of the ground component of IMT due to co-channel HIBS base station interference

Inter-Network Distance (IND)	Average throughput degradation of ground-based IMT UL
90 km	0.93%
110 km	0.74%
130 km	0.37%
150 km	0.19%
180 km	0.28%
200 km	0.05%

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Inter-Network Distance (IND)	Average throughput degradation of ground-based IMT UL
250 km	0.01%

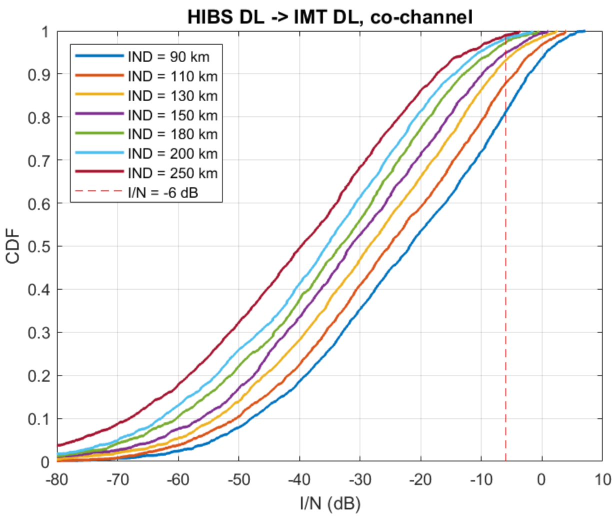
The reduced performance impact for the ground-based IMT base stations of interference caused by HIBS base station transmissions is explained by the fact that the ground-based network is already interference limited. This means that the levels of intra-system interference of the ground-based network with the characteristics described in Section 1.2 are elevated, and the additional interference due to HIBS base station transmissions, even crossing the *I/N* protection level of -6 dB, leads to a limited increase in the interference levels seen at the ground-based IMT base stations.

A4.1.3.4.1.2 HIBS base station interference into IMT UEs

Figure A4.1.3.4 presents simulation results of interference at the IMT UEs due to HIBS base station transmissions. This is the scenario shown in Figure A4.1.3.2 as DL to DL interference, which is representative of a fully synchronized operation of the two networks. Results are presented as curves of cumulative distribution of *I/N* for IND varying from 90 km to 250 km, where IND = 90 km means that the centre of the simulated ground-based IMT network is placed at the edge of the HIBS coverage area.

FIGURE A4.1.3.4

Co-channel interference at IMT UEs due to HIBS base station transmissions



As observed in Figure A4.1.3.4, also in this case the protection level for the ground component of IMT, i.e. *I/N* = -6 dB, is crossed even for the largest IND considered, i.e. 250 km. Again, additional assessment of the impact of HIBS base station interference, this time into the IMT UEs, is considered. Table A4.1.3.4 shows that the degradation of the average DL throughput is negligible (no more than 0.05%) for all simulated INDs.

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TABLE A4.1.3.4

Degradation of the average DL throughput of the ground component of IMT due to co-channel HIBS base station interference

Inter-Network Distance (IND)	Average throughput degradation of ground-based IMT UL
90 km	0.05%
110 km	0.04%
130 km	0.02%
150 km	0.03%
180 km	0.03%
200 km	0.02%
250 km	0.02%

The reduced performance impact for the IMT UEs of interference caused by HIBS base station transmissions is also explained by the fact that the ground-based network is already interference limited, and the additional interference due to HIBS base station transmissions, even crossing the *I/N* protection level of -6 dB, leads to a limited increase in the interference levels seen at the IMT UEs.

A4.1.3.4.2 Adjacent channel operation of HIBS and the ground component of IMT

A4.1.3.4.2.1 HIBS base station interference into ground-based IMT base stations

Figure A4.1.3.5 presents simulation results of interference at the ground-based IMT base stations due to HIBS base station transmissions at the adjacent channel. This DL to UL interference scenario represents a fully unsynchronized operation of the two networks. Results are presented as curves of cumulative distribution of *I/N* for Inter-Network Distance (IND) varying from 0 km (co-located network coverage centres) to 110 km. The combined effect of the HIBS base station ACLR and the ground-based IMT base station ACS results in an Adjacent Channel Interference Ratio (ACIR) of 36.9 dB.

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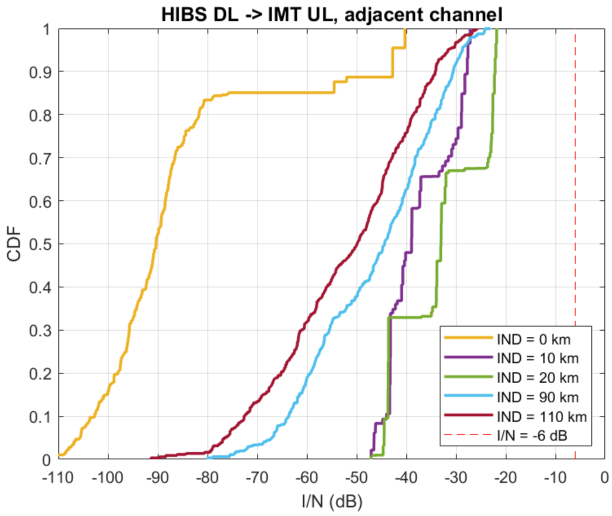
FIGURE A4.1.3.5

Adjacent channel interference at IMT base stations due to HIBS base station transmissions



As observed in Figure A4.1.3.5, the protection level for the ground component of IMT, i.e. *I/N* = -6 dB, is not crossed for any of the INDs considered. The case of IND = 0 km, i.e. superposition of coverage areas with co-located network coverage centres, leads to reduced interference levels in comparison with other INDs. This is a direct consequence of the reduced antenna gain of the IMT base station at 90° above horizon line, towards the HIBS base station. A trend of increase in the interference levels at the ground-based IMT base station with an increase in the IND is seen for IND = 10 km and 20 km. This is due to slightly reduced elevation angles above horizon line towards the HIBS base station in comparison to the case of IND = 0 km, and consequential increased receiver antenna gain in that direction. The interference behaviour observed for the largest INDs evaluated, i.e. 90 km and 110 km, is dominated by the path loss, with longer IND leading to lower interference.

A4.1.3.4.1.2 HIBS base station interference into IMT UEs

Figure A4.1.3.6 presents simulation results of interference at the IMT UEs due to HIBS base station transmissions at the adjacent channel. This DL to DL interference scenario represents a fully synchronized operation of the two networks. Results are presented as curves of cumulative distribution of I/N for Inter-Network Distance (IND) varying from 0 km (co-located network coverage centres) to 110 km. The combined effect of the HIBS base station ACLR and the IMT UE ACS results in an ACIR of 26.9 dB.

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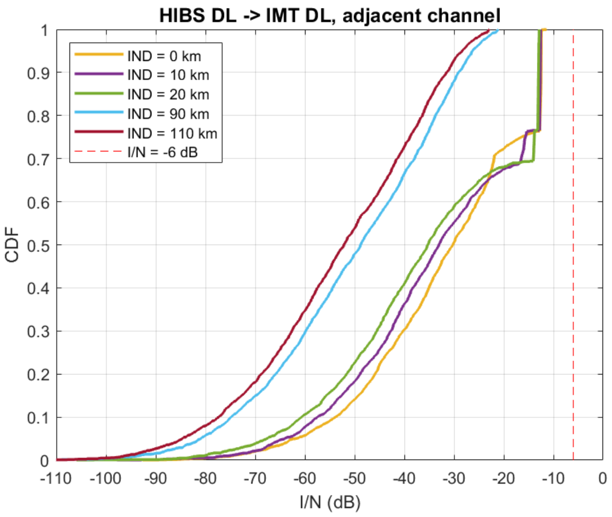
FIGURE A4.1.3.6

Adjacent channel interference at IMT UEs due to HIBS base station transmissions



As observed in Figure A4.1.3.6, the protection level for the ground component of IMT, i.e. *I/N* = -6 dB, is not crossed for any of the INDs considered. The variation of interference levels with respect to different INDs is basically governed by the radiation level and pattern of the HIBS base station and the path loss, as the IMT UEs have isotropic antennas. This explains similar interference levels for slightly different INDs, including a percentage of IMT UEs subject to practically the same interference levels for INDs between 0 km and 20 km due to very small variations on the propagation losses (no building entry loss, small range of clutter loss for elevation angles between 45° and 90° above horizon line).

A4.1.3.5 Summary and analysis of the results of study

Considering that a maximum *I/N* = -6 dB at the IMT base station or UE receiver is required for its protection, separation distances larger than 250 km between the HIBS coverage centre and a ground-based IMT network are required for co-channel operation in the 2 500-2 690 MHz frequency range. No interference issue is expected for adjacent channel operation.

It is also observed that due to the characteristics of the ground-based IMT network (interference limited), the increase in interference due to co-channel HIBS transmissions leads to limited or negligible performance degradation for a ground-based IMT network even at around the edge of the HIBS coverage area.

A4.2 Sharing studies between fixed service and HIBS operating in the 2 500-2 690 MHz frequency range

A4.2.1 Study A

A4.2.1.1 Technical and operational characteristics of HIBS operating 2 500-2 690 MHz frequency range

The technical and operational characteristics of HIBS are those for Band 3 from the working document towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS],

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including Table 2, Table 2-A, Table 3, and Table 5. It should be emphasized that the analysis is needed only with the HIBS (BS), as the user equipment is the same as the IMT ground-based network.

FIGURE A4.2.1.1

HIBS antenna pointing and network topology

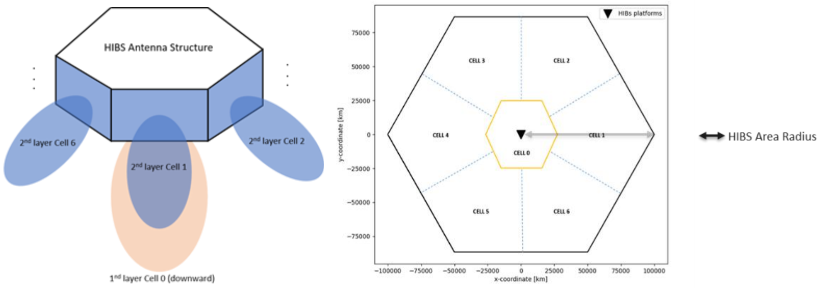
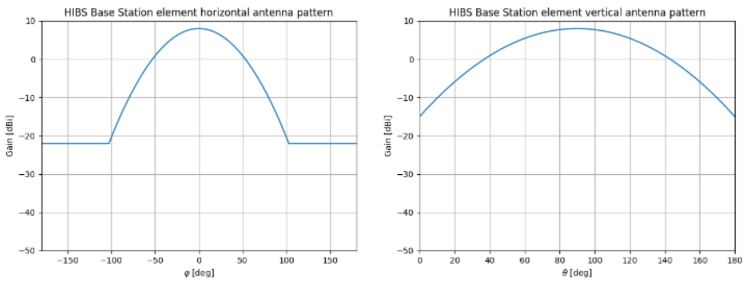
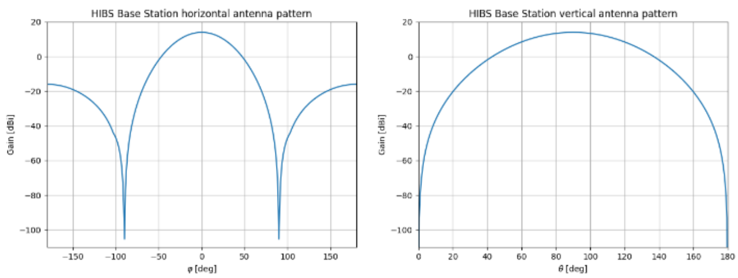


FIGURE A4.2.1.2

HIBS antenna pattern (Recommendation ITU-R M.2101)
(a) Single element (for adjacent case)



(b) 1st layer (2 × 2)



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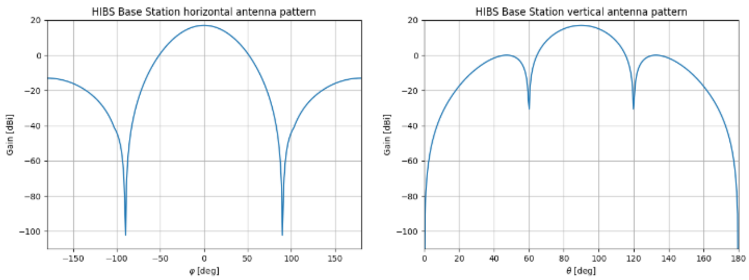
(c) 2nd layer (4 × 2)



A4.2.1.2 Technical and operational characteristics of fixed service operating in the 2 500-2 690 MHz frequency range

The characteristics for the fixed service (FS) for point-to-point (PP) systems are based on the information contained in the Recommendation ITU-R F.758, Table 16, as summarized below.

TABLE A4.2.1.1

Characteristics of the FS (PP) systems

Parameter	Value
Band of operation	2 290-2 670 MHz
Reference	Recommendation ITU-R F.1243
Modulation	MSK
Bandwidth	14 MHz
Receiver noise figure	4 dB
Antenna height	30 m
Antenna pattern	Recommendation ITU-R F.1245
Antenna gain	25 dBi
Antenna beamwidth	8.68^0
Diameter of the antenna	0.9 m
Protection criteria (I/N)	−6 dB

For FS (PP), in cases of analysis consisting of many interference entries, as it is the case with the HIBS multiple cells, using a peak envelope radiation pattern would result in aggregate interference values that are greater than values that would be experienced in practice. In this case, it is more appropriate to use an antenna pattern in accordance with Recommendation ITU-R F.1245, representing average sidelobe levels.

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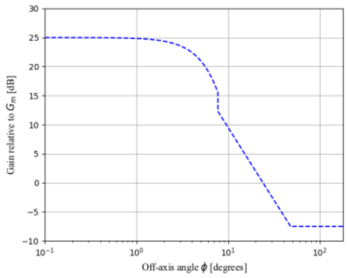
FIGURE A4.2.1.3

FS (PP) antenna pattern (Recommendation ITU-R F.1245)



A4.2.1.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at −15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. Finally, the HIBS visible horizon when deployed at 18 km and 20 km of altitude is approximately 478 km and 500 km, respectively, from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A4.2.1.4 Methodology

The SHARC open-source simulation tool is used, which is a coexistence static system-level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa. In this study the interference-to-noise ratio is calculated and compared with the protection criteria for their specific frequency range.

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A4.2.1.5 Scenarios and results of the study

The study was implemented in accordance with the scenarios described in Figure A4.2.1.4, with the FS stations positioned at different distances from the HIBS nadir, as described in Table A4.2.1.2. The simulations were done with 10 000 snapshots.

FIGURE A4.2.1.4

HIBS-FS (PP) simulation scenario

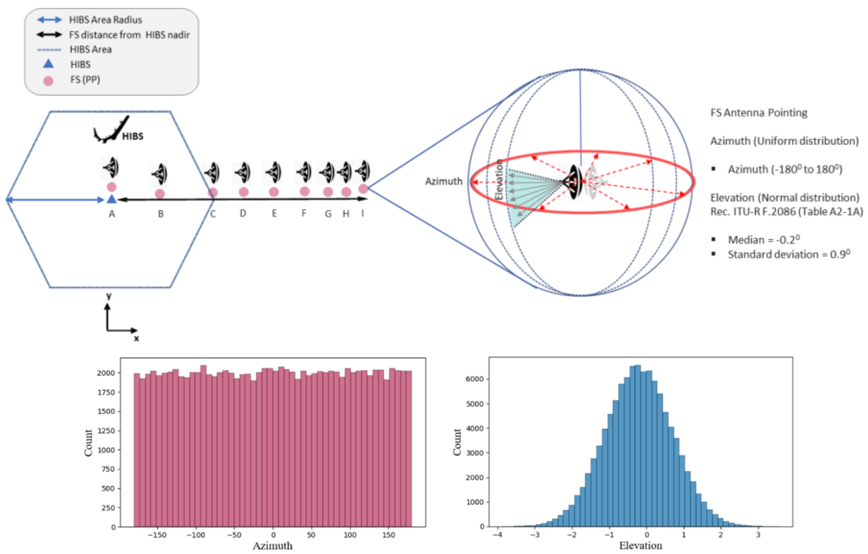

TABLE A4.2.1.2

Geographical coordinates of the FS (PP) stations in the simulation

Position	Distance from point A	Latitude	Longitude
A(1)	–	−15.809422°	−47.866732°
B	50 km	−15.356298°	−47.866732°
C	100 km	−14.901080°	−47.866732°
D	150 km	−14.458172°	−47.866732°
E	250 km	−13.560102°	−47.866732°
F	350 km	−12.660001°	−47.866732°
G	450 km	−11.760120°	−47.866732°
H	478 km	−11.510010°	−47.866732°
I	500 km	−11.310301°	−47.866732°

(1) HIBS nadir.

The simulation for co-channel sharing analysis was done considering HIBS central frequency at 2 660 MHz, and the FS (PP) at 2 663 MHz, as shown in Figure A4.2.1.5.

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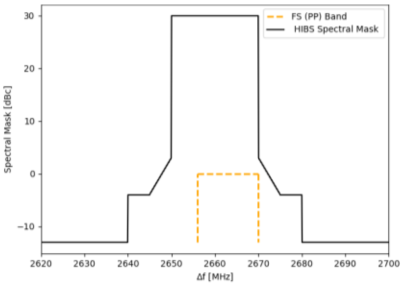
FIGURE A4.2.1.5

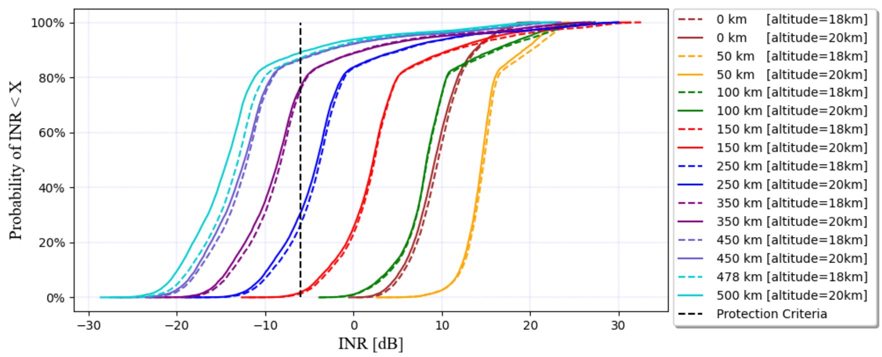
HIBS-FS (PP) co-channel analysis



The results of the simulations, as shown in Figure A4.2.1.6, indicates the probability of the achieved protection criteria (*I/N*) for each of the distances described above. At each snapshot, the FS (PP) station elevation angle varied following a normal distribution with a median of -0.2º and standard deviation of 0.9º, according to the Recommendation ITU-R F.2086 (Table A2-1A), and the azimuth varied from -180º to 180º in a uniform distribution. Furthermore, a sensitivity analysis was performed considering HIBS at an altitude of 18 km.

FIGURE A4.2.1.6

HIBS-FS (PP) co-channel simulation results



In case no additional measures are implemented for the HIBS station, the results show that the achieved I/N will not meet the FS (PP) protection criteria of −6 dB. As such, an analysis was done to verify what the appropriate pfd values for the HIBS station would be to protect the FS systems, in calculating pfd levels as the following:

$$Thermal\ noise_{(\mathrm{dBm/MHz})} = 10 \times \log\left(Boltzmann\ constant\ \times Receiver\ Noise\ figure_{Kelvin} \times 1000\right) + 10 \times \log(Bandwidth)$$

$$INR_{(dB)} = Interference\ level_{dBm} - Thermal\ noise_{dBm}$$

$$PFD_{dB(\mathrm{m}/(m^2*\mathrm{MHz}))} = 10\ \times log\left(\frac{10^{\frac{Interference\ level_{dBm}}{10}}}{Effective\ area \times 10^{\frac{G_\theta}{10}} \times Bandwidth}\right)$$

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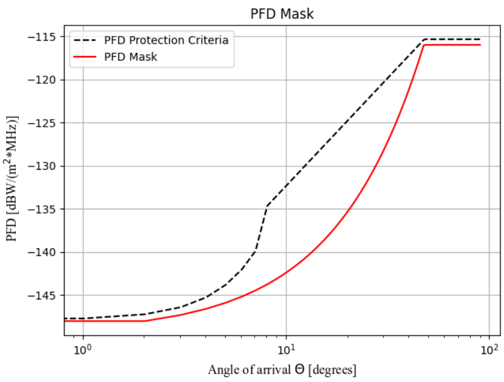
$$PFD_{dB(W/(m^2*MHz))} = PFD_{dB(m/(m^2*MHz))} - 10 \times log(1000)$$

Where G_θ = antenna gain at each angle of arrival.

As shown in Figure A4.2.1.7, the results indicate that considering all the possible cases, it is possible to achieve the FS (PP) protection criteria (*I/N*) always lower than −6 dB when implementing the HIBS pfd mask in red.

FIGURE A4.2.1.7

HIBS pfd mask for FS (PP) co-channel feasibility



A4.2.1.6 Summary and analysis of the results of Study A

The results of this study show that for HIBS operating in the 2 500-2 690 MHz frequency range the sharing with FS co-channel is only feasible if additional measures are implemented for the HIBS stations. As such, HIBS, in order to protect fixed stations from co-channel interference, shall not exceed the following limits of a co channel power flux-density (pfd) at the Earth's surface:

– −148 dB(W/(m^2 · MHz)) for angles of arrival (θ) less than 2° above the horizontal plane;

– −148 + 0.71 (θ − 2) dB(W/(m^2 · MHz)) for angles of arrival between 2° and 47° above the horizontal plane; and

– −116 dB(W/(m^2 · MHz)) for angles of arrival between 47° and 90° above the horizontal plane.

A4.3 Sharing studies between broadcasting satellite service in the 2 520-2 630 MHz frequency range and HIBS operating in the 2 500-2 690 MHz frequency range

A4.3.1 Study A

[Editor's note: The study may be revised to include the contributions of multiple HIBS for BSS Carriers 1 and 3, which earth stations have omni-directional antennas, in case the study is to be validated for cross-border scenario. Also, the pfd values pertaining to the protection criteria for 0.6% time and 0.02% time may also be included.]

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As per RR No. **5.416**, coordination scheme based on RR No. **9.19** may be applied for sharing between BSS and HIBS in the 2 520-2 630 MHz frequency range. This study calculated the pfd values as a possible threshold level in application of this coordination.

A4.3.1.1 Technical and operational characteristics of broadcasting satellite service in the 2 520-2 630 MHz frequency range

Tables A4.3.1.1 and A4.3.1.2 summarized the technical and operational characteristics of BSS downlink for this study, which are included in the liaison statement from WP 4A (5D/732).

TABLE A4.3.1.1

BSS downlink parameters in the 2 520-2 630 MHz frequency range

Parameters	Units	Carrier 1	Carrier 2	Carrier 3
Frequency range	MHz	2 550-2 630	2 520-2 550	2 520-2 550
Noise bandwidth	MHz	0.007-0.1	0.009-0.2	0.009-0.2
Antenna diameter	M	0.042 × 0.042	0.12 × 0.12	0.042 × 0.042
Peak receiver antenna gain	dBi	2.5	10	2.5
Antenna receive gain pattern	-	Omni	Non-directional (NOTE)	Omni
System receive noise temperature	K	450	150	450
Minimum earth station elevation angle	Degrees	5	10	5

NOTE : ITU standard antenna pattern APEND_099V01 (G = Gmax for all angles) is assumed to be used. There is a general understanding that using an earth station antenna with the maximum antenna gain of 10 dBi may lead to directivity and antenna discrimination. However, this case refers to the envelope of the peak gain of the main beam which is steerable. It should be noted that using such an antenna, compared to using a directional antenna, can make the system more sensitive to interference.

TABLE A4.3.1.2

Protection criteria of BSS in the 2 520-2 630 MHz frequency range

Frequency Ranges	Percentage of time for which the *I/N* value could be exceeded (%)	*I/N* Criteria (dB)
2 520 to 2 630 MHz	can be exceeded not more than 20% of time can be exceeded not more than 0.6% of time can be exceeded not more than 0.02% of time	-10.5 dB I/N -6 dB I/N 0 dB I/N

A4.3.1.2 Propagation model

Free space and depolarization loss from Recommendation ITU-R P.619 were used as the baseline propagation model based on section 2.1 of the draft revision of Recommendation ITU-R P.1409-1.

A4.3.1.3 Calculation of pfd threshold level for the protection of broadcasting satellite services

The pfd calculation for the protection of BSS earth stations in the 2 520-2 630 MHz frequency range is provided in Table A4.3.1.3.1.

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TABLE A4.3.1.3

Pfd threshold levels for the protection of BSS in the 2 520-2 630 MHz frequency range

Parameter	Carrier 1	Carrier 2	Carrier 3
Frequency	2 590 MHz	2 535 MHz	2 535 MHz
$10\log(\lambda^2/4\pi)$	−29.7 m^2	−29.5 m^2	−29.5 m^2
Noise bandwidth	7 kHz	9 kHz	9 kHz
System receive noise temperature	450 K	150 K	450 K
Noise spectral density	−163.6 dBW/7 kHz = −142.1 dBW/MHz	−167.3 dBW/9 kHz = −146.8 dBW/MHz	−162.5 dBW/9 kHz = −142.1 dBW/MHz
Protection criterion (*I/N*), *can be exceeded not more than 20% of time*	−10.5 dB	−10.5 dB	−10.5 dB
Interferences level to satisfy the protection criterion	−152.6 dBW/MHz	−157.3 dBW/MHz	−152.6 dBW/MHz
Peak receiver antenna gain	2.5 dBi	10 dBi	2.5 dBi
Antenna discrimination loss	0 dB	0 dB	0 dB
Depolarization loss (See section 2.2 of Recommendation ITU-R P.619)	3 dB	3 dB	3 dB
pfd value, *can be exceeded not more than 20% of time*	−122.4 dBW/m²·MHz	−134.8 dBW/m²·MHz	−122.5 dBW/m²·MHz

Note to the table:

The pfd calculation formula is listed as follows:

pfd (dB(W/m²·MHz)) = Noise spectrum density (dB(W/MHz)) + *I/N* (dB) - Peak receiver antenna gain (dBi) + Antenna discrimination loss (dB) + Depolarization loss (dB) - $10\log(\lambda^2/4\pi)$.

As Note to the Table A4.3.1.1.1, although maximum antenna gain of the earth station for Carrier 2 is 10 dBi, the antenna pattern of this earth station is “Non-directional” in order to describe the envelope of the peak gain of the main beam which is steerable. However, this means that the main beam of this earth station can direct to below the minimum elevation angle (=10 degrees) and the pfd value of Carrier 2 overestimates the interference from HIBS below the elevation angle of 10 degrees.

Based on the above considerations, it would be appropriate for the protection of BSS in the 2 520-2 630 MHz frequency range to set the pfd value of Carrier 2 at the elevation angle of 10 degrees or higher and the pfd value of Carrier 3 at the elevation angle lower than 10 degrees. Therefore, this study showed that the following pfd mask that can be exceeded not more than 20% of time as a possible threshold of the coordination.

−122.5 dB(W/m²) in 1 MHz for $0° \leq \theta < 10°$

−134.8 dB(W/m²) in 1 MHz for $10° \leq \theta \leq 90°$

where θ is the angle of arrival above the horizontal plane, in degrees.

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A4.3.1.4 Summary and analysis of the results of Study A

This study showed that the following pfd mask that can be exceeded not more than 20% of time as a possible threshold of the coordination to protect BSS from HIBS in the 2 520-2 630 MHz frequency range.

−122.5 dB(W/m²) in 1 MHz for $0° \leq \theta < 10°$

–134.8 dB(W/m²) in 1 MHz for $10° \leq \theta \leq 90°$

where θ is the angle of arrival above the horizontal plane, in degrees.

A4.3.2 Study B

~~*[Editor's note: Concerns were expressed regarding the inclusion of HIBS UEs in studies under WRC-23 agenda item 1.4, as the UE parameters for HIBS are the same as those for ground-based IMT, and Resolution **247 (WRC-19)** strictly limits sharing and compatibility studies only to HIBS and not for ground-based IMT including UEs. In this regard, further consideration of this matter is needed at the next meeting to further discuss the assumptions used in this study.]*~~

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A4.3.2.1 Introduction

This document includes the Sharing studies between Broadcast satellite service (BSS) in frequency band of 2 520-2 630 MHz and HIBS operating in the 2 500-2 690 MHz frequency range in pursuance with the *resolves to invite ITU-R* 2 of Resolution **247 (WRC-19)** under WRC-23 agenda item 1.4. This study provides assessment of the possible interference from HIBS base station (BS) and user equipment (UE) to the BSS.

The Study has been carried out considering following cases:

– Case I: HIBS BS to BSS user terminals

– Case II: HIBS UE to BSS user terminals.

A4.3.2.2 Technical characteristics

This section provides the specific parameters of HIBS used in the included study/studies, as provided in Annex 4.19 of Document 5D/716. The specific parameters of BSS used are as provided by the contributing group WP 4A to WP 5D (Doc. 5D/732).

A4.3.2.2.1 Technical and operational characteristics of HIBS systems operating in the 2 500-2 690 MHz frequency range

Tables show parameters values used for IMT base station and IMT UE in the sharing studies. Only those parameters that are relevant to this study are included.

TABLE A4.3.2.1

HIBS Base Station Specification & deployment related parameters

BS density	1 BS/HIBS area
HIBS altitude	20 km
HIBS transmit antenna pattern	ITU-R M.2101
Channel bandwidth	20 MHz
HIBS network configuration	TDD
HIBS platform e.i.r.p. spectral density/cell	45 dBm/MHz (2nd layer cell) 42 dBm/MHz (1st layer cell)

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HIBS element antenna gain	8 dBi
HIBS area radius	90 km
Ohmic losses	2 dB
Polarization loss	3 dB

TABLE A4.3.2.2

UE Specification & deployment related parameters

UE density	21 UEs/HIBS area (3 UEs per cell)
UE height	1.5 m
HIBS UE transmit antenna gain	−3 dBi
Body loss	4 dB
Maximum UE transmitter output power	23 dBm
Polarization loss	3 dB

A4.3.2.2.2 Technical and operational characteristics of BSS systems operating in the 2 520-2 630 MHz frequency range

Below tables show parameters values used for BSS in the sharing studies. Only those parameters that are relevant to this study are included.

TABLE A4.3.2.3

BSS receiver parameters

Noise bandwidth (MHz)	0.007-0.1
Peak receive antenna gain (dBi)	2.5
Antenna receive gain pattern (ITU-R Recommendation)	Omni
System receive noise temperature (K)	450

A4.3.2.2.3 Protection criteria

TABLE A4.3.2.4

Protection criteria for BSS system

Frequency ranges	Percentage of time for which the *I/N* value could be exceeded (%)	*I/N* criteria (dB)
2 520 to 2 630 MHz	can be exceeded not more than 20% of time can be exceeded not more than 0.6% of time can be exceeded not more than 0.02% of time	−10.5 dB I/N −6 dB I/N 0 dB I/N

In the frequency band 2 520-2 630 MHz, there are primary allocations to the fixed service and the mobile service in all regions, apart from broadcasting satellite service. This means that, two more services could be operating in the same frequency band 2 520-2 630 MHz that could be

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possible source of undesirable emissions to the BSS user terminals. An apportionment of 3 dB in the protection criteria is therefore considered in the analysis.

A4.3.2.3.1 Case I: HIBS BS to BSS user terminal

Considering above technical and deployment related parameters worst case analysis is carried out to find interference power received at BSS UE due to emission from HIBS BS.

Parameters	Unit	Values
HIBS platform e.i.r.p. spectral density/cell (1st layer cell)	dBm/MHz	42.0
HIBS BS ohmic loss	dB	2.0
HIBS BS polarization loss	dB	3.0
Maximum effective HIBS BS e.i.r.p. density	dBW/MHz	7
Transmit frequency of BS	MHz	2 550-2 570
Path length	m	20 000.0
Path loss	dB	126.6
Aggregate received interference density	dBW/MHz	−119.6
BSS user terminal receive antenna gain	dBi	2.5
Aggregate received interference density to BSS receiver	dBW/Hz	−177.1
Interference noise temp.	K	141 253.8
BSS receiver noise temperature	K	450
Degradation in noise temp.	%	31 389.7
I/N	dB	25
Protection criteria	%	25 (*I/N*: −6 dB)
Exceedance		31 dB
Exceedance after applying apportionment of 3 dB in protection criteria		34 dB

Sensitivity Analysis - With respect to HIBS BS altitude change from 20 to 18 Kms, the sensitivity analysis has been carried out. The maximum interference and corresponding exceedance against protection thresholds increases by 0.9 dB for 18 km altitude compared to 20 kms altitude of HIBS BS.

A4.3.2.3.2 Case II: HIBS UE to BSS user terminal

Parameters	Unit	Values		
Maximum HIBS UE output power	dBm	23.0	23.0	23.0
HIBS UT antenna gain	dBi	−3.0	−3.0	−3.0
HIBS UT body loss	dB	4.0	4.0	4.0
HIBS UT polarization loss	dB	3.0	3.0	3.0
Maximum HIBS UE e.i.r.p. density	dBW	−17.0	−17.0	−17.0
Maximum HIBS UE e.i.r.p. density	dBW/Hz	−90.0	−90.0	−90.0
Transmit frequency of UE	MHz	2550.0	2550.0	2550.0

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Propagation loss (ITU-R P.1812)	dB	125.0	120.6	114.6
Aggregate received interference density	dBW/Hz	−215.0	−210.6	−204.6
BSS user terminal receive antenna gain	dBi	2.5	2.5	2.5
Aggregate received interference density	dBW/Hz	−212.5	−208.1	−202.1
Interference noise temp.	K	40.6	111.9	445.6
BSS receiver noise temperature	K	450.0	450.0	450.0
Degradation in noise temp.	%	9	25.0	100
Protection criteria (Δ*T*/*T*)	%	9 (*I*/*N*: −10.5 dB)	25 (*I*/*N*: −6 dB)	100 (*I*/*N*: 0 dB)
keep-out distance between HIBS UE & BSS user terminals to maintain protection criteria	km	5.2	4.3	3.7
keep-out distance between HIBS UE & BSS user terminals to maintain protection criteria after applying apportionment of 3 dB	km	5.9	4.9	3.9

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A4.3.2.4 Summary

A4.3.2.4.1 HIBS BS to BSS UE

This preliminary sharing study on assessing the possible interference from HIBS BS into BSS user terminals in the 2 520-2 630 MHz frequency bands shows the following trend:

a) *I/N* protection criteria is exceeded by about 35.5 dB assuming an *I/N* of −10.5 dB.

b) *I/N* protection criteria is exceeded by about 31 dB assuming an *I/N* of −6 dB.

c) *I/N* protection criteria is exceeded by about 25 dB assuming an *I/N* of 0 dB.

Further, *I/N* is exceeded by 3 dB in each of the above cases with 3 dB apportionment in the protection criteria.

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The maximum interference and corresponding exceedance against protection thresholds increases by 0.9 dB for 18 km altitude compared to 20 kms altitude of HIBS BS.

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Considering the amount of exceedance, the coexistence of HIBS and BSS is not possible in this frequency band.

A4.3.2.4.2 HIBS UE to BSS UE

Sharing study on assessing the interference from HIBS UE to BSS user terminals in the 2 520-2 630 MHz frequency bands shows the following results:

a) 5.2 km of keep-out distance required to meet protection criteria of *I/N* of −10.5 dB.

b) 4.3 km of keep-out distance required to meet protection criteria of *I/N* of −6 dB.

c) 3.7 km of keep-out distance required to meet protection criteria of *I/N* of 0 dB.

Further, keep-out distances are increased in the range of 3.9 Km to 5.9 Km with 3 dB apportionment in the protection criteria.

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Considering the ubiquitous nature of HIBS UE and BSS user terminals, it would not be practically possible to ensure such large keep-out distances. Hence, the coexistence of HIBS UE and BSS is not possible in this frequency band.

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A4.3.2.5 Conclusion

Based on the outcome of the sharing studies, it is concluded that there would be harmful interference from HIBS BS with the *I/N* exceedance in the range of 25 dB to 35.5 dB (28 dB to 38.5 dB with 3 dB apportionment in the protection criteria) to the BSS user terminals, if both HIBS and BSS shares the same frequency band 2 520-2 630 MHz. Also, keep-out distances in the range of 3.7 km to 5.2 km (3.9 km to 5.9 km with 3 dB apportionment in protection criteria) between the HIBS UE and BSS user terminals would be needed in order to meet the protection criteria for protection of BSS services. Considering the ubiquitous nature of HIBS UE and BSS user terminals, it would not be practically possible to ensure such large keep-out distances.

Hence, the coexistence of HIBS and BSS is not possible in this frequency band.

A4.4 Sharing and compatibility studies between mobile satellite service in the 2 500-2 535 MHz (space-to-Earth) and 2 655-2 690 MHz (Earth-to-space) bands in Region 3 and HIBS operating in the 2 500-2 690 MHz frequency range

Resolution **247 (WRC-19)** *resolves to invite the ITU Radiocommunication Sector 2* indicates that for HIBS operating in the 2 500-2 690 MHz frequency range there are limitations specifically for Region 3, including that the 2 500-2 535 MHz range is to be used for uplink only, and that the 2 655-2 690 MHz range should not be used. Hence, the 2 500-2 535 MHz frequency range would fall in the proposed HIBS uplink arrangement for Region 3, and no studies are required for HIBS operating in the 2 655-2 690 MHz frequency range in Region 3

In terms of the analysis of HIBS operating in Regions 1 and 2, and its sharing and compatibility with MSS in Region 3, the following should be considered:

– For MSS(s-E) in the 2 500-2 535 MHz frequency range, sharing studies on the impact from HIBS operating in Region 2 on the MSS in Region 3 are not necessary as the interference from HIBS to mobile earth stations (MES) is negligible due to high attenuation. Similarly, no adjacent band compatibility studies are needed to assess the impact of out-of-band emissions from HIBS operating in Regions 1 and 2 on the MSS operating in Region 3.

– For MSS (E-s) in the 2 655-2 690 MHz frequency range, the interference from HIBS in Regions 2 to MSS space stations in Region 3 is unlikely to be a problem, since the interference level from HIBS to space stations is much lower due to high attenuation. Similarly, no adjacent band compatibility is necessary between HIBS operating in 2 500-2 655 MHz and MSS operating in the 2 655-2 690 MHz frequency band.

Based on the above considerations, this section is focused on:

– For the 2 500-2 535 MHz (s-E) range, in-band sharing studies between HIBS in Region[s] 1 [and 3] and MSS in Region 3;

– For the 2 655-2 690 MHz (E-s) range, the in-band sharing studies between HIBS in Region 1 and MSS in Region 3;

– And in Region 3, adjacent band compatibility studies between HIBS in the 2 500-2 690 MHz frequency band and MSS in the 2 500-2 535 MHz (s-E) frequency range.

A4.4.1 Study A

[*Editor's note: The study may be updated for clarifying the assumptions which could present a worst-case scenario for single entry interference analysis and also providing the justification as to why the interference scenario involving multiple HIBS is not a worst-case scenario for assessing the interference to MSS.*]

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This study considered the horizontal separation distance from area edge of HIBS to MES based on the calculations of interference-to-noise ratio (*I/N*) in order to evaluate whether HIBS specific mitigation measures would be necessary to protect MSS (s-E).

A4.4.1.1 Technical and operational characteristics of HIBS in the 2 535-2 690 MHz frequency range

This study used technical and operational characteristics of HIBS in Band 3 (2 500-2 690 MHz frequency range) contained in section 6.1.3 of the working document towards a PDN Report ITU-R M.[HIBS-CHARACTERISTICS]. The single element antenna pattern of Recommendation ITU-R M.2101 was used for this adjacent compatibility study. With regard to Platform Altitude, this study considers at 18 km and 20 km in order to perform the sensitivity analysis on the interference from HIBS operating at altitude below 20 km.

A4.4.1.2 Technical and operational characteristics of MSS (s-E) in the 2 500-2 535 MHz frequency range

Tables A4.4.1.1 and A4.4.1.2 summarized the technical and operational characteristics of MSS (s-E) for this study, which are included in Attachment 2 of the liaison statement from WP 4C (5D/731).

TABLE A4.4.1.1

Technical and operational characteristics of MSS (s-E) in the 2 500-2 535 MHz frequency range

Parameters	Units	Values
Beam carrier bandwidth	kHz	4
Maximum MES antenna discrimination towards the horizon	dBi	15
User G/T	dB(K^{-1})	−23 to −25

TABLE A4.4.1.2

MSS Protection criteria for the purpose of sharing and compatibility study for allocations within the 2 500-2 690 MHz frequency range

Parameter	Values
For Co-frequency sharing and adjacent band compatibility, $\Delta T/T$	6% (I/N = −12.2 dB) or 10% (I/N = −10 dB) or 25% (I/N = −6 dB)
Note to the Table : Presently no ITU-R recommendation exists for the protection criteria for MSS in the frequency band 2.6 GHz (noting that there are variations on the MSS allocation for each Region), and that this contribution is based on previous studies contained in ITU-R reports in the frequency band 2 500-2 690 MHz that have considered the protection criteria for MSS for the purpose of that specific study. Studies using this protection criteria for MSS could be assessed on the basis that these range of values were put forward by WP 4C to facilitate the work for WRC-23 agenda item 1.4 and these values may evolve in the future based on inputs to the ITU-R, but no conclusions on the application of this protection criteria and its associated assumptions should be extrapolated to other studies.	

A4.4.1.3 Propagation model

Free space and depolarization loss from Recommendation ITU-R P.619 were used as the baseline propagation model based on section 2.1 of the draft revision of Recommendation ITU-R P.1409-1.

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A4.4.1.4 Methodology

This study calculated I/N produced by HIBS at MES in the interference scenarios in Table A4.4.1.3 and considered the horizontal separation distance from area edge of HIBS to comply with the MSS protection criteria (I/N = −6/−10/−12.2 dB) in Table A4.4.1.2.2.

TABLE A4.4.1.3

Interference scenarios

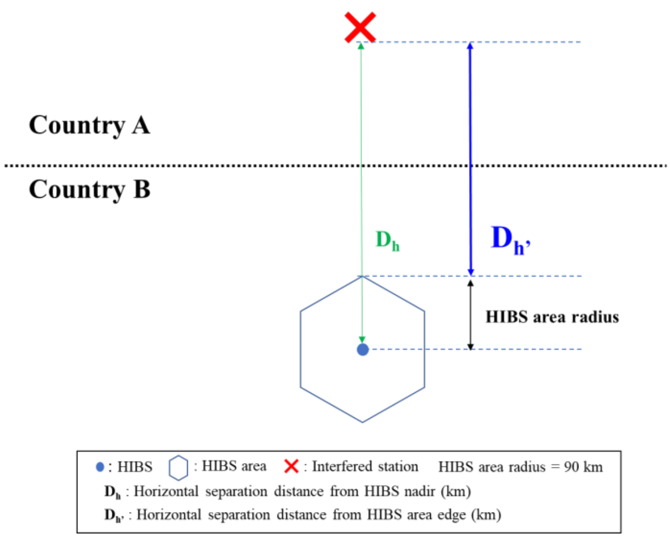
Interfered with		Interfering	
Frequency range	**Interfered Station**	**Frequency range**	**Interfering station**
2 500-2 535 MHz	MES	2 535-2 690 MHz	HIBS (Platform altitude: 18/20 km)

A4.4.1.4.1 Relative relationship between HIBS and the interfered station

Figure A4.4.1.4.1.1 shows the relative relationship between HIBS and MES. The horizontal separation distance D_h is defined as the distance from the nadir of HIBS to the interfered station. $D_{h'}$ is defined as the distance from the area edge of HIBS to the interfered station. $D_{h'}$ can be calculated as "$D_{h'} = D_h$ −90 km (HIBS area radius)".

FIGURE A4.4.1.1

Relative relations between HIBS and interfered station



A4.4.1.4.2 Calculation method of separation distance

The separation distance D between HIBS and the interfered station is calculated by the horizontal separation distance D_h (see also Figure A4.4.1.4.2.1) as follows:

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$$D = \sqrt{R^2 + (R+H)^2 - 2R(R+H)\cos\left(\frac{D_h}{R}\right)} \quad \text{(km)}$$

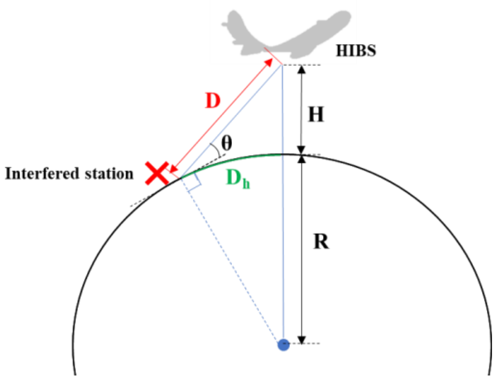
where:

R: Earth radius = 6 378 km;

H: Platform Altitude = 18/20 km.

FIGURE A4.4.1.2

Separation distance from HIBS to Interfered station



A4.4.1.4.3 Calculation method of I/N

The following steps were performed to calculate *I/N* produced by HIBS at MES.

Step 1: Calculate Noise spectrum density (N_{MSS}) of MES as Table A4.4.1.4:

TABLE A4.4.1.4

Calculation of Noise spectrum density of MES in the 2 500-2 535 MHz frequency range

Parameters	Units	Values
Frequency	MHz	2 035
Beam carrier bandwidth	kHz	4
User G/T	dB(K^{-1})	-23
Maximum MES antenna discrimination towards the horizon	dBi	15
Thermal noise	dB(K)	38
Noise spectrum density	dBW/4 kHz	-154.6

Step 2: Calculate received interference level (I_{HIBS}) produced by HIBS at MES as follows:

$$I_{HIBS} = 10\log\left(\sum_{n=1}^{N} \frac{EIRP_{HIBS}(n)}{ADL_{HIBS}(n)}\right) - FSL - DPL$$

where:

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$EIRP_{HIBS}(n)$: HIBS maximum e.i.r.p (W/MHz) in cell *n*;

N: number of cells;

$ADL_{HIBS}(n)$: angular discrimination loss of HIBS in cell *n*;

FSL: free space loss (dB) of the separation distance between HIBS and the Interfered station (*D*);

DPL: Depolarization loss (dB) (See section 2.2 of Recommendation ITU-R P.619).

Step 3: Calculate *I/N* as follows:

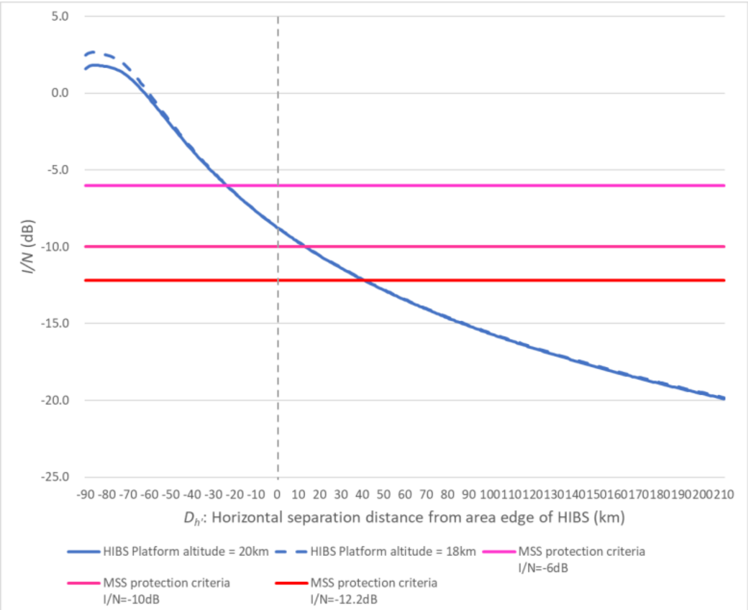
$$\frac{I}{N} = I_{HIBS} - N_{MSS}$$

A4.4.1.5 Study results

The calculation results of *I/N* produced by HIBS at MES are shown in Figure A4.4.1.3.

FIGURE A4.4.1.3

Calculation results of I/N



The horizontal separation distances from area edge of HIBS to comply with MSS protection criteria were 0 km/not required (*I/N*= −6 dB), 14 km (*I/N*= −10 dB) and 42 km (*I/N*= −12.2 dB) in the cases of HIBS operating at the altitude of both 18 km and 20 km.

A4.4.1.6 Summary and analysis of the results of Study A

The results of this study show that the horizontal separation distance from area edge of HIBS to comply with MSS protection criteria in the 2 500-2 535 MHz frequency range is 0 km to 42 km. This means that the compatibility between MSS (s-E) in the 2 500-2 535 MHz frequency range and HIBS in the 2 535-2 690 MHz frequency range could be addressed by maintaining the above-

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mentioned separation distances between the area edge of HIBS and adjacent countries and any HIBS specific mitigation measures to protect MSS (s-E) would not be necessary.

A4.4.2 Study B

*[Editor's note: Concerns were expressed regarding the inclusion of HIBS UEs in studies under WRC-23 agenda item 1.4, as the UE parameters for HIBS are the same as those for ground-based IMT, and Resolution **247 (WRC-19)** strictly limits sharing and compatibility studies only to HIBS and not for ground-based IMT including UEs. In this regard, further consideration of this matter is needed at the next meeting to further discuss the assumptions used in this study.]*

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A4.4.2.1 Introduction

This document includes the Sharing and compatibility studies between Mobile satellite service (MSS) in frequency band of 2 500-2 535 MHz (space-to-Earth) and 2 655-2 690 MHz (Earth-to-space) and HIBS operating in the 2500-2690 MHz frequency range in pursuance with the *resolves to invite ITU-R* 2 of Resolution **247 (WRC-19)** under WRC-23 agenda item 1.4. This study provides assessment of the possible interference from HIBS base station (BS) and user equipment (UE) to the MSS space station receiver and MSS user terminals.

The Study is carried out considering following cases:

– Case I: Adjacent band compatibility study to assess possible interference from HIBS BS to MSS UE in 2 500-2 535 MHz (space-to-Earth).

– Case II: In-band sharing study to assess possible interference from HIBS UE to MSS UE in 2 500-2 535 MHz (space-to-Earth).

– Case III: In-band sharing study to assess possible interference from HIBS BS to MSS space station receiver in 2 655-2 690 MHz (Earth-to-space).

A4.4.2.2 Technical characteristics

This section provides the specific parameters of HIBS used in the study, as provided in Annex 4.19 of Document 5D/716. The specific parameters of MSS used in the study are as per Document 5D/731.

A4.4.2.2.1 Technical and operational characteristics of HIBS systems operating in the 2 500-2 690 MHz frequency range

Below tables show parameters values used for IMT base station and IMT UE in the sharing studies. Only those parameters that are relevant to this study are included.

TABLE A4.4.2.1

HIBS base station specification and deployment related parameters

BS density	1 BS/HIBS area
HIBS altitude	20 km
HIBS transmit antenna pattern	ITU-R M.2101
Channel bandwidth	20 MHz
HIBS network configuration	TDD
HIBS platform e.i.r.p. spectral density/cell	45 dBm/MHz (2nd layer cell) 42 dBm/MHz (1st layer cell)
HIBS area radius	90 Kms
Ohmic losses	2 dB

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Polarization loss	3 dB

TABLE A4.4.2.2

Spectrum mask - HIBS (BS)

Frequency offset from "edge of transmission" Δf	Emission limit	Measurement bandwidth
0 MHz ≤ Δf < 5 MHz	$-7dBm - \frac{7}{5} \cdot \left(\frac{f\_offset}{MHz} - 0.05 \right) dB$	100 kHz
5 MHz ≤ Δf < 10 MHz	−14 dBm	100 kHz
10 MHz ≤ Δf	Spurious domain limits	–

TABLE A4.4.2.3

UE Specification & deployment related parameters

UE density	21 UEs/HIBS area (3 UEs per cell)
UE Height	1.5 m
HIBS UE transmit antenna gain	−3 dBi
Body loss	4 dB
Maximum UE transmitter output power	23 dBm
Ohmic losses	2 dB
Polarization loss	3 dB

A4.4.2.2.2 Technical and operational characteristics of MSS systems operating in the 2 500-2 535 MHz and 2 655-2 690 MHz frequency range

Below tables show parameters values used for MSS in the sharing studies. Only those parameters that are relevant to this study are included.

TABLE A4.4.2.4

MSS receiver parameters (2500-2535 MHz)

Burst rate (Kbps)	2.7-64
Receive antenna (G/T)	−23
User terminal noise temperature	446 K
Peak receive antenna gain (dBi)	3.5 dBi
Note: The values of antenna gain and system noise temperature are not provided by WP 4C in Document 5D/731, though the G/T is retained the same in the study.	

TABLE A4.4.2.5

MSS space station receiver parameters (2655-2690 MHz)

EOC satellite G/T (dB/K)	+6

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Space station receiver noise temp (K)	1 000
Satellite orbital location	83°E
Beam location	North region of Indian Mainland

A4.4.2.2.3 Protection criteria

TABLE A4.4.2.6

MSS Protection criteria for the purpose of sharing and compatibility study for allocations within the 2 500-2 690 MHz range

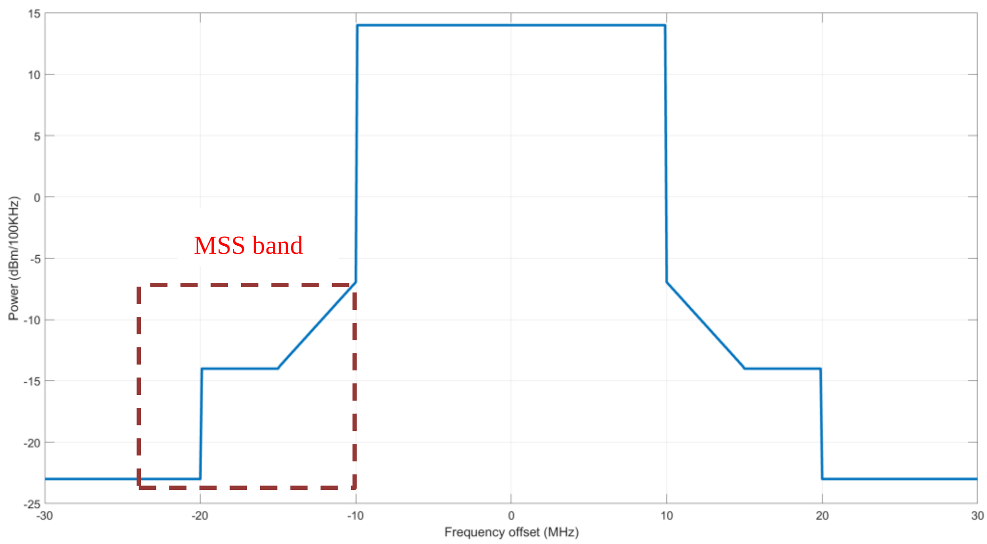
Parameter	Values
For co-frequency sharing and adjacent band compatibility, ΔT/T	6% (I/N = −12.2 dB) or 10% (I/N = −10 dB) or 25% (I/N = −6 dB)

A4.4.2.3.1 Case I: Adjacent band compatibility study to assess interference from HIBS BS to MSS User Terminals in 2 500-2 535 MHz (space-to-Earth)

Considering above technical and deployment related parameters, analysis is carried out to assess the possible interference power received at MSS user terminals due to the OOB emission from HIBS BS. The worst case 1 MHz OOB emission within MSS band (2 500-2 535 MHz) is considered which falls within the signal bandwidth of defined MSS parameters. The spectrum mask of the HIBS BS is shown in Figure A4.4.2.1.

FIGURE A4.4.2.1

HIBS BS emission mask



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Parameters	Unit	Values
Out of band maximum HIBS BS terminal output power/MHz (with 0 MHz Offset)	dBm/MHz	3.1
HIBS BS antenna gain	dBi	8.0
HIBS BS ohmic loss	dB	2.0
HIBS BS polarization loss	dB	3.0
Maximum HIBS BS e.i.r.p. density	dBW/MHz	−23.9
Transmit frequency of BS	MHz	2 535-2 555 MHz
Path length (20 km)	m	20 000
Path loss	dB	126.6
Aggregate received interference density	dBW/MHz	−150.5
MSS user terminal receive antenna gain	dBi	3.5
Aggregate received interference density to the receiver	dBW/Hz	−207
Interference noise temp.	K	144.5
MSS receiver noise temperature	K	446.0
Degradation in noise temp.	%	32.4
I/N	dB	−4.9
Protection criteria	%	6.0 (*I/N* = −12.2 dB)
Exceedance		7.3 dB

Sensitivity Analysis - With respect to HIBS BS altitude change from 20 to 18 Kms, the sensitivity analysis has been carried out. The maximum interference and corresponding exceedance against protection thresholds increases by 0.9 dB for 18 km altitude compared to 20 kms altitude of HIBS BS.

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A4.4.2.3.2 Case II: In-band sharing study to assess interference from HIBS UE to MSS user terminals in 2 500-2 535 MHz (space-to-Earth)

Parameters	Unit	Values		
Maximum HIBS UE terminal output power	dBm	23.0	23.0	23.0
HIBS UT Antenna gain	dBi	−3.0	−3.0	−3.0
HIBS UT body loss	dB	4.0	4.0	4.0
HIBS UT Polarization loss	dB	3.0	3.0	3.0
Maximum HIBS UE e.i.r.p.	dBW	−17.0	−17.0	−17.0
Maximum HIBS UE e.i.r.p. density	dBW/Hz	−90.0	−90.0	−90.0
Transmit Frequency of UE	MHz	2 500-2 520	2 500-2 520	2 500-2 520
Propagation loss (ITU-R P.1812)	dB	127.8	125.6	121.6
Aggregate received interference density	dBW/Hz	−217.8	−215.6	−211.6
MSS user terminal receive antenna gain	dBi	3.5	3.5	3.5
Aggregate received interference density to MSS receiver	dBW/Hz	−214.3	−212.1	−208.1
Interference noise temp.	K	26.9	44.6	111.9
MSS receiver noise temperature	K	446.7	446.7	446.7

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Degradation in noise temp.	%	6.0	10.0	25.1
Protection criteria	%	6.0 (I/N = −12.2 dB)	10.0 (I/N = −10 dB)	25.0 (I/N = −6 dB)
Required keep-out distance to maintain protection criteria	km	6	5	4

A4.4.2.3.3 Case III: In-band sharing study to assess possible interference from HIBS BS to MSS space station receiver in 2 655-2 690 MHz (Earth-to-space)

Methodology: As a case study, aggregate interference from HIBS towards space station receiver located at 83°E longitude is estimated. S-band space station receive beam is directed towards the northern region of Indian mainland for the presented interference analysis. Interference is computed from the in-band emissions from multiple HIBS towards the S-band space station receiver.

– Contribution from all countries in Region 3 which are visible from space station located at 83°E are not considered, as the band 2 655-2 690 MHz is not to be used for HIBS in Region 3, as per *resolves to invite ITU-R* 2 of Resolution **247 (WRC-19)**.

– As a worst case analysis, all countries in Region 1 that are visible from space station located at 83°E are assumed to be fully covered by HIBS operating in 2 655-2 690 MHz band. Approx. 57 523 116 km^2 area (total area of 85 countries in Region 1 that are visible from the space station located at 83°E location) covered by 2222 number of HIBS BS (90 km radius) is considered in assessing the aggregate interference.

– As HIBS are located uniformly over the countries, average path loss and average on-board antenna gain over each country are computed and used in the aggregate interference analysis. Clutter loss is estimated as per ITU-R P.2108.

– Polarization loss of 3 dB is considered between HIBS and on-board space station receiver due to mismatch in the polarization sense of each system and random orientation of each HIBS towards space station receiver.

– In the analysis, azimuth averaged antenna pattern of 2nd layer cell is considered in computing aggregate interference. This is used to estimate the antenna gain towards space station. HIBS BS average antenna pattern (average antenna gain vs. elevation angle) of 2nd layer cell for HIBS with 20 km and 50 km altitudes are shown in Figure 1.

– In the frequency band 2 655-2 690 MHz, there are primary allocations to the fixed service and the mobile service in Region-1. This means that two services could be operating in Region-1 in the frequency band 2 655-2 690 MHz that could be source of undesirable off-axis emissions from Region-1 to the MSS space station. An apportionment of 3 dB in the protection criteria is therefore considered in the analysis.

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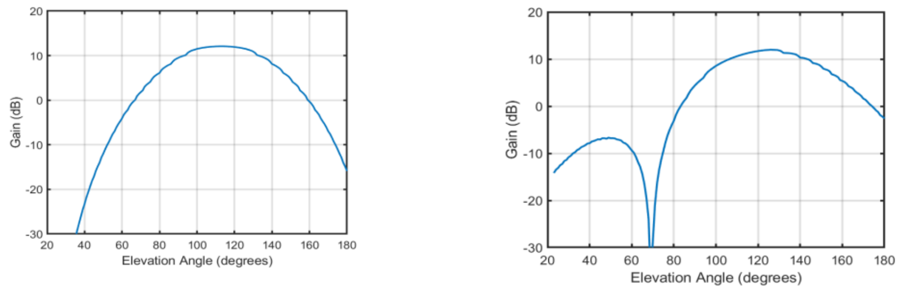
FIGURE A4.4.2.2

HIBS BS average antenna pattern over azimuth



1a. HIBS BS average antenna pattern of 2nd layer cell with 23° mechanical tilt (HIBS Height: 20 km)

1b. HIBS BS average antenna pattern of 2nd layer cell with 23° mechanical tilt and 18° electrical (HIBS Height: 50 km)

Results of interference analysis for in-band cases are shown in Table A4.4.2.7

Parameters	HIBS Altitude	
	20 km	**50 km**
ΔT/T (%)	173	75
I/N Exceedance (in dB) for *I/N*=-12.2 dB criteria	14.6	11.0
I/N Exceedance (in dB) for *I/N*=-10 dB criteria	12.4	8.8
I/N Exceedance (in dB) for *I/N*=-6 dB criteria	8.4	4.8
Applying an apportionment of 3 dB in the protection criteria		
I/N Exceedance (in dB) for *I/N*=-15.2 dB criteria	17.6	14.0
I/N Exceedance (in dB) for *I/N*=-13 dB criteria	15.4	11.8
I/N Exceedance (in dB) for *I/N*=-9 dB criteria	11.4	7.8

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A4.4.2.4 Summary of outcome

A4.4.2.4.1 HIBS BS to MSS user terminal

This adjacent band compatibility study on OOBE interference from HIBS BS (operating in 2 535-2 555 MHz, the band adjacent to MSS) into MSS user terminals operating in the 2 500-2 535 MHz frequency band shows that the *I/N* protection criteria of −12.2 dB is exceeded by about 7.3 dB.

It is to be noted that 7.3 dB exceedance is computed with single element antenna gain. However, as the HIBS BS channel allocation starts immediately after MSS band and there is no frequency separation among them, the single element approximation may not be valid. Hence, for this adjacent band study, if composite antenna is considered then the exceedance would be 13.3 dB.

The maximum interference and corresponding exceedance against protection thresholds increases by 0.9 dB for 18 km altitude compared to 20 kms altitude of HIBS BS.

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Hence, measures like guard band between HIBS and MSS and/or containing the OOBE from HIBS are required in order to ensure coexistence of MSS and HIBS in this band.

A4.4.2.4.2 HIBS UE to MSS user terminal

In-band sharing study on interference from HIBS UE to MSS user terminal in the 2 500-2 535 MHz frequency bands shows the following results:

a) 4 km of protection distance required to meet protection criteria of *I/N* of −6 dB.

b) 5 km of protection distance required to meet protection criteria of *I/N* of −10 dB.

c) 6 km of protection distance required to meet protection criteria of *I/N* of −12.2 dB.

Considering the ubiquitous nature of HIBS UE and MSS user terminals, it would not be practically possible to ensure such large keep-out distances. Hence, the coexistence of HIBS UE and MSS is not possible in this frequency band.

A4.4.2.4.3 HIBS BS to MSS space station receiver

This in-band sharing study on aggregate interference from HIBS BS in Region 1 into MSS satellite receiver with service area in Region 3 in the 2 655-2 690 MHz frequency band shows that the *I/N* is exceeded by 8.4 dB to 14.6 dB for the protection criteria *I/N* range of −6 to −12.2 dB. Further, *I/N* is exceeded by 11.4 to 17.6 dB with 3 dB apportionment in these protection criteria. Hence, the coexistence of HIBS and MSS is not possible in this frequency band.

A4.5 Compatibility studies between radiodetermination satellite service in the adjacent 2 483.5-2 500 MHz (space-to-Earth) band and HIBS operating in the 2 500-2 690 MHz frequency range

A4.5.1 Study A

[*Editor's note: The study may be revised to include the contributions of multiple HIBS for RDSS Types 1, 2 and 3, which earth stations have omni-directional antennas, in case the study is to be validated for cross-border scenario. Also, the updated outcome may be included after revising the Table A4.6.1.4.3.1 for appropriately considering the narrowband and wideband interferences and receiver system noise temperature in calculation of noise spectrum density.*]

This study considered the horizontal separation distance from area edge of HIBS to radiodetermination satellite service (RDSS) receiver based on the calculations of interference-to-noise ratio (*I/N*) in order to evaluate whether HIBS specific mitigation measures would be necessary to protect RDSS (s-E).

A4.5.1.1 Technical and operational characteristics of HIBS in the 2 500-2 690 MHz frequency range

This study used technical and operational characteristics of HIBS in Band 3 (2 500-2 690 MHz frequency range) contained in section 6.1.3 of the working document towards a PDN Report ITU-R M.[HIBS-CHARACTERISTICS]. The single element antenna pattern of Recommendation ITU-R M.2101 was used for this adjacent compatibility study. The value of spurious emissions were selected for "−13 dBm/ MHz" considering Note to the Table 2 of the working document towards a PDN Report ITU-R M.[HIBS-CHARACTERISTICS]. With regard to Platform Altitude, this study considers at 18 km and 20 km in order to perform the sensitivity analysis on the interference from HIBS operating at altitude below 20 km.

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A4.5.1.2 Technical and operational characteristics of RDSS in the 2 483.5-2 500 MHz frequency range

Tables A4.5.1.1 and A4.5.1.2 summarized the technical and operational characteristics of RDSS (s-E) for this study, which are included in Attachment 1 of the liaison statement from WP 4C (5D/731).

TABLE A4.5.1.1

Technical and operational characteristics of RDSS (s-E) receiver

Receiver use cases	Land mobile, aero mobile & maritime mobile			
Types of Receiver	Type-1	Type-2	Type-3	Type-4
Receive Antenna Gain Pattern	Mentioned in Table A4.6.1.2.1-A			
Maximum receive antenna gain	2.3 dBi	2.3 dBi	2.3 dBi	7 dBi
Minimum receive antenna gain	−7 dBi	−7 dBi	−7 dBi	−3 dBi
RF filter 3 dB bandwidth	16.5/24/60/90 MHz			
Pre-correlation filter 3 dB bandwidth	16.5 MHz			
Receiver noise figure	2 dB	3 dB	3 dB	2 dB
Receiver system noise temperature	270 K	389 K	589 K	270 K
Receiver input compression level	−135 dBW			
Receiver survival level	−20 dBW			
Note to the table: The defined receiver input compression level is applicable over corresponding RF filter 3-dB BW				

TABLE A4.5.1.1-A

RDSS Receiver Antenna Gain

Elevation angle (deg)	**Antenna gain (dBic)**	
	Type-1, 2, 3 Receivers	**Type-4 Receiver**
0	−7.0	−3.0
5	−5.5	−2.0
10	−1.4	−0.5
15	0.0	0.0
20	0.8	1.5
25	1.1	2.0
30	1.2	3.0
35	1.2	3.5
40	1.2	4.0
45	1.3	4.5
50	1.3	5.0
55	1.5	5.6
60	1.6	6.2
65	1.8	6.2
70	1.9	6.4

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75	2.1	6.6
80	2.2	6.8
85	2.3	7.0
90	2.3	7.0

TABLE A4.5.1.2

Protection criteria for RDSS system

Types of receiver	**Type-1**	**Type-2**	**Type-3**	**Type-4**
Acquisition mode threshold power density level of aggregate wideband interference (incl. all non-RDSS interferences) at the passive antenna output, *I/N* = −6 dB criteria	−150.3 dBW/MHz	−148.7 dBW/MHz	−146.9 dBW/MHz	−150.3 dBW/MHz
Tracking mode threshold power density level of aggregate wideband interference (incl. all non-RDSS interferences) at the passive antenna output	−144.3 dBW/MHz	−142.7 dBW/MHz	−140.9 dBW/MHz	−144.3 dBW/MHz
Acquisition mode threshold power level of aggregate narrowband interference (incl. all non-RDSS interferences) at the passive antenna output	−160.3 dBW	−158.7 dBW	−156.9 dBW	−160.3 dBW
Tracking mode threshold power level of aggregate narrowband interference (incl. all non-RDSS interferences) at the passive antenna output	−154.3 dBW	−152.7 dBW	−150.9 dBW	−154.3 dBW

Note 1 to the Table: Thresholds for acquisition and tracking modes should account for all the aggregate wideband/narrowband interference other than non-RDSS signals.

Note 2 to the Table: Acquisition and tracking modes wideband/narrowband interference thresholds are defined at the output of receiver antenna. However, interference analysis is to be done considering the peak receive antenna gain in the direction of source of interference.

Note 3 to the Table: Bandwidth of wideband and narrowband interference is defined as ≥1 MHz and ≤700 Hz respectively.

Note 4 to the Table: Presently no ITU-R recommendation exists for the protection criteria for RDSS in the frequency band 2 483.5-2 500 MHz. Studies using this protection criteria for RDSS could be assessed on the basis that these values were put forward by WP 4C to initiate the work for WRC-23 agenda item 1.4 and these values may evolve in the future based on inputs to the ITU-R, but no conclusions on the application of this protection criteria and its associated assumptions should be extrapolated to other studies.

A4.5.1.3 Propagation model

Free space and depolarization loss from Recommendation ITU-R P.619 were used as the baseline propagation model based on section 2.1 of the draft revision of Recommendation ITU-R P.1409-1.

A4.5.1.4 Methodology

This study calculated *I/N* produced by HIBS at RDSS receiver in the interference scenarios of Table A4.5.1.3 and considered the horizontal separation distance from area edge of HIBS to comply with the RDSS protection criteria (*I/N* = −6 dB) in Table A4.5.1.2. Since *invite ITU-R* 2 of Resolution **247 (WRC-19)** limits the studies of the frequency band in 2 500-2 535 MHz for HIBS in uplink only for Region 3, Scenario A-2 for Region 3 did not include 2 500-2 535 MHz for the frequency range of HIBS operation.

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TABLE A4.5.1.3

Interference scenarios

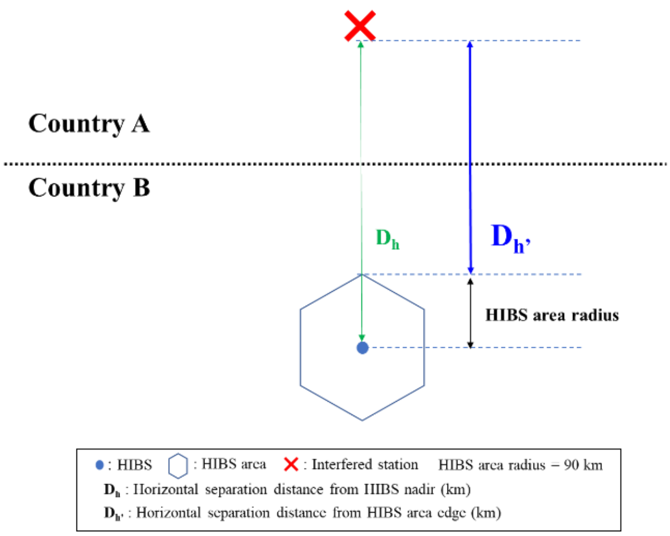
Scenario No.	Interfered service		Interfering services	
	Frequency range	**Interfered Station**	**Frequency range**	**Interfering station**
A-1 (in Regions 1 and 2)	2 483.5-2 500 MHz	RDSS receiver (Type-1/2/3/4)	2 500- 2 690 MHz	HIBS (Platform altitude: 18/20km)
A-2 (in Region 3)	2 483.5-2 500 MHz	RDSS receiver (Type-1/2/3/4)	2 535- 2 690 MHz	HIBS (Platform altitude: 18/20km)

A4.5.1.4.1 Relative relations between HIBS and interfered station

Figure A4.5.1.1 shows the relative relation between HIBS and RDSS receiver. The horizontal separation distance D_h is defined as the distance from the nadir of HIBS to the interfered station. $D_{h'}$ is defined as the distance from the area edge of HIBS to the interfered station. D_h can be calculated as "$D_{h'}=D_h-90$ km (HIBS area radius)".

FIGURE A4.5.1.1

Relative relations between HIBS and interfered station



A4.5.1.4.2 Calculation method of separation distance

The separation distance D between HIBS and the interfered station is calculated by the horizontal separation distance D_h (see also Figure A4.5.1.2) as follows:

$$D = \sqrt{R^2 + (R+H)^2 - 2R(R+H)\cos\left(\frac{D_h}{R}\right)} \quad \text{(km)}$$

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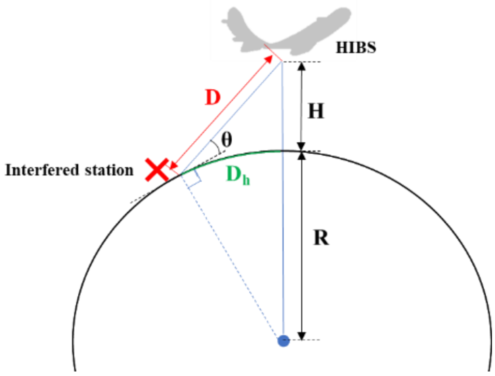
where:

R: Earth radius = 6 378 km;

H: Platform Altitude = 18/20 km.

FIGURE A4.5.1.2

Separation distance from HIBS to Interfered station



A4.5.1.4.3 Calculation method of *I/N*

The following steps were performed to calculate *I/N* produced by HIBS at RDSS receiver.

Step1: Calculate Noise spectrum density (N_{RDSS}) of RDSS receiver as Table A4.5.1.4

TABLE A4.5.1.4

Calculation of Noise spectrum density of RDSS receiver in the 2 483.5-2 500 MHz frequency range

Parameters	**Type-1**		**Type-2**		**Type-3**		**Type-4**	
	Wide band	**Narrowband**	**Wide band**	**Narrowband**	**Wide band**	**Narrowband**	**Wide band**	**Narrowband**
Frequency	2 500 MHz							
Bandwidth	1 MHz	700 Hz	1 MHz	700 Hz	1 MHz	700 Hz	1 MHz	700 Hz
Receiver system noise temperature	270 K		389 K		589 K		270 K	
Receiver noise figure	2 dB		3 dB		3 dB		2 dB	
Noise spectrum density	−142.3 dBW/MHz	−152.3 dBW/700 Hz*	−139.7 dBW/MHz	−149.7 dBW/700 Hz*	−137.9 dBW/MHz	−147.9 dBW/700 Hz*	−142.3 dBW/MHz	−152.3 dBW/700 Hz*
* Noise spectrum density of Narrowband RDSS system was subtracted by 10 dB from that of Wideband RDSS system based on Table A4.6.1.2.2.								

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Since Noise spectrum density for Wideband RDSS system is lower than that for Narrowband RDSS system in all types of RDSS, the values of *I/N* for Wideband RDSS system are smaller than that for Narrowband RDSS system. Therefore, the values of Noise spectrum density for Wideband RDSS system were used in Step 3.

Step 2: Calculate received interference level (I_{HIBS}) of RDSS receiver by HIBS as follows:

$$I_{HIBS} = 10\log\left(\sum_{n=1}^{N}\frac{EIRP_{HIBS}(n)}{ADL_{HIBS}(n)}\right) + ADL_{RDSS} - FSL - DPL$$

where:

- $EIRP_{HIBS}(n)$: HIBS maximum e.i.r.p (W/MHz) in cell *n*;
- N: number of cells;
- $ADL_{HIBS}(n)$: angular discrimination loss of HIBS in cell *n*;
- ADL_{RDSS}: angular discrimination loss of RDSS;
- FSL: free space loss (dB) of the separation distance between HIBS and the Interfered station (*D*);
- DPL: Depolarization loss (dB) (See section 2.2 of Recommendation ITU-R P.619).

Step3: Calculate *I/N* as follows:

$$\frac{I}{N} = I_{HIBS} - N_{RDSS}$$

A4.5.1.5 Study results

The calculation results of *I/N* produced by HIBS at RDSS receiver in Scenario A-1 are shown in Figure A4.5.1.3.

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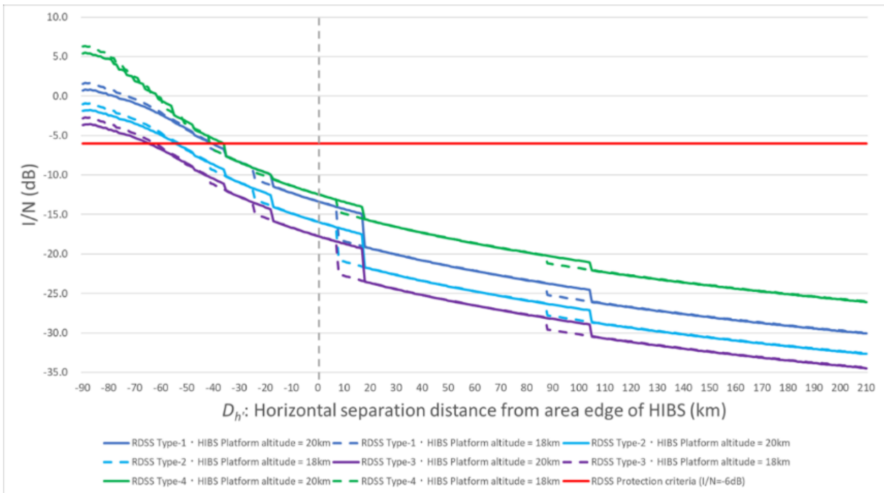
FIGURE A4.5.1.3

Calculation results of *I/N* in scenario A-1
(Compatibility between HIBS in the 2 500-2 690 MHz frequency range in Regions 1 and 2 and RDSS in the 2 483.5 -2 500 MHz frequency range)



The calculation results of *I/N* produced by HIBS at RDSS receiver in Scenario A-2 are shown in Figure A4.5.1.4.

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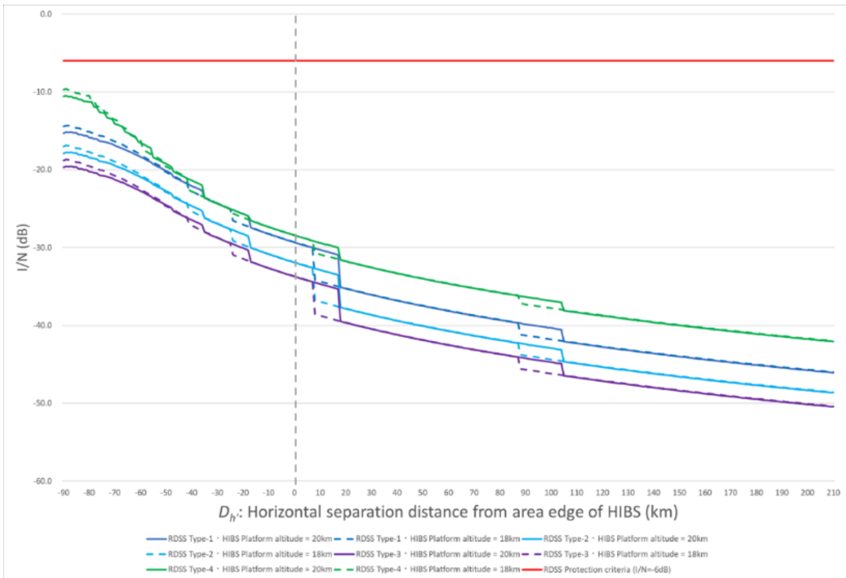
FIGURE A4.5.1.4

Calculation results of *I/N* in scenario A-2
(Compatibility between HIBS in the 2 535-2 690 MHz frequency range in Region 3 and RDSS in the 2 483.5 -2 500 MHz frequency range)



The horizontal separation distances from area edge of HIBS to comply with RDSS protection criteria (*I/N*= −6 dB) is not required in the cases of HIBS operating at the altitude of both 18 km and 20 km in Scenarios A-1 and A-2.

A4.5.1.6 Summary and analysis of the results of Study A

The results of this study show that the horizontal separation distance from area edge of HIBS to comply with RDSS protection criteria in the 2 483.5-2 500 MHz frequency range is not required. This means that any HIBS specific mitigation measures to protect RDSS (s-E) in the 2 483.5-2 500 MHz frequency range from HIBS in the 2 500-2 690 MHz would not be necessary.

A4.5.2 Study B

~~[*Editor's note: Concerns were expressed regarding the inclusion of HIBS UEs in studies under WRC-23 agenda item 1.4, as the UE parameters for HIBS are the same as those for ground-based IMT, and Resolution **247 (WRC-19)** strictly limits sharing and compatibility studies only to HIBS and not for ground-based IMT including UEs. In this regard, further consideration of this matter is needed at the next meeting to further discuss the assumptions used in this study.*]~~

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A4.5.2.1 Introduction

This document includes the compatibility studies between radiodetermination satellite service (RDSS) in frequency band of 2 483.5-2 500 MHz and HIBS operating in the 2 500-2 690 MHz frequency range in pursuance to the *resolves to invite ITU-R* 2 of Resolution **247 (WRC-19)** under WRC-23 agenda item 1.4. This study provides the assessment of possible interference from HIBS base station (BS) and user equipment (UE) to the RDSS in adjacent band.

The Study has been carried out considering the following cases:

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– Case I: HIBS BS to RDSS USER TERMINAL
– Case II: HIBS UE to RDSS USER TERMINAL.

A4.5.2.2 Technical characteristics

This section provides the specific parameters of HIBS used in the included study/studies, as provided in Annex 4.19 of Document 5D/716. The specific parameters of RDSS used in study are as given in Document 5D/731.

A4.5.2.2.1 Technical and operational characteristics of HIBS systems operating in 2 500-2 690 MHz frequency range

Below tables show parameters values used for IMT base station and IMT UE in the sharing studies. Only those parameters that are relevant to this study are included.

TABLE A4.5.2.1

HIBS Base Station Specification & deployment related parameters

BS density	1 BS/HIBS area
HIBS altitude	20 km
Channel bandwidth	20 MHz (2 500-2 520 MHz)
HIBS transmit antenna pattern	– As per ITU-R M.2101 (Single element pattern for Adjacent band studies) – As per ITU-R M.2101 (Composite antenna Pattern)
HIBS network configuration	TDD
HIBS area radius	90 km

TABLE A4.5.2.2

Spectrum mask - HIBS (BS)

Frequency offset from “edge of transmission” Δf	Emission limit	Measurement bandwidth
0 MHz ≤ Δf < 5 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < 10 MHz	-14 dBm	100 kHz
10 MHz ≤ Δf	Spurious domain limits	-

TABLE A4.5.2.3

UE Specification & deployment related parameters

UE density	21 UEs/HIBS area (3 UEs per cell)
UE height	1.5 m
Channel BW	20 MHz (2 500-2 520 MHz)
HIBS UE transmit antenna gain	−3 dBi
Body loss	4 dB
Maximum UE transmitter output power	23 dBm
HIBS UE location	50 000 Random co-ordinates within the analysis region

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	(Area with 90 km radius from HIBS Nadir)

TABLE A4.5.2.4

Spectrum mask – UE served by HIBS

Frequency offset from "edge of transmission" Δ*f*	Emission limit	Measurement bandwidth
$0 \leq \Delta f < 1$ MHz	–13 dBm	0.2 MHz
1 MHz $\leq \Delta f < 5$ MHz	–10 dBm	1 MHz
5 MHz $\leq \Delta f < 15$ MHz	–13 dBm	1 MHz
15 MHz $\leq \Delta f < 25$ MHz	–25 dBm	1 MHz
$\Delta f > 25$ MHz	Spurious domain limits	–

A4.5.2.2.2 Technical and operational characteristics of RDSS systems operating in the 2 483.5-2 500 MHz frequency range

Below tables show parameters values used for RDSS in the sharing studies. Only those parameters that are relevant to this study are included.

TABLE A4.5.2.5

RDSS receiver parameters

RDSS USER TERMINAL antenna gain	Type−1,2,3: −5.5 dBi and Type 4: −2.0 dBi
RDSS USER TERMINAL antenna pattern	As per Table 5a
Receiver input compression level	−135 dBW
RF filter 3 dB bandwidth	16.5/24/60/90 MHz
RDSS USER TERMINAL location	50 000 Random co−ordinates within the analysis region (Area with 90 km radius from HIBS Nadir)

TABLE A4.5.2.5-A

RDSS receiver antenna gain pattern

Elevation angle (deg)	Antenna gain (dBic)	
	Type-1, 2, 3 Receivers	Type-4 Receiver
0	−7.0	−3.0
5	−5.5	−2.0
10	−1.4	−0.5
15	0.0	0.0
20	0.8	1.5
25	1.1	2.0
30	1.2	3.0
35	1.2	3.5
40	1.2	4.0

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45	1.3	4.5
50	1.3	5.0
55	1.5	5.6
60	1.6	6.2
65	1.8	6.2
70	1.9	6.4
75	2.1	6.6
80	2.2	6.8
85	2.3	7.0
90	2.3	7.0

A4.5.2.2.3 Protection criteria

TABLE A4.5.2.6

Protection criteria for RDSS system

Types of receiver	Type-1	Type-2	Type-3	Type-4
Acquisition mode threshold power density level of aggregate wideband interference (incl. all non-RDSS interferences) at the passive antenna output, $I/N = -6$ dB criteria	−150.3 dBW/MHz	−148.7 dBW/MHz	−146.9 dBW/MHz	−150.3 dBW/MHz

In the frequency bands 2 500-2 520 MHz and 2 450-2 483.5 MHz, adjacent bands to RDSS, there are primary allocations to the fixed service and the mobile service in all regions. This means that two services could be operating in in the adjacent bands to RDSS that could be source of undesirable out of band emissions to the RDSS user terminals. An apportionment of 3 dB in the protection criteria is therefore considered in the analysis.

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A4.5.2.3 Case-I HIBS BS to RDSS user terminal

A4.5.2.3.1 Propagation model

Recommendation ITU-R P.1409 (Doc. 5D/723) is used for the possible sharing study scenarios relating to the HIBS and RDSS for the following interference scenarios/paths:

– Interference scenario/path between HIBS and stations on the surface of the Earth.
– Interference scenario/path between HIBS and stations in the atmosphere of the Earth.
– Interference scenario/path between HIBS and stations in the space.

The total propagation loss considered is the sum of free space loss and atmospheric loss. Additionally, the study considered 3 dB of polarization loss.

A4.5.2.3.2 Methodology

Considering above technical and deployment related parameters Monte-Carlo simulations were carried out to find the probabilities of interference power received at RDSS user terminal due to the OOB emission from HIBS BS. The worst case 1 MHz OOB emission within RDSS band is

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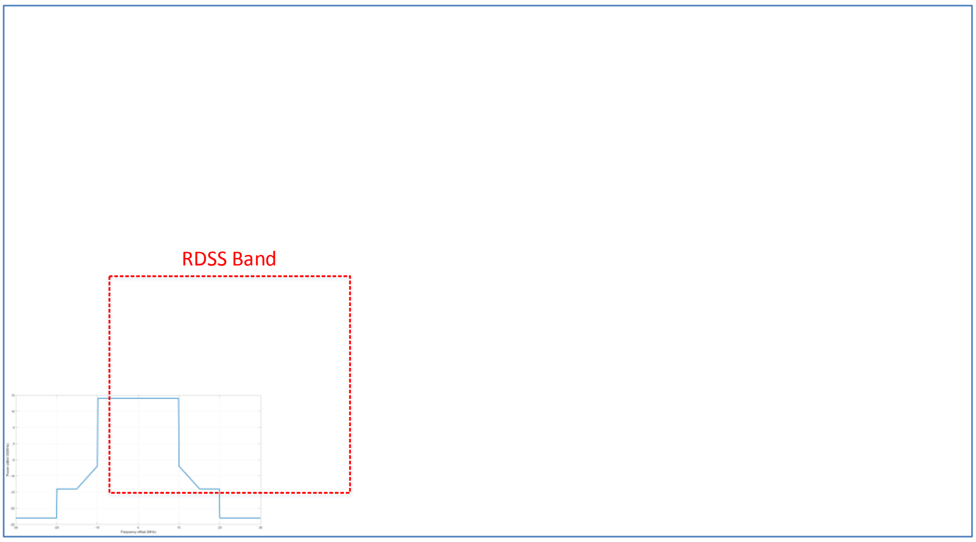
considered which falls within the signal bandwidth of defined RDSS parameters. The spectrum mask of the HIBS BS is shown in Figure A4.5.2.1.

FIGURE A4.5.2.1

HIBS BS Emission mask



For the adjacent band analysis, the single element antenna pattern of HIBS BS has to be used in pursuance with Recommendation ITU-R M.2101. However, as the HIBS BS channel allocation starts immediately after RDSS band and there is no frequency separation among them, the single element approximation may not be valid. Hence, the adjacent band study is carried out considering the composite HIBS BS antenna pattern also. The single element and composite antenna patterns of HIBS BS are shown in Figures A4.5.2.2-A and A4.5.2.2-B.

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FIUGRE A4.5.2.2-A

HIBS BS Single Element Antenna Pattern

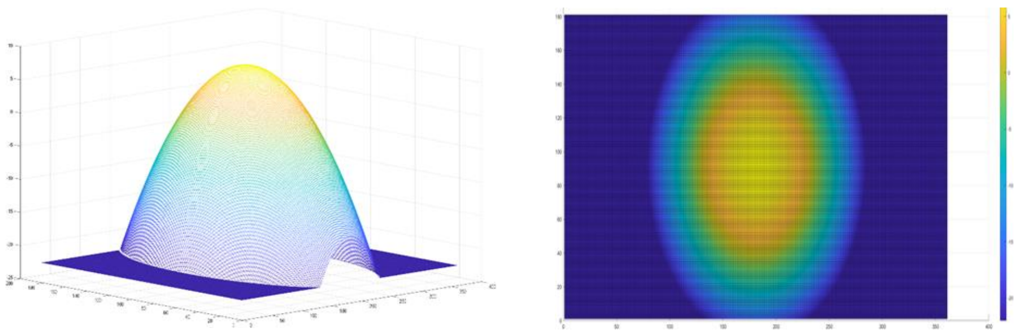
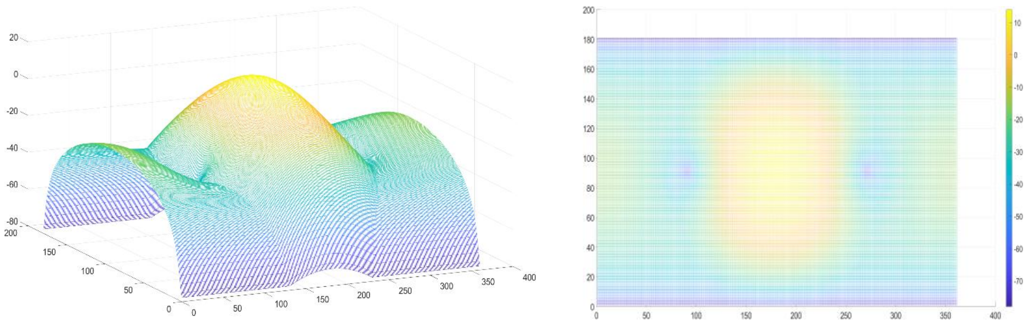


FIGURE A4.5.2.2-B

HIBS BS composite antenna pattern (1st Layer)



A4.5.2.3.3 Case-1: Study with single element antenna pattern for adjacent band

To generate the CDF of received interference power, Monte Carlo simulation with 50000 snapshots was carried out. The study scenario and distribution of RDSS USER TERMINALs is shown in Figure 3a and 3b respectively. The CDFs were obtained for RDSS USER TERMINAL Type 1/2/3 and Type 4 as shown in Figures A4.5.2.4-A and A4.5.2.4-B respectively.

FIGURE A4.5.2.3-A

HIBS BS and study area

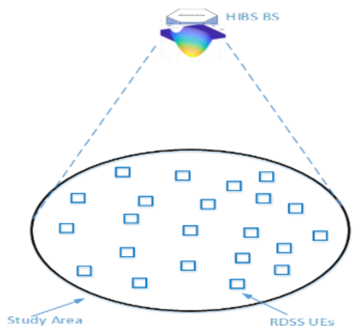


FIGURE A4.5.2.3-B

Distribution of RDSS USER TERMINALs

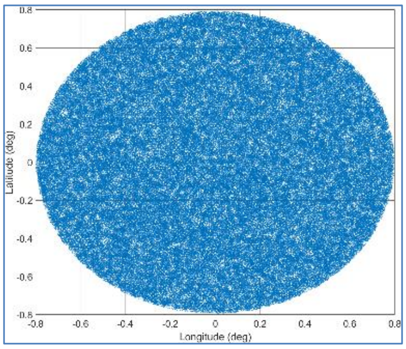


FIGURE A4.5.2.4-A

CDF of HIBS Interference power at RDSS USER TERMINAL Type 1/2/3

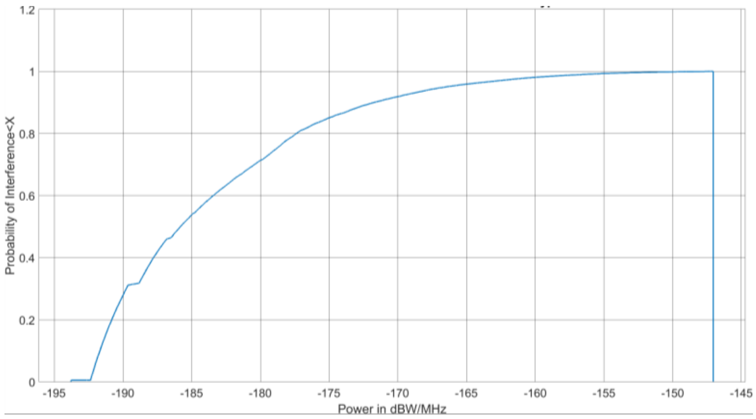


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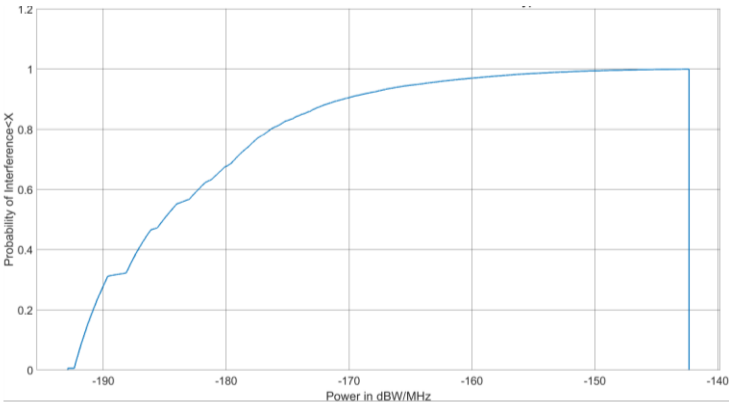
FIGURE A4.5.2.4-B

CDF of HIBS Interference power at RDSS USER TERMINAL Type 4



The HIBS BS interference exceeding the RDSS acquisition mode protection threshold (for wideband interference) defined is included in Table A4.5.2.7.

TABLE A4.5.2.7

HIBS BS interference exceeding the RDSS protection threshold (Single element antenna pattern)

RDSS USER TERMINAL Type	Acquisition mode threshold (wideband interference) (dBW/MHz)	Max interference (dBW/MHz)	Exceedance with respect to protection criteria (dB)
Type - 1	−150.3	−147.0	3.3
Type - 2	−148.7		1.7
Type - 3	−146.9		−0.1
Type - 4	−150.3	−142.3	8

HIBS BS interference exceeding the RDSS protection threshold (Single element antenna pattern) with 3 dB apportionment in the protection criteria

RDSS USER TERMINAL Type	Acquisition mode threshold (wideband interference) (dBW/MHz)	Max interference (dBW/MHz)	Exceedance with respect to protection criteria (dB)
Type - 1	−153.3	−147.0	6.3
Type - 2	−151.7		3.7
Type - 3	−149.9		2.9
Type - 4	−153.3	−142.3	11

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A4.5.2.3.4 Case-1: Study with composite antenna pattern for adjacent band

The HIBS BS deployment characteristics states that the HIBS area consists of 7 cells and each cell is serviced by a single beam as shown in Figure A4.5.2.5. The HIBS area structure is shown in Figure A4.6.2.6.

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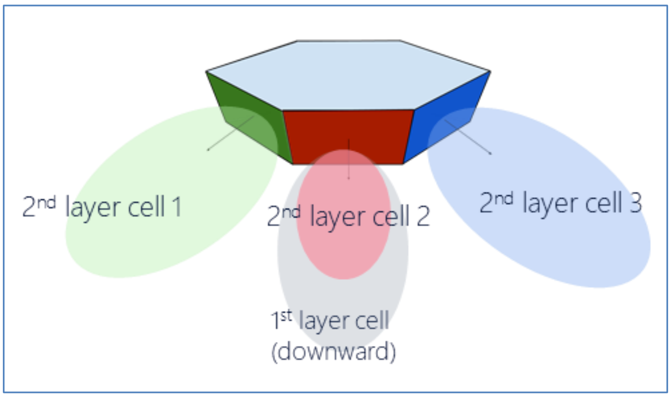
FIGURE A4.5.2.5

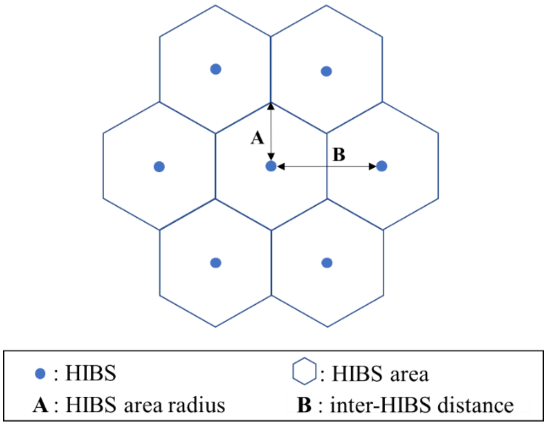
Example of HIBS deployment (7 cells)



The HIBS area structure is shown in Figure A4.5.2.6.

FIGURE A4.5.2.6

HIBS area structure (7 cells)



As the HIBS area radius is defined as 90 km, the radius of each cell can be approximated to 30 km. The HIBS BS antenna generate one beam for each cell, hence the analysis is carried out over a cell area of 30 km radius with composite antenna pattern. To generate the CDF of received interference power, Monte Carlo simulation with 50 000 snapshots was carried out as show in Figure A4.5.2.7. The CDFs were obtained for RDSS USER TERMINAL Type 1/2/3 and Type 4 as shown in Figures A4.5.2.8a and A4.5.2.8b respectively.

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FIGURE A4.5.2.7

Distribution of 50 000 RDSS USER TERMINAL over a cell area

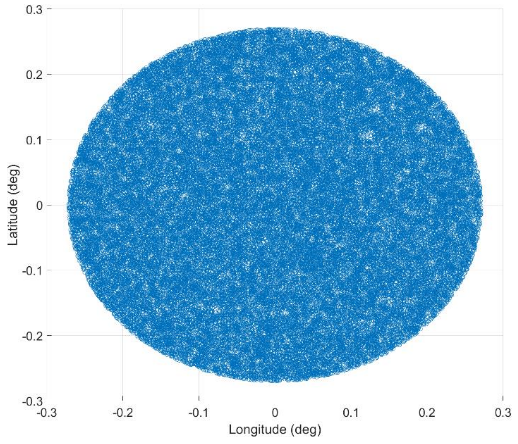

FIGURE A4.5.2.8A

CDF of HIBS Interference power at RDSS USER TERMINAL Type 1/2/3

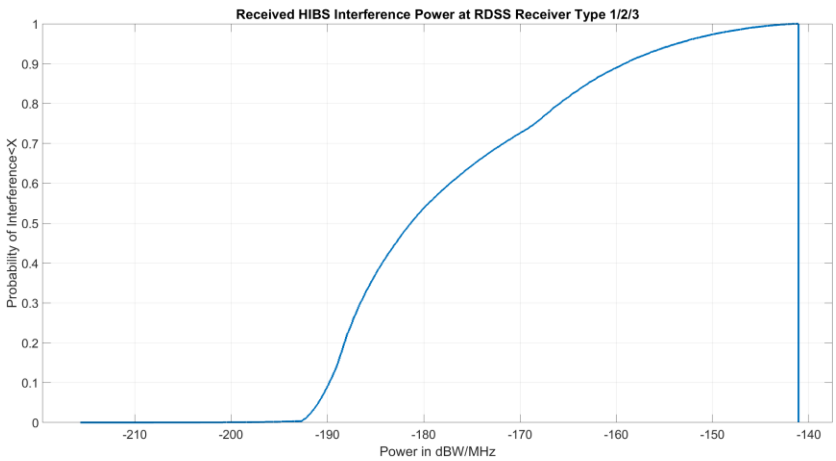

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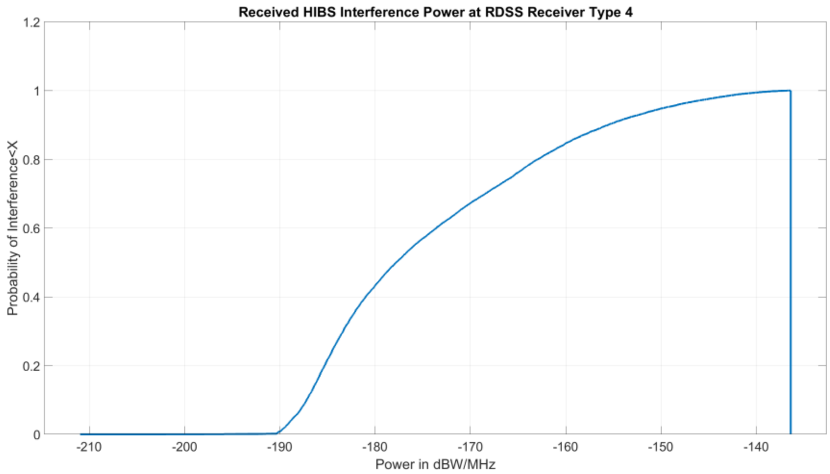
FIGURE A4.5.2.8-B

CDF of HIBS interference power at RDSS USER TERMINAL Type 4



The expected HIBS BS interference exceeding the RDSS acquisition mode protection threshold (for wideband interference) defined, is included in Table A4.5.2.8.

TABLE A4.5.2.8

HIBS BS interference exceeding the RDSS protection threshold (Composite antenna pattern)

RDSS USER TERMINAL Type	Acquisition mode Threshold (wideband Interference) (dBW/MHz)	Max Interference (dBW/MHz)	Exceedance with respect to protection criteria (dB)
Type - 1	−150.3	−141.0	9.3
Type - 2	−148.7		7.7
Type - 3	−146.9		5.9
Type - 4	−150.3	−136.3	14

HIBS BS interference exceeding the RDSS protection threshold (Composite antenna pattern) with 3 dB apportionment in the protection criteria

RDSS USER TERMINAL Type	Acquisition mode Threshold (wideband Interference) (dBW/MHz)	Max Interference (dBW/MHz)	Exceedance with respect to protection criteria (dB)
Type - 1	−153.3	−141.0	12.3
Type - 2	−151.7		10.7
Type - 3	−149.9		8.9
Type - 4	−153.3	−136.3	17

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A4.5.2.3.5 Study for RDSS user terminal blocking / saturation

Due to high e.i.r.p. and OOB emission of HIBS BS there is possibility of RDSS user terminals driven to compression. As defined in Table A4.5.2.5, the receiver input compression level threshold is −135 dBW. This threshold is defined over 3 dB bandwidth of receiver RF filter. Accordingly, Monte Carlo simulations were carried out to find out the probability of HIBS interference levels exceeding the RDSS USER TERMINAL input compression thresholds. This has been done for all the receiver RF filters. Transmit power of HIBS within the receiver BW is estimated as under:

HIBS BS emission mask (with channel Center frequency at 2510 MHz and measurement bandwidth of 0.1 MHz) can be represented as below:

P_mask_hibs:

14 dBm	-	|Δf|<10 MHz
$-7dBm - \frac{7}{5}\cdot\left(\frac{f\_offset}{MHz} - 0.05\right)dB$	-	10 MHz ≤ |Δf|< 15 MHz
-14 dBm	-	15 MHz ≤ |Δf| < 20 MHz
-23 dBm	-	|Δf|>20 MHz

The HIBS BS transmit power is the integrated power over the RDSS receiver RF Filter bandwidth.

$$P_{hibs,\ dBm} = \sum_{f\_low}^{f\_high} P\_mask\_hibs$$

Here, *f_low* and *f_high* are lower and upper ends of RDSS receive RF filter centered at 2491.75 MHz.

-The results are provided in Table A4.5.2.9.

TABLE A4.5.2.9

HIBS BS interference exceeding the RDSS compression threshold

Receive Filter BW	Transmit Power of HIBS (dBm) within the receiver BW	Receiver input compression level threshold (dBW)	Max Interference (dBW/MHz)		Exceedance with respect to protection criteria (dB)	
			Type 1/2/3	Type 4	Type 1/2/3	Type 4
16.5 MHz	8.6	−135	−134.9	−130.2	0.1	4.8
24 MHz	29.9	−135	−113.5	−108.8	21.5	26.2
60 MHz	37.0	−135	−106.4	−101.7	27.6	33.3
90 MHz	39.4	−135	−103.9	−99.2	31.1	35.8

HIBS BS interference exceeding the RDSS compression threshold with 3 dB apportionment

Receive Filter BW	Transmit Power of HIBS (dBm) within the receiver BW	Receiver input compression level threshold (dBW)	Max Interference (dBW/MHz)		Exceedance with respect to protection criteria (dB)	
			Type 1/2/3	Type 4	Type 1/2/3	Type 4
16.5 MHz	8.6	−138	−134.9	−130.2	3.1	7.8
24 MHz	29.9	−138	−113.5	−108.8	24.5	29.2

60 MHz	37.0	−138	−106.4	−101.7	30.6	36.3
90 MHz	39.4	−138	−103.9	−99.2	34.1	38.8

[Editor's note: Further clarifications are needed on the source of "Transmit Power of HIBS (dBm) within the receiver BW".]

Sensitivity Analysis: with respect to HIBS BS altitude change from 20 to 18 Kms, the sensitivity analysis has been carried out. The maximum interference and corresponding exceedance against protection thresholds increases by 0.9 dB for 18 km altitude compared to 20 kms altitude of HIBS BS.

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Comment [P4]: The information on transmit power of HIBS within the receiver BW is provided.

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A4.5.2.4 Case II: HIBS UE to RDSS USER TERMINAL

A4.5.2.4.1 Propagation model

For the possible study scenarios relating to the user equipment (UE) communicating with HIBS (herein called HIBS UE) and RDSS, based on the input from contributing group to WP 5D (Doc. 5D/723), following Recommendations are used:

– Interference scenario/path between HIBS UE and stations on the surface of the Earth, Recommendation ITU-R P.1812
– Interference scenario/path between HIBS UE and stations in the atmosphere of the Earth, Recommendation ITU-R P.528
– Interference scenario/path between HIBS UE and stations in the space, Recommendation ITU-R P.619.

Accordingly, for the study of interference from HIBS BS and RDSS USER TERMINAL the document Recommendation ITU-R P.1812 has been followed. Additionally, the study considered 3 dB of polarization loss.

A4.5.2.4.2 Methodology

Considering above technical and deployment related parameters Monte-Carlo simulations were carried out to find the probabilities of Interference power received at RDSS USER TERMINAL due to the OOB emission from HIBS UE. The worst case 1 MHz OOB emission within RDSS band has been considered which falls within the signal bandwidth of defined RDSS parameters. The spectrum mask of the HIBS UE is shown in Figure A4.5.2.9.

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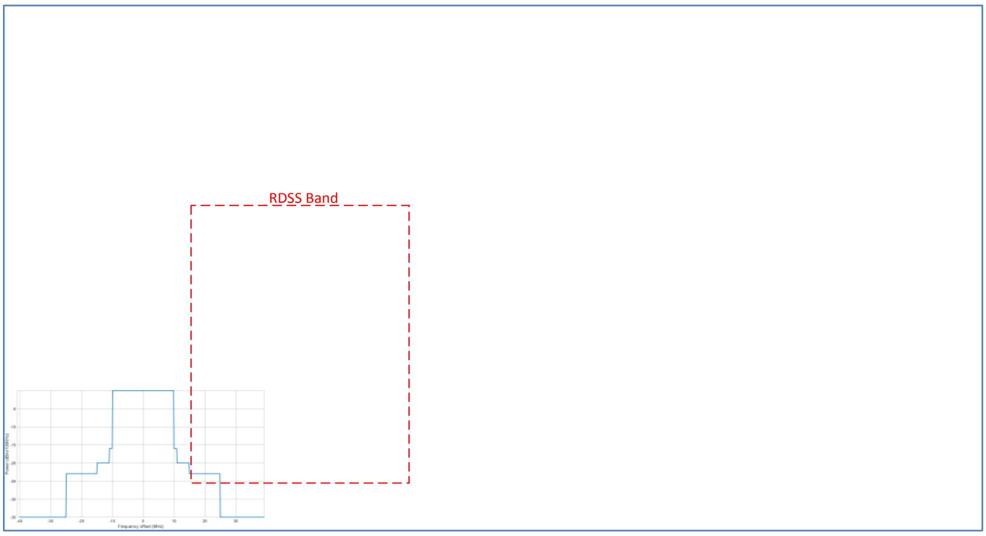
FIGURE A4.5.2.9

HIBS UE emission mask



To generate the CDF of received interference power, Monte Carlo simulation with 50 000 snapshots was carried out. The typical single simulation snapshot is shown in Figure A4.5.2.10. The received interference power is aggregate of all 21 HIBS UEs within the study area. The CDFs were obtained for RDSS USER TERMINAL Type 1/2/3 and Type 4 separately as shown in Figures A4.5.2.11a and A4.5.2.11b.

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FIGURE A4.5.2.10

Typical snapshot of the simulation scenario

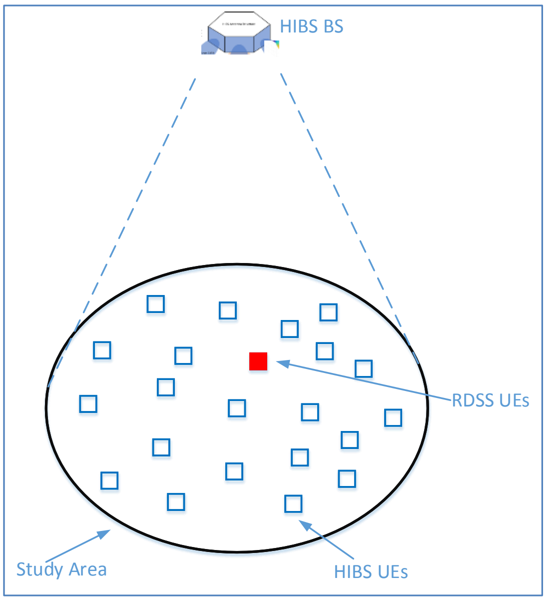

FIGURE A4.5.2.11-A

CDF of HIBS UE interference power at RDSS USER TERMINAL Type 1/2/3

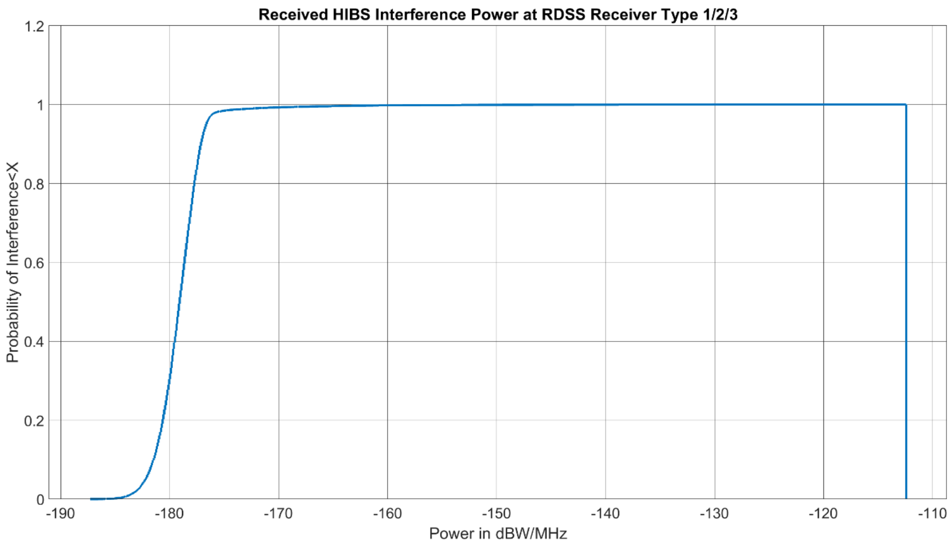

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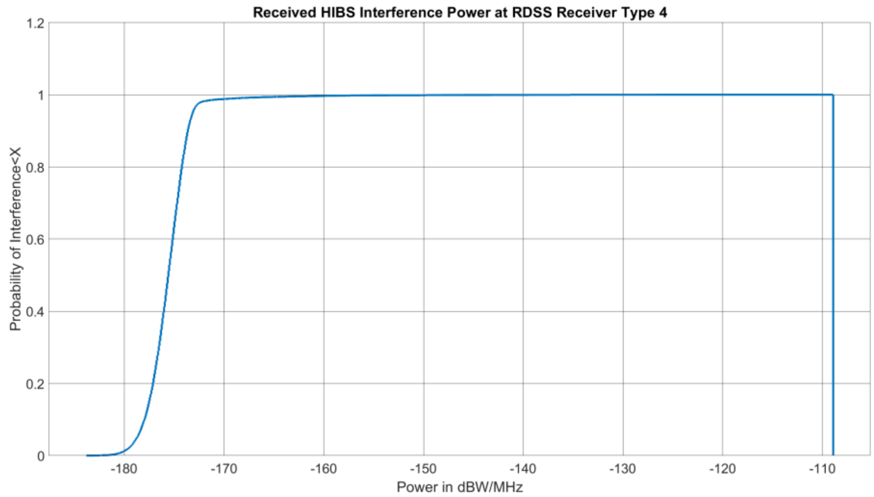
FIGURE A4.5.2.11-B

CDF of HIBS UE interference power at RDSS USER TERMINAL Type 4



The expected HIBS UE interference exceeding the RDSS protection threshold (for wideband interference) defined and is shown in Table A4.5.2.10.

TABLE A4.5.2.10

HIBS UE interference exceeding the RDSS protection threshold

RDSS USER TERMINAL Type	Acquisition mode Threshold (wideband Interference) (dBW/MHz)	Keep out distance (meters)	Max Interference (dBW/MHz)	Exceedance with respect to protection criteria (dB)
Type 1	−150.3	460	−112.4	37.9
Type 2	−148.7	420		36.3
Type 3	−146.9	370		34.5
Type 4	−150.3	580	−108.9	41.4

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HIBS UE interference exceeding the RDSS protection threshold with 3 dB apportionment

RDSS USER TERMINAL Type	Acquisition mode Threshold (wideband Interference) (dBW/MHz)	Keep out distance (meters)	Max Interference (dBW/MHz)	Exceedance with respect to protection criteria (dB)
Type 1	−153.3	540	−112.4	40.9
Type 2	−151.7	490		39.3
Type 3	−149.9	440		37.5
Type 4	−153.3	660	−108.9	44.4

Note to above Table ~~10~~: The maximum interference has occurred at 10 meters distance between HIBS UE and RDSS UE. However, as both HIBS and RDSS USER TERMINALs are mobile, the maximum interference power can be higher than the shown value depending on the distance between HIBS and RDSS user terminals.

A4.5.2.5 Summary of outcome:

A4.5.2.5.1 HIBS BS to RDSS USER TERMINAL:

a) The adjacent band study is carried out considering single element and composite antenna patterns for HIBS BS. Considering that there is no gap between RDSS and proposed HIBS spectrum band, composite antenna pattern analyses is relevant.

b) The interference due to OOB emission of HIBS BS to RDSS USER TERMINAL is exceeding the protection threshold with significant probability. This can be avoided by reducing the worst-case HIBS OOB emissions in any 1 MHz within the RDSS band by at least ~~14~~ 17 dB.~~.~~

c) To protect the RDSS receiver from compression/blocking, the total HIBS OOB emission within the RDSS band needs to be reduced by at least ~~5~~ 8 dB.

d) To protect the RDSS receiver with wide RF filters from compression, the total HIBS e.i.r.p. has to be reduced by ~~26 to 36~~ 29 to 39 dB.

e) The maximum interference and corresponding exceedance against protection thresholds increases by 0.9 dB for 18 km altitude compared to 20 kms altitude of HIBS BS.

Considering the amount of exceedance in all cases, coexistence of HIBS and RDSS in the adjacent band may not be possible.

A4.5.2.5.2 HIBS UE to RDSS USER TERMINAL

a) The interference due to OOB emission of HIBS UE to RDSS USER TERMINAL is exceeding the protection threshold in the range of 34.5 to 41.4 dB requiring the keep-out distances in the range of 370-~~5~~480 meter to meet the protection criteria. Protection threshold is further increases in the range of 37.5 to 44.4 dB and requiring the keep-out distances in the range of 440-660 meter to meet the protection criteria *with* 3 dB apportionment.

b) The maximum interference from HIBS UE to RDSS USER TERMINAL will depend on distance among the UEs, and can be significantly higher than the RDSS protection thresholds.

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Considering the ubiquitous nature of HIBS UE and RDSS user terminals, it is not practically possible to ensure the required keep-out distances to meet the protection criteria. Hence, the coexistence of HIBS and RDSS may not be possible in these adjacent frequency bands.

A4.6 Compatibility studies between aeronautical radionavigation service in the adjacent 2 700-2 900 MHz band and HIBS operating in the 2 500-2 690 MHz frequency range

[Editor's note: In order to facilitate the comparison of results among different studies, it is invited that the summary and analysis of each study contains the different elements used, including among others, the AAS antenna pattern, propagation model (and % used), use of polarization loss, use of CDF, pfd, and protection criteria. Common agreement on each of these elements would facilitate comparison of studies.]

A4.6.1 Study A

This study is revised to consider the discussions that occurred during the June 2021 WP 5D meeting.

This study evaluates possible interference from a High-altitude platform station as IMT Base Station (HIBS). The user equipment is not considered as a source of interference in this case.

Abbreviations and acronyms

ARNS	Aeronautical Radio Navigation Service
ATC	Air Traffic Control
BS	Base station
BW	Bandwidth
e.i.r.p.	Equivalent isotopically radiated power
FDD	Frequency division duplex
FDR	Frequency dependent rejection
H/V	Horizontal/vertical
HIBS	High-altitude platform station as IMT Base Stations
I/N	Interference-to-noise ratio
IMT	International Mobile Telecommunications
NF	Noise Figure
Ptx	Transmit power
TDD	Time division duplex
UE	User equipment (user terminal)

A4.6.1.1 Technical and operational characteristics of HIBS operating in the 2 500-2 690 MHz frequency range

HIBS stands for a High-altitude platform station as IMT Base Stations. A high-altitude platform station is defined in RR No. **1.66A** as a "A station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth". RR No. **4.23** limits transmissions to or from high altitude platform stations to bands specifically identified in Article **5**.

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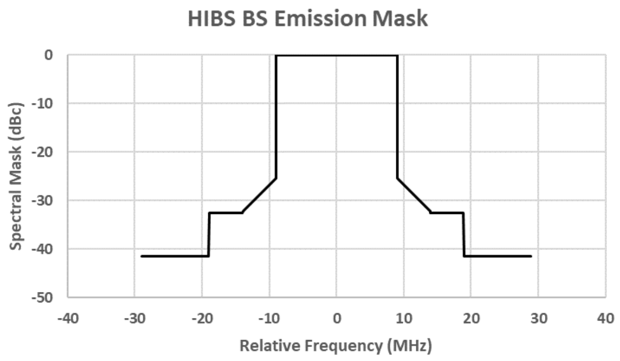
In this document analysis is conducted to determine the effect of the HIBS base station transmissions on selected radionavigation radar found in ITU-R Recommendation ITU-R M.1464.The HIBS user equipment are not considered as a source of interference in this case.

HIBS parameters are found in Annex 4.19 to Working Party 5D Chairman's Report titled "WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[HIBS-CHARACTERISTICS]/WORKING DOCUMENT RELATED TO WRC-23 AGENDA ITEM 1.4. (Spectrum needs, USA 9/16/21ge and deployment scenarios, and technical and operational characteristics for the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT)". The HIBS parameters are not repeated in this document.

The calculated HIBS emission mask, with Spurious domain limits of -13 dBm/MHz, is used to calculate the radar frequency dependent rejection (FDR) is provided in the figure below.

FIGURE A4.6.1.1



A4.6.1.2 Technical and operational characteristics of aeronautical radionavigation radars used for air traffic control at airports

The frequency band 2 700-2 900 MHz is allocated on a primary basis to the aeronautical radionavigation service (ARNS) in ITU R for land-based fixed radars and is extensively used by critical radars such as Air Traffic Control (ATC). The radar operating frequencies can be assumed to be uniformly distributed throughout this band. Most radars use more than one frequency to achieve the benefits of frequency diversity to improve target detection. It is important to note that these radars use a cosecant squared antenna pattern defined by the required operation as shown in the figure below.

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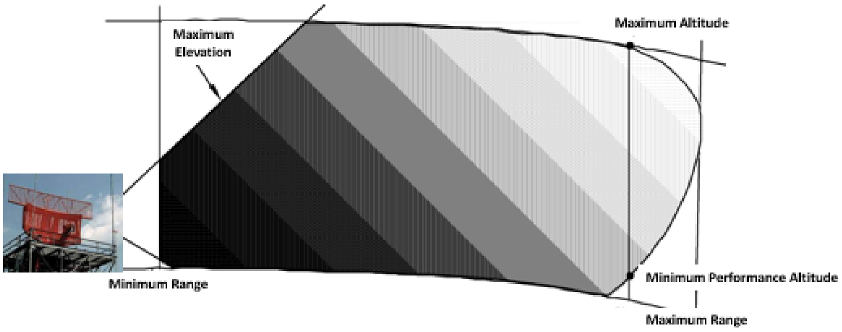
FIGURE A4.6.1.2

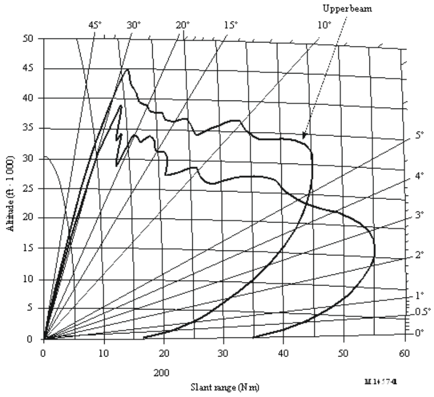
ATC Radar Cosecant Squared Pattern Requirement



These radars operate using two beams, a low beam, and a high beam, with offset from each other in elevation as portrayed below. In this study the low and high beams susceptibility to possible interference from a HIBS platform located at a maximum height of 20 km was evaluated. The analysis is not valid for other HIBS altitudes. Typical antenna patterns for both high and low beams are shown in the figure below.

FIGURE A4.6.1.3

ATC Radar Cosecant Squared Patterns (M.1464)



The table below, an extract from Recommendation ITU-R M.1464, contains technical characteristics of representative aeronautical radionavigation ATC radars B and C that are deployed in the frequency band 2 700-2 900 MHz in the United States of America. It should be noted that radars with similar characteristics are used on a global scale and similar radars are also used by operators of airports located on government-owned facilities for the purpose of air navigation.

TABLE 4.6.1.1

Characteristics of ground-based aeronautical radionavigation radars in the frequency band 2 700-2 900 MHz (ITU-R M.1464)

Characteristics	Units	Radar B	Radar C
Transmitter power into antenna	kW	1 320	25
Pulse width	□s	1.03	1.0, 89
Duty cycle	%	0.14 maximum	9.34 maximum
RF emission bandwidth: –20 dB	MHz	5	2.6 (short pulse)

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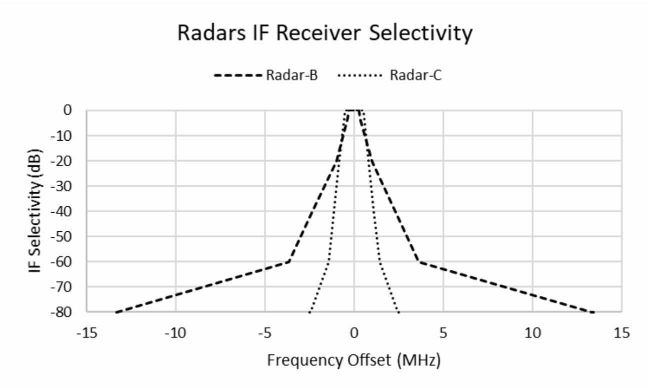
Characteristics	Units	Radar B	Radar C
			5.6 (long pulse)
RF emission bandwidth: –3 dB	MHz	0.6	1.9
Antenna pattern type	degrees	Cosecant-squared +30	Cosecant-squared 6 to +30
Antenna type		Parabolic reflector	Parabolic reflector
Antenna polarization		Vertical or right hand circular polarization	Circular or linear
Antenna main beam gain	dBi	33.5	34
Antenna elevation beamwidth	degrees	4.8	4.8
Antenna azimuthal beamwidth	degrees	1.3	1.45
Antenna horizontal scan rate	degrees/s	75	75
Antenna side lobe (SL) levels (1st SLs and remote SLs)	dBi	+7.3	+9.5 3.5
Antenna height	m	8	8
Receiver IF 3 dB bandwidth	MHz	0.7	1.1
Receiver noise figure	dB	4	3.3
Minimum discernible signal	dBm	–108	–110
Receiver front-end 1 dB gain compression point	dBm	–6	–14
Receiver on-tune saturation level	dBm	–45	
Receiver RF 3 dB bandwidth	MHz	12	345

The ATC radars receiver Intermediate Frequency (IF) selectivity is shown in the figure below.

FIGURE A4.6.1.4



A4.6.1.2.1 Cosecant-Squared (CSC^2) Radar Antenna Pattern Description

The following section describes the method used to calculate the CSC^2 Radar antenna pattern for this analysis. A cosecant-squared beam is a fan beam in which the elevation pattern above the main lobe follows the gain relationship for both radars B and C given by ITU-R Recommendation M.1851 as:

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$$G(\theta) = G(\theta_{Start}) \cdot \left(\frac{CSC(\theta)}{CSC(\theta_{Start})}\right)^2, \qquad \theta_{Start} \le \theta \le \theta_{Max}$$

where

$G(\theta)$: cosecant squared pattern between angles of θ_{Start} and θ_{Max};

$G(\theta_{Start})$: the gain pattern value at θ_{Start} is given by $\frac{sin\left(\frac{\pi \cdot 50.8 \cdot sin(\theta_{Start})}{\theta_3}\right)}{\frac{\pi \cdot 50.8 \cdot sin(\theta_{Start})}{\theta_3}}$;

θ_{start}: elevation of the half-power beamwidth, θ_3, point on the main lobe where CSC^2 pattern starts. This value is $\frac{\theta_3}{2} + \theta_{Tilt}$;

θ_{Min}: One half $\frac{sin(x)}{x}$ antenna pattern Null-to-Null beamwidth given by $\frac{\theta_3}{0.88}$ in degrees. Using the antenna beam pointing angle, the value for θ_{Min} is $\theta_{Tilt} - \frac{\theta_3}{0.88}$ in degrees. This defines the lowest value of the $\frac{sin(x)}{x}$ pattern. Beyond this value, the antenna gain is 55 dB less than the antenna peak gain (front-to-back ratio is 55 dB);

θ_{Max}: maximum angle where cosecant-squared pattern stops. Beyond this value, the antenna gain is 55 dB less than the antenna peak gain (front-to-back ratio is 55 dB);

θ: angle to evaluate the antenna pattern (degrees);

θ_3: half power antenna beamwidth (degrees);

θ_{Tilt}: Antenna beam tilt elevation angle or beam pointing angle (degrees).

The cosecant pattern is applied as shown in the table below:

TABLE 4.6.1.2

Cosecant-squared antenna pattern equations

Cosecant-squared equation	**Condition**	**Comment**
Cosecant floor level (example = −55 dB + Peak antenna gain)	$\theta \le \theta_{Min}$	At angles less than θ_{Min} use -55 dB front to back ratio (-55 dB+Peak antenna gain)
$\frac{sin(\mu)}{\mu}$; $\mu = (\pi \cdot 50.8 \cdot sin(\theta - \theta_{Tilt}))/\theta_3$	$\theta > \theta_{Min}$ & $\theta < \theta_{start}$	Use $\frac{sin(x)}{x}$ from the lower one half the null to-null beamwidth to the start of the CSC^2 pattern at θ_3 *or* θ_{start} whichever is provided
$G(\theta_{Start}) \cdot \left(\frac{CSC(\theta)}{CSC(\theta_{Start})}\right)^2$	$\theta \ge \theta_{Start}$ & $\theta < \theta_{MAx}$	Start the CSC^2 pattern up to the maximum CSC^2 angle
Cosecant floor level (example = −55 dB + Peak antenna gain)	$\theta \ge \theta_{Max}$	At angles greater than θ_{Max} use -55 dB front to back ratio (-55 dB+Peak antenna gain)

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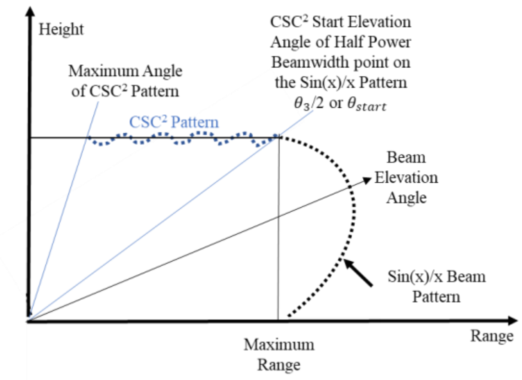
Cosecant-squared equation	Condition	Comment
$G(\theta_{Start}) = \frac{sin\left(\frac{\pi \cdot 50.8 \cdot sin(\theta_{Start})}{\theta_3}\right)}{\frac{\pi \cdot 50.8 \cdot sin(\theta_{Start})}{\theta_3}}$	Antenna gain where the CSC[2] patterns starts	The gain at θ_{Start} is the gain of the $\frac{sin(x)}{x}$ pattern at θ_{Start}. The pattern gain is lower than the peak antenna gain by 3 dB at θ_{Start}

A graphical representation of the radar coverage using the CSC[2] patterns is shown in the Figures below.

FIGURE A4.6.1.5

Cosecant squared beam coverage for search radar



An example using the above procedure provides an antenna pattern for radar B and shown below.

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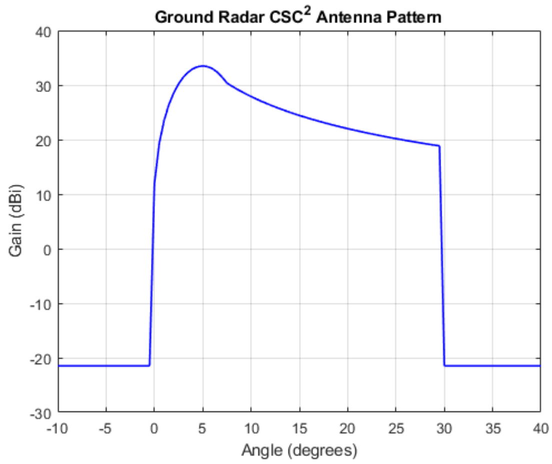
FIGURE A4.6.1.6

Radar-B Cosecant Squared (CSC^2) Beam Pattern centred at 5°



A4.6.1.3 Propagation Models

The propagation model used is contained in Recommendation ITU-R P.528 “A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands”.

This Recommendation can be used to calculate the expected protection ratio or wanted-to-unwanted signal ratio exceeded at the receiver for at least 95% of the time, R (0.95). This calculation requires the following additional data for both the wanted and unwanted signals: the transmitted power, the gain of transmitting antenna, and the gain of receiving antenna.

The use of the band 2 700-2 900 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders when actuated by radars. Ground-based radars including ATC radar operating in the aeronautical radionavigation service provide and are used for the safeguarding of human life and property, so RR No. **4.10** applies to these radars. For this HIBS interferer analysis, a time availability value of 0.05 is used, noting that other representative or sensitivity analysis values could be considered.

In addition, taking into account both these radars and the HIBS operate in clutter free surroundings, to account for clutter when HIBS is near the horizon, an additional 30 dB loss (approximated from Rec. ITU-R P.2108) is included at the radio horizon to eliminate HIBS interference from such distances at or beyond the radio horizon due to clutter.

A4.6.1.4 Analysis Scenario and Assumptions

In the United States of America, for example, ATC radars are used in many large civilian airports as shown in the figure below. The blue squares represent the radar locations. The situation will be different for other countries and the density for ATC radars might be more or might be less.

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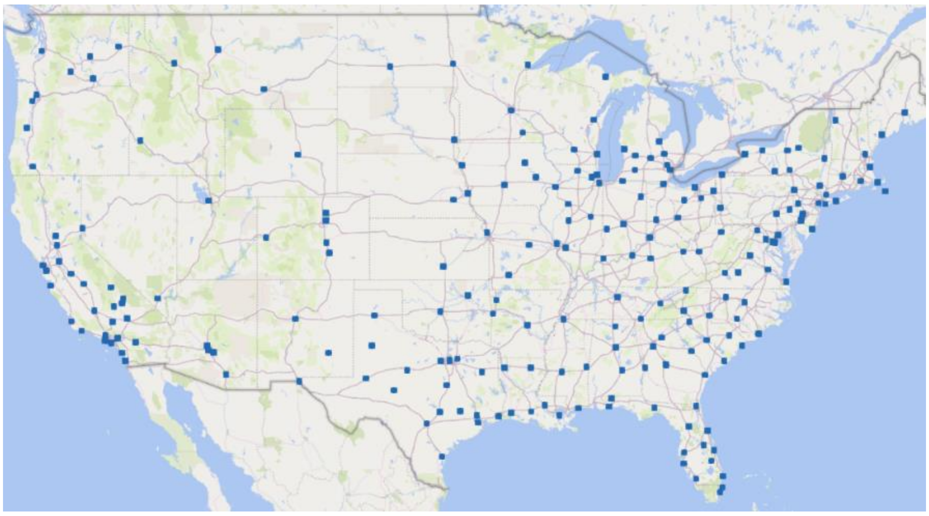
FIGURE A4.6.1.7

Map of ATC radars operating in the 2 700-2 900 MHz frequency band in the USA

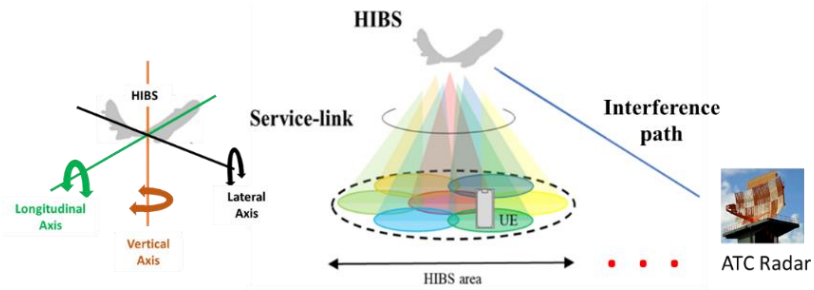


The analysis scenario is set such that a single HIBS with its service links is placed at fixed points in latitude and longitude. The ATC radar is randomly placed in a circle with a 550 km radius from the HIBS center. For each latitude and longitude point, the aggregate I/Ns of all seven HIBS beams are collected at each distance. Interference to noise values that exceed the ATC radar protection criteria of I/N = -6 dB, or -10 dB are then plotted.

Note that for the victim radars, the HIBS vertical axis orientation of the 2nd layer in azimuth is unknown. Note that from Document 5D/716 Annex 4.19 paragraph 6.1.2 System architecture there is text as follows “Moreover, HIBS are likely to move up/down and/or turn during a day, depending on the type of carriers, and certain measures to maintain the footprints (e.g., beamforming, mechanical tilt) would be implemented to ensure stable mobile connectivity.” This means that the orientation of the HIBS beams towards the ATC radar is not known ahead of time as the HIBS turns during the day.

FIGURE A4.6.1.8

Interference Path and HIBS Possible Vertical Axis Orientation



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The following assumptions are used in the analysis:

1 ATC radar location is random within a 550 km radius from HIBS.

2 ATC radar antenna beam rotates at 75 degrees per second starting at zero azimuth.

3 ATC radar upper beam antenna pattern elevation angle is set to +5° and the lower beam is set at 2°. The 3D antenna pattern is generated using ITU-R Recommendation M.1851 as shown in the cosecant-squared (CSC^2) radar antenna pattern description. The azimuth patterns is generated using Recommendation ITU-R M.1851 with average envelope cosine pattern. The front-to-back 3D antenna pattern is 55 dB.

4 ATC radar receiver center frequency is set to 2 705 MHz to ensure that the ATC radar necessary bandwidth is inside the allocated frequency band.

5 Only one HIBS is included in the analysis. If more HIBS are present in or near the radar azimuth beamwidth, the interference levels may increase.

6 HIBS Frequency reuse of one is used.

7 HIBS location is fixed.

8 HIBS center frequency is 2 680 MHz.

9 FDR is considered for the selected frequency separation.

10 Propagation model used is Recommendation ITU-R P.528 with a time availability value of 0.05 (5%).

11 Additional loss of 30 dB is applied to HIBS interference values at smooth spherical Earth horizon.

12 Antenna polarization discrimination is 3 dB.

A4.6.1.4.1 Advanced Antenna System (AAS) with modified d/ parameter in the adjacent band

This section employs procedures found in annex 2.4 of document 5D/716 annex 4.6 titled "Adjustments to Advanced Antenna System (AAS) Antenna Pattern for adjacent frequency band Source: Document 5D/936". The procedure is described below. This same procedure was used in previous WRC work.

AAS needs its antenna elements correlated to generate narrow beams towards specific directions. Antenna elements correlation outside the designed frequency band of operation is not well defined, but the antenna elements are expected to gradually lose the correlation observed in the operational band as the frequency offset increases outside that band. For the HIBS compatibility analysis where HIBS operate at a centre frequency of 2.68 GHz and the Radars operate at 2.705 GHz, it is reasonable to consider that HIBS antennas designed to operate in a wide frequency band will generally keep a level of correlation between their elements along the frequency offset that includes the Radar frequency.

In this study it is assumed that the HIBS antenna pattern may remain beamformed especially for small frequency offset between HIBS operating frequency band and the radar operating frequency. To generate the HIBS AAS beam pattern at the radar frequency, an adjustment to the element spacing d/λ is required. From the electromagnetic wave equation:

$$c = f \times \lambda$$

where

c : speed of light (m/s);

f : frequency (Hertz);

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λ : wavelength (meter).

With HIBS centre frequency f_0 = 2.68 GHz, and the radar centre frequency f_1 = 2.705 GHz and with HIBS AAS design $\frac{d}{\lambda_0} = 0.5$, the equation can be written as:

$$c = f_0 \times \lambda_0 = f_1 \times \lambda_1$$

$$\frac{\lambda_0}{\lambda_1} = \frac{f_1}{f_0}$$

$$\frac{d}{\lambda_1} = \frac{f_1}{f_0} \times 0.5,$$

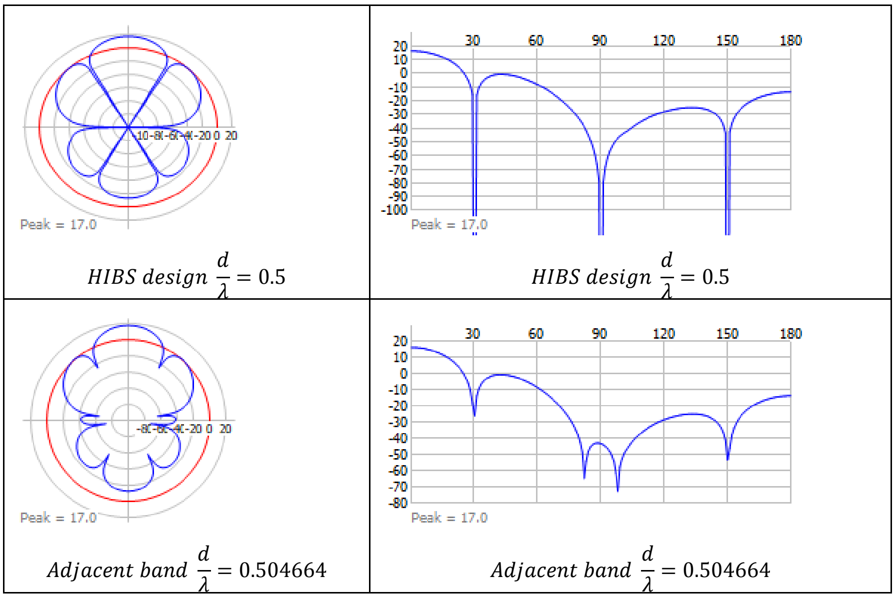
resulting in adjacent band $\frac{d}{\lambda_1}$ of:

$$\frac{d}{\lambda_1} = 0.504664$$

The AAS model from Recommendation ITU-R M.2101 is used with a modified $\frac{d}{\lambda_1}$ to generate a new antenna pattern and calculate the interference results. A comparison between two sets of d/λ element spacings is shown in the Figure below.

FIGURE A4.6.1.9

HIBS 4x2 antenna pattern with different d/λ



A4.6.1.5 Preliminary summary of results

The plots below show the interference results for ATC Radar B and Radar C with respect to HIBS. The plots represent the fixed location HIBS with random distances for radars B and C.

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The resulting ground separation distance between HIBS and ATC radars are provided in the table below. One day worth of data collected at one second step size is repeated ten times with different Monte-Carlo random seed numbers in the simulation. Results show that the median separation distance required varies from 289 to 487 km depending on radar type, radar beam elevation angle and I/N protection criteria

TABLE 4.6.1.3

Preliminary Results for 10 Simulations of One Day Each Sampled Every Second

Rec. ITU-R M.1464	**Radar B**	**Radar B**	**Radar C**	**Radar C**	**Radar B**	**Radar B**	**Radar C**	**Radar C**
Beam Elevation Type	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Protection Criteria I/N (dB)	**-6**	**-6**	**-6**	**-6**	**-10**	**-10**	**-10**	**-10**
Simulation-1	406	282	406	305	488	342	488	363
Simulation-2	396	296	396	296	477	342	477	342
Simulation-3	390	288	416	303	485	351	487	363
Simulation-4	375	282	416	293	479	347	494	355
Simulation-5	387	298	387	298	476	301	476	365
Simulation-6	404	290	410	300	471	339	497	339
Simulation-7	404	269	404	305	462	352	483	364
Simulation-8	395	279	416	279	474	350	498	350
Simulation-9	373	294	396	303	483	346	483	346
Simulation-10	402	294	402	306	470	330	493	358
Median Distance (km)	**395.5**	**289**	**405**	**301.5**	**476.5**	**344**	**487.5**	**356.5**

The results show that adjacent frequency compatibility is expected to be difficult. It should be noted that because HIBS is in one azimuth location relative to the radar, if interference occurs it will be observed for every radar antenna azimuth scan in the HIBS azimuth direction. Persistent interference in one or more azimuthal direction would be an unacceptable problem for the ATC radar operators.

The figures below show graphical representation for the results of one simulation. Note that only samples that are equal to or above the threshold are shown.

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FIGURE A4.6.1.10

**Radar B: I/N=-6 dB. Random Locations . Antenna Rotates at 75°/s
HIBS Beams are at -90, 0°, ±60°, ±120° and 180°**

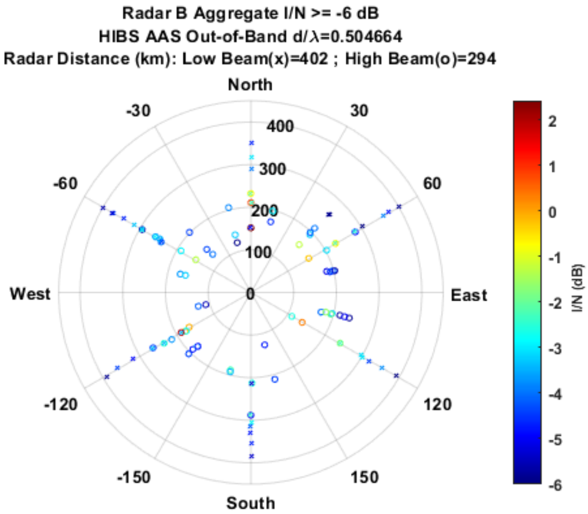

FIGURE A4.6.1.11

**Radar C: I/N=-6 dB. Random Locations. Antenna Rotates at 75(/s
HIBS Beams are at -90, 0(, (60(, (120(and 180**

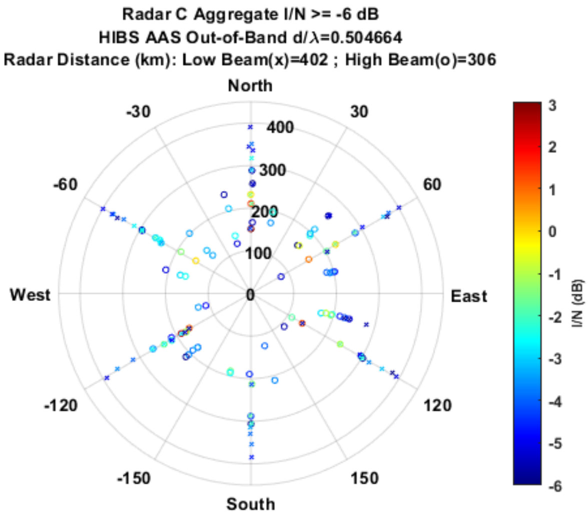

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FIGURE A4.6.1.12

**Radar B: I/N=-10 dB. Random Locations. Antenna Rotates at 75(/s
HIBS Beams are at -90, 0(, (60(, (120(and 180(**

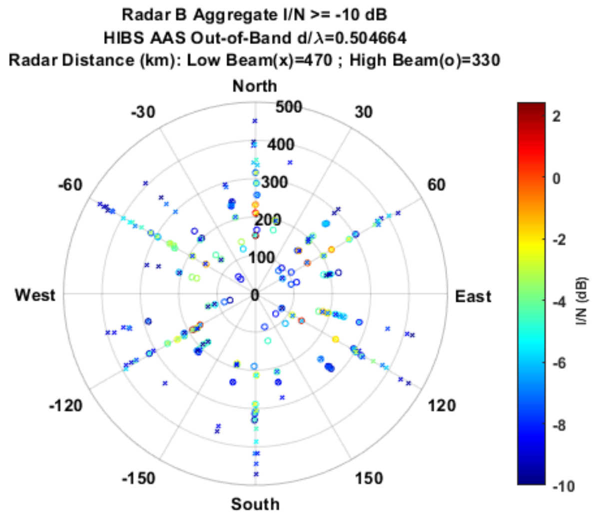
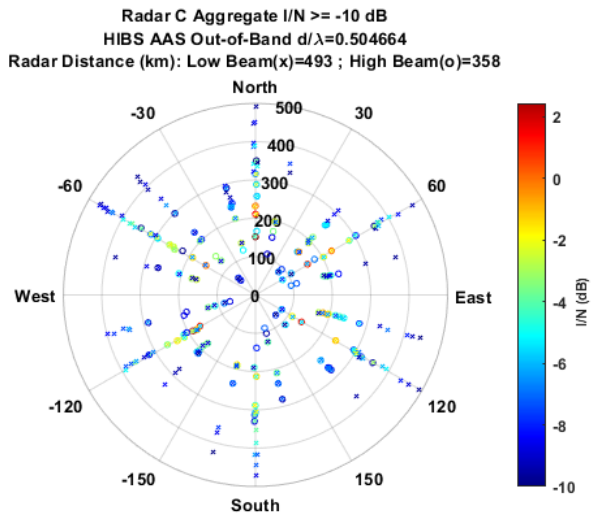


FIGURE A4.6.1.13

**Radar C: I/N=-10 dB. Random Locations. Antenna Rotates at 75(/s
HIBS Beams are at -90, 0(, (60(, (120(and 180(**



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A4.6.1.6 Power Flux Density (PFD) Analysis to Protect ATC Radars in Adjacent Band

This section provides a method for calculating the out of band power flux density (PFD) mask received at an ATC radar antenna from a single HIBS platform that contains 7 base stations operating in the adjacent frequency band.

The measure of interference used in this method is the *I/N* protection threshold of the ATC radionavigation radar system. The parameters defining the level of interference are the radar noise power and antenna gain. The radar noise power density, N, in 1 MHz bandwidth is given by:

$$N = kTB$$

where:

k: Boltzmann's constant (W/(K · Hz))

T: receiving system noise temperature (300 K)

B: reference bandwidth (1 MHz).

The *I/N* protection threshold can be used to determine the maximum interference power dB(W/MHz))

where

$$I = N + I/N$$

The single HIBS base station power flux-density $PFD(\theta)_{single\_HIBS\_BS}$ in dB(W/(m^2 · MHz)) that produces interference at the ATC radar is:

$$PFD(\theta)_{single\_HIBS\_BS} = I - G_r(\theta) + 10\log_{10}\left(\frac{4\pi}{\lambda^2}\right),$$

Substituting $I = N + I/N$, λ

$= \frac{c}{f}$ with speed of light $c = 3{\times}10^8$ m/s, and radar frequency $f = 2705$ MHz in the $PFD(\theta)_{single\_HIBS\_BS}$ equation we get

$$PFD(\theta)_{single\_HIBS\_BS} = N + \frac{I}{N} - G_r(\theta) + 30.099,$$

where:

$G_r(\theta)$: effective antenna gain in dBi of the ATC radar receiver antenna in the direction of the interfering HIBS platform,

θ is the elevation angle direction towards HIBS

I/N: the radar protection criteria,

The total $PFD(\theta)_{total}$ from all seven HIBS base stations, N_{BS}, transmissions at the ATC radar can be approximated by

$$PFD(\theta)_{total} = PFD(\theta)_{single\_HIBS\_BS} - 10\log_{10}(N_{BS}),$$

Where N_{BS} is the number of HIBS base stations that is seven base stations in this case.

To derive the level of unwanted emission received by the ATC radars based on the in-band $PFD(\theta)_{total}$ the out-of-band (OoB) emission mask in the spurious domain of the HIBS base stations is required. The unwanted emission $PFD(\theta)_{unwanted}$ is then given by:

$$PFD(\theta)_{unwanted} = PFD(\theta)_{total} - OoB,$$

where:

$PFD(\theta)_{unwanted}$: power flux-density level at the ATC radar receiver

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$PFD(\theta)_{total}$: in band PFD levels of HIBS.

OoB: out-of-band HIBS spurious emission rejection value. For example, for HIBS one value for the spurious emission is -43 dBW/MHz.

A4.6.2 Study B

A4.6.2.1 Technical and operational characteristics of HIBS operating in the 2 500-2 690 MHz frequency range

The technical and operational characteristics of HIBS are those for Band 3 in the working documents towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS], including Tables 2, 2-A, 3, 3-A, and 5. The platform altitude is considered at 20 km, with additional sensitivity analysis with an altitude of 18 km.

FIGURE A4.6.2.1

HIBS antenna pointing and network topology

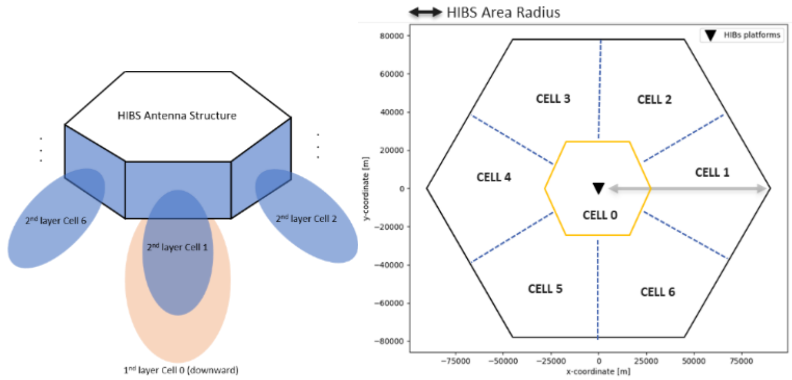
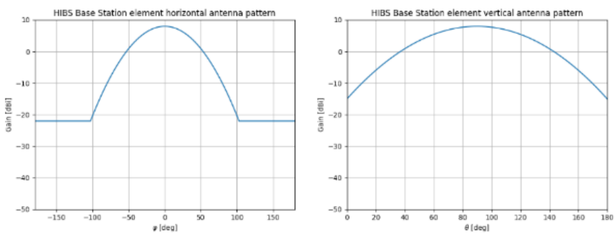


FIGURE A4.6.2.2

HIBS antenna pattern (Recommendation ITU-R M.2101)

(a) Single element (for adjacent case)



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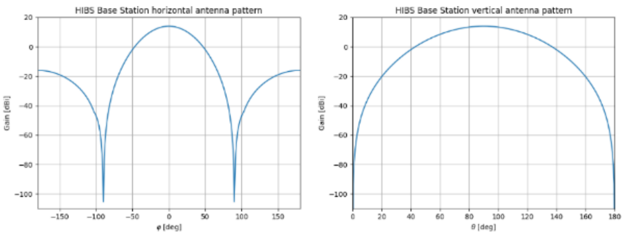
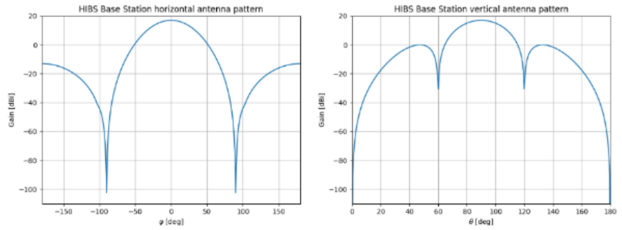
(b) 1st layer (2 x 2)



(c) 2nd layer (4 x 2)



A4.6.2.2 Technical and operational characteristics of aeronautical radionavigation service operating in the 2 700-2 900 MHz frequency range

The characteristics for aeronautical radionavigation service are based on the information contained in the Recommendation ITU-R M.1464, as well as the antenna patterns in Recommendation ITU-R M.1851, as summarized below.

TABLE A4.6.2.1

Characteristics of ground air traffic control (ATC) radars

Parameter	Unit	Radar A	Radar B	Radar C	Radar D	Radar E	Radar F
Platform type		Ground/ATC					
Transmitter power	kW	1 400	1 320	25	450	22	70
Pulse width	µs	0.6	1.03	1.0, 89	1.0	1.0, 55.0	0.4,20 0.5, 27
Pulse repetition	pps	973- 1 040	1 059- 1 172	722-935 788-1 050	1050	8 sets, 1 031 to 1 080	1 100 840
Output device		Klystron		Magnetron	Magnetron	Solid state transistors	TWT
Antenna pattern	degrees	Cosecant-squared + 30		Cosecant-squared 6 to +30			Cosecant-squared Enhaced to +40
Antenna type		Parabolic reflector					
Antenna main beam gain	dBi	33.5		34	32.8	34.3 low beam, 33 high beam	33.5

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Antenna elevation beamwidth	degrees	4.8			4	4.8	5
Antenna azimutal beamwidth	degrees	1.35	1.3	1.45	1.6	1.4	1.5
Antenna side lobe (SL)	dBi		7.3	9.5			7.5
Receiver IF 3 dB bandwidth	MHz	13	0.7	1.1		1.2	4
Receiver noise figure	dB	4 dB maximum		3.3	2.7	2.1	2
Antenna horizontal scan		360^0					
Antenna vertical scan	degrees	-		+2.5 to -2.5	-	-	-
Antenna height	m	8					8-24
Receiver RF 3dB bandwidth	MHz	13	12	345			400
Geographical distribution		Worldwide					
Protection criteria	dB	-10					

Parameter	Unit	Radar F1	Radar F2
Platform type		Ground/ATC	
Transmitter power	kW	40	160
Pulse width	µs	1 (SP) 60.0 (LP)	1.0 (SP) ≤ 250.0 (LP)
Pulse repetition	pps	973-1 040	1 059-1 172
Output device		Solid state	
Antenna pattern	degrees	Pencil beam (coverage 70 000 feet)	Pencil beam (coverage 100 000 feet)
Antenna type		Phased array, 4 faces (4 meter diameter phased array per face)	Phased array, 4 faces (8 meter diameter phased array per face)
Antenna main beam gain	dBi	41	46
Antenna elevation beamwidth	degrees	1.6-2.7	0.9-1.5
Antenna azimutal beamwidth	degrees	1.6-2.7	0.9-1.4
Antenna side lobe (SL)	dBi	17	17
Antenna horizontal scan		Irregular to cover 3600	

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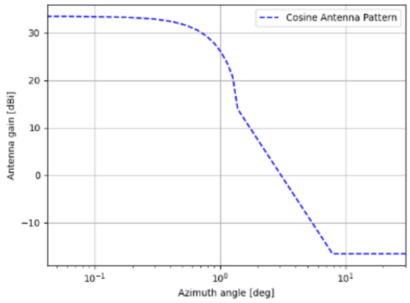
Antenna vertical scan		Irregular to cover required volume	
Receiver RF 3dB bandwidth	MHz	200	300
Receiver noise figure	dB	< 6	
Antenna height		Variable	
Receiver IF 3 dB bandwidth	MHz	1.2 at -6 dB (SP) 1.8 at -6 dB (LP)	1.2 at -6 dB (SP) 1.8 at -6 dB (LP)
Geographical distribution		Worldwide	
Protection criteria	dB	-10	

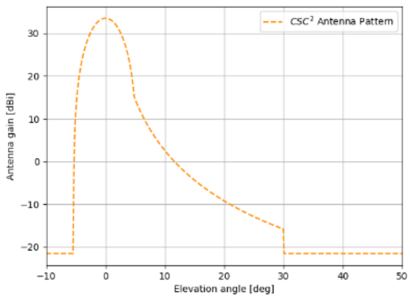
FIGURE A4.6.2.3

Ground ATC radars antenna patterns

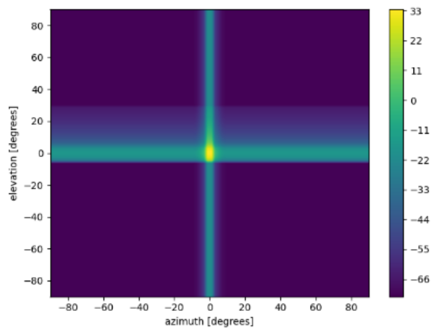
Radar A: antenna gain = 33.5 dBi, beamwidthφ = 1.35º, beamwidthθ = 4.8º, CSC2 angle = +30º



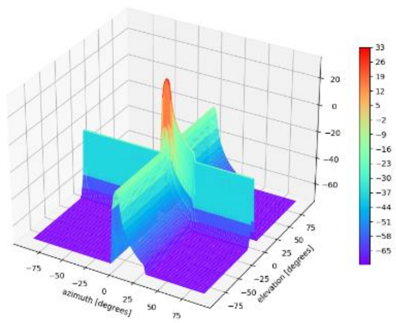
(a) Azimuth antenna pattern



(b) Elevation antenna pattern



(c) 3D antenna pattern



(d) 3D antenna pattern

Radar B: antenna gain = 33.5 dBi, beamwidthφ = 1.3º, beamwidthθ = 4.8º, CSC2 angle = +30º

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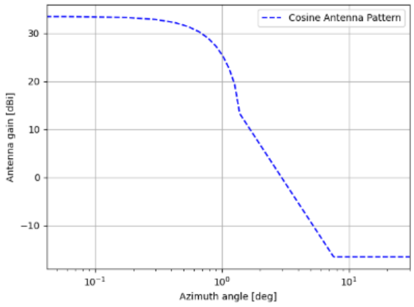
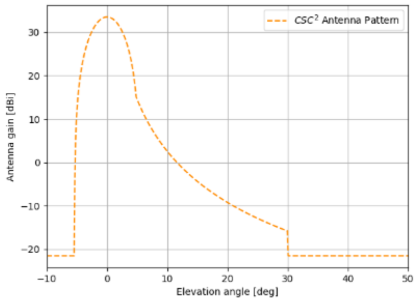
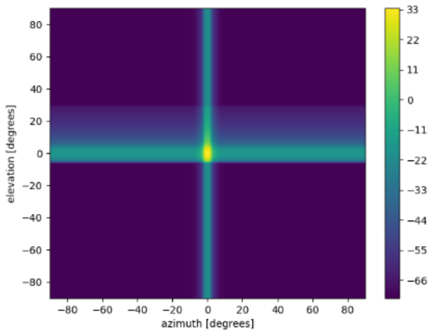


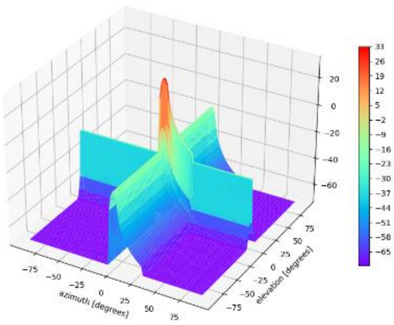
(a) Azimuth antenna pattern



(b) Elevation antenna pattern

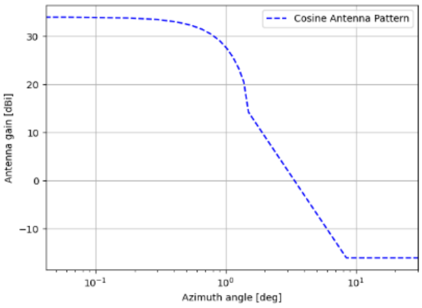


(c) 3D antenna pattern

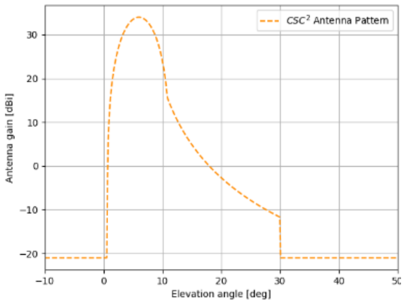


(d) 3D antenna pattern

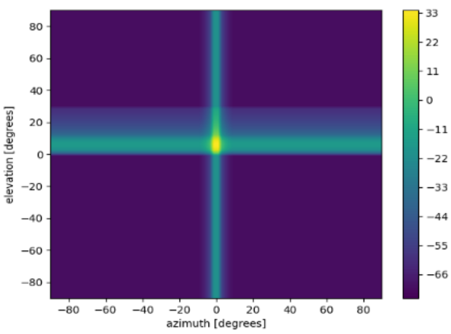
Radar C: antenna gain = 34 dBi, beamwidthφ = 1.45º, beamwidthθ = 4.8º, CSC2 angle = +6º to +30º



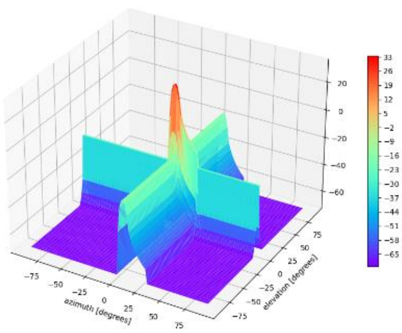
(a) Azimuth antenna pattern



(b) Elevation antenna pattern

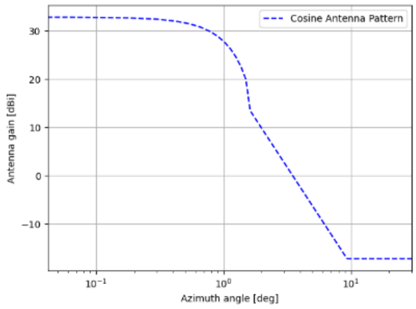


(c) 3D antenna pattern

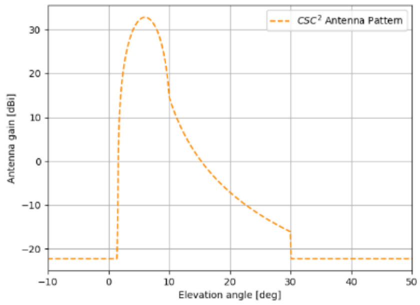


(d) 3D antenna pattern

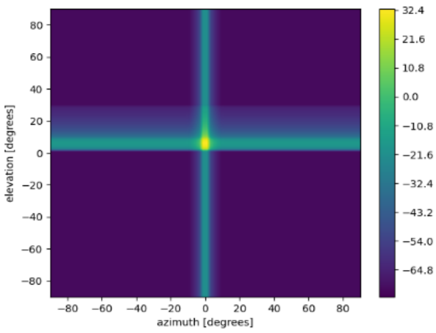
Radar D: antenna gain = 32.8 dBi, beamwidthφ = 1.6º, beamwidthθ = 4º, CSC2 angle = +6º to +30º



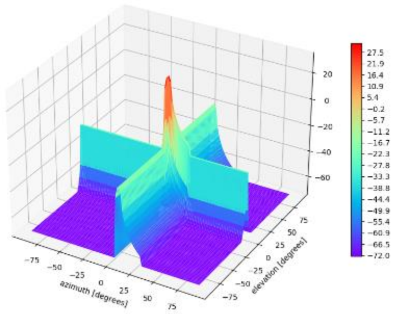
(a) Azimuth antenna pattern



(b) Elevation antenna pattern

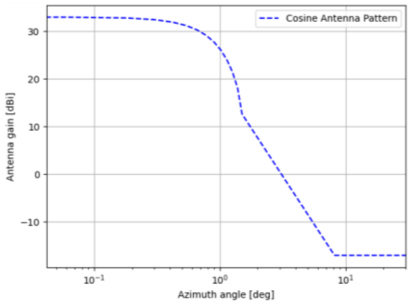


(c) 3D antenna pattern

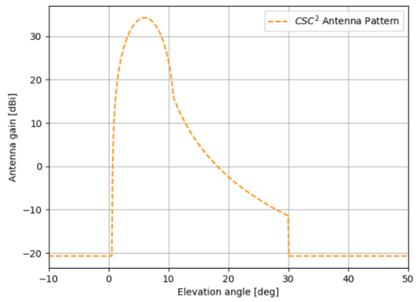


(d) 3D antenna pattern

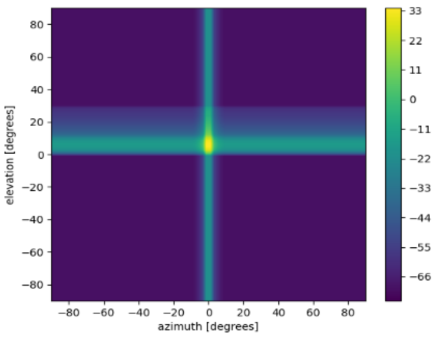
Radar E: antenna gain = 33 dBi, beamwidthφ = 1.4º, beamwidthθ = 4.8º, CSC2 angle = +6º to +30º



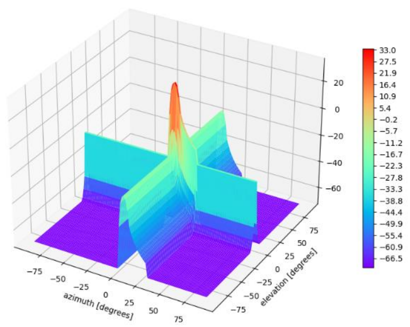
(a) Azimuth antenna pattern



(b) Elevation antenna pattern



(c) 3D antenna pattern



(d) 3D antenna pattern

Radar F: antenna gain = 33.5 dBi, beamwidthφ = 1.5º, beamwidthθ = 5º, CSC2 angle = +40º

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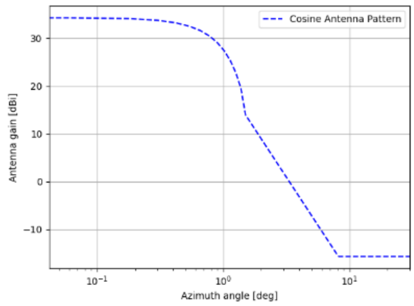
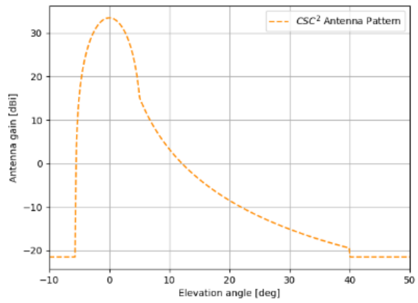
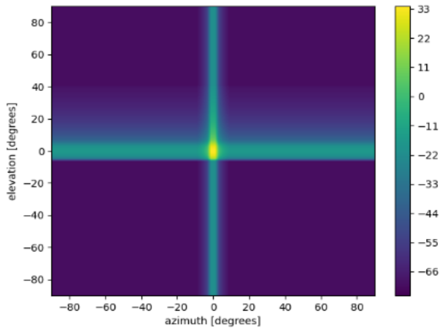


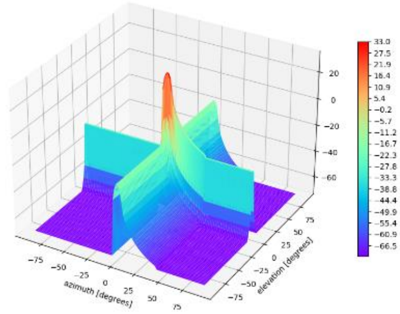
(a) Azimuth antenna pattern



(b) Elevation antenna pattern

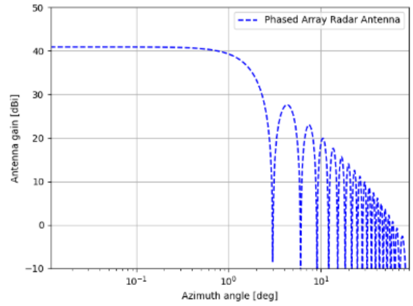


(c) 3D antenna pattern

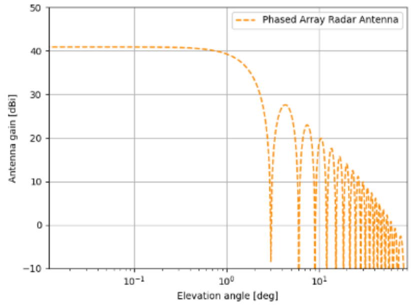


(d) 3D antenna pattern

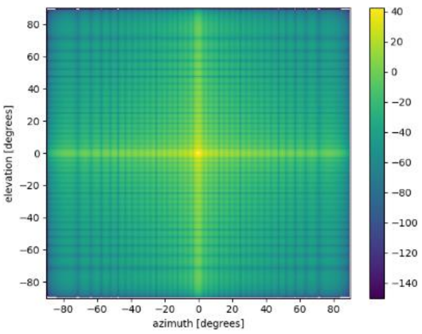
Radar F1: antenna gain = 41 dBi, beamwidthφ = 2.7º, beamwidthθ = 2.7º, element space: 0.5 λ



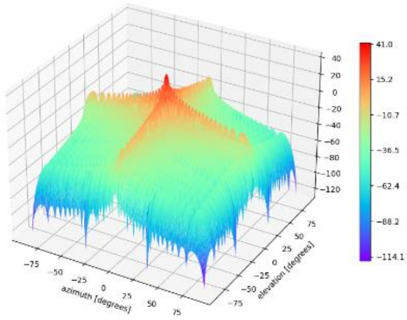
(a) Azimuth antenna pattern



(b) Elevation antenna pattern



(c) 3D antenna pattern



(d) 3D antenna pattern

Radar F2: antenna gain = 46 dBi, beamwidthφ = 1.4º, beamwidthθ = 1.4º, element space: 0.5 λ

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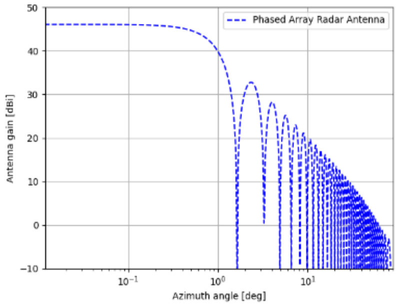
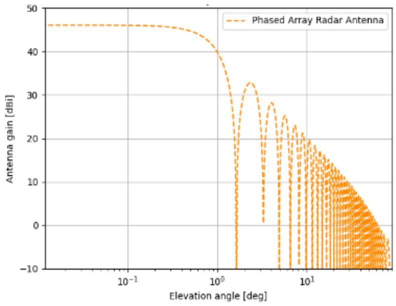
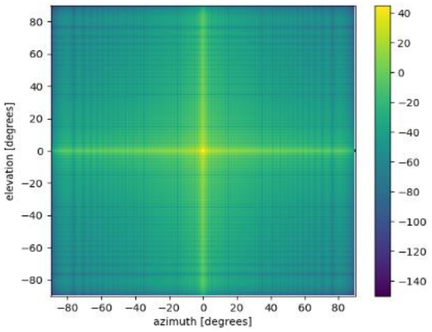


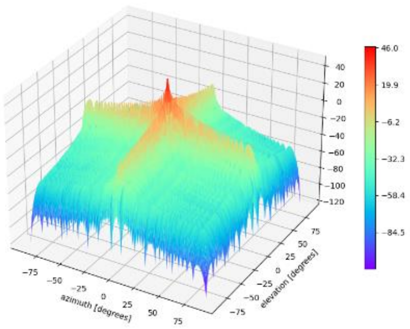
(a) Azimuth antenna pattern



(b) Elevation antenna pattern



(c) 3D antenna pattern



(d) 3D antenna pattern

A4.6.2.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at -15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. Finally, the HIBS visible horizon when deployed at 20 km of altitude is approximately 500 km from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A4.6.2.4 Methodology

The Brazilian administration continues to use and develop, in cooperation with partners in the industry and academia, an open-source simulation tool, named SHARC, to support Sharing and Compatibility studies between IMT and other radio communication systems, according to the framework proposed by Recommendation ITU-R M.2101. SHARC is a coexistence static system-level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs

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resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa. In this study the interference-to-noise ratio is calculated and compared with the protection criteria for their specific frequency range.

A4.6.2.5 Scenarios and results of the study

The study was implemented in accordance with the scenarios described in Figure A4.6.2.4, with the radars positioned at different distances from the HIBS nadir, as described in Table A4.6.2.2. The simulations were done with 10 000 snapshots.

TABLE A4.6.2.2

Geographical coordinates of the air traffic control radar stations used in the simulation

Position	Distance from point A	Latitude	Longitude
A[(1)]	-	-15.809422°	-47.866732°
B	45 km	-15.396298°	-47.866732°
C	90 km	-14.991080°	-47.866732°
D	250 km	-13.560102°	-47.866732°
E	350 km	-12.660001°	-47.866732°
F	450 km	-11.760120°	-47.866732°
G	500 km	-11.310301°	-47.866732°

[(1)] HIBS nadir

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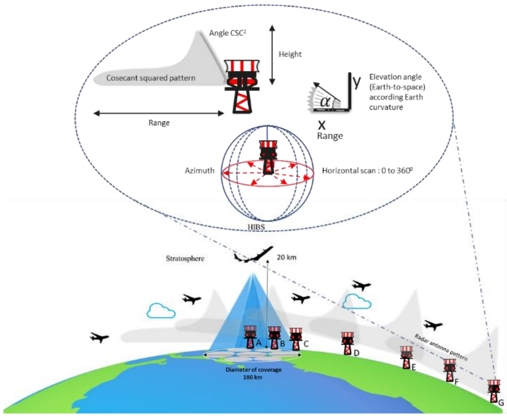
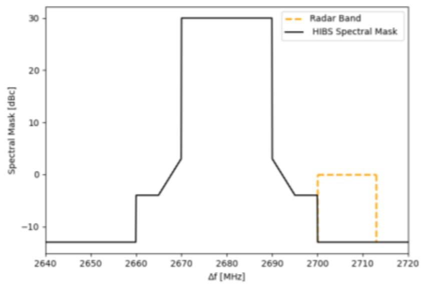
FIGURE A4.6.2.4

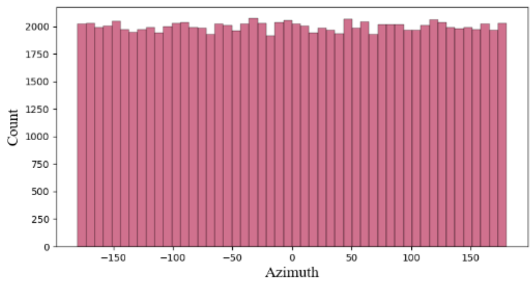
Ground ATC radar simulation scenarios



Radar A: antenna height = 8 m, receiver noise figure = 4 dB, horizontal scan: -180º to 180º

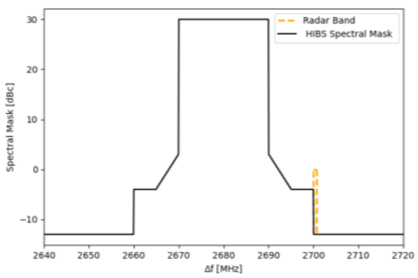


(a) Adjacent channel analysis

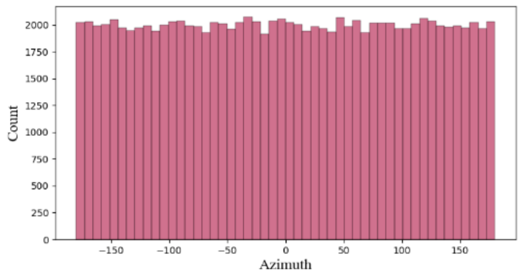


(b) Uniform distribution of azimuth scan

Radar B: antenna height = 8 m, receiver noise figure = 4 dB, horizontal scan: -180º to 180º



(a) Adjacent channel analysis



(b) Uniform distribution of azimuth scan

Radar C: antenna height = 8 m, receiver noise figure = 3.3 dB, horizontal scan: -180º to 180º, vertical scan: -2.5º to 2.5º

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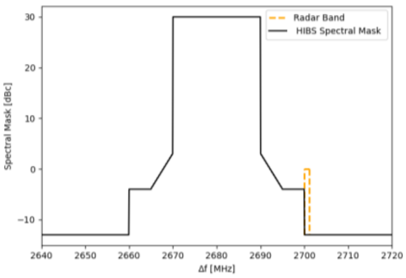
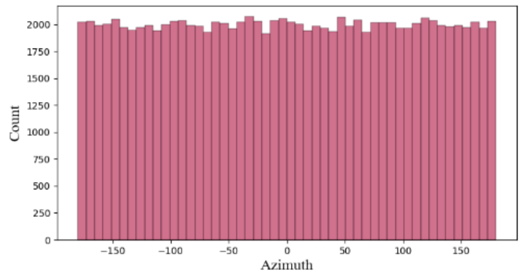
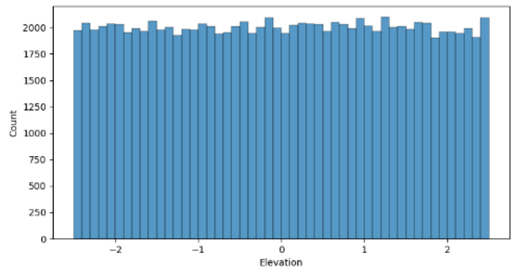


(a) Adjacent channel analysis

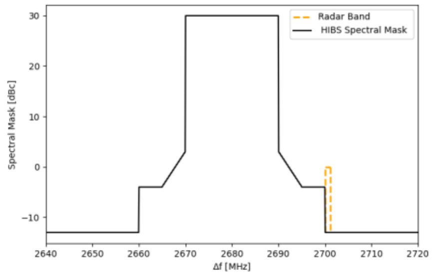


(b) Uniform distribution of azimuth scan

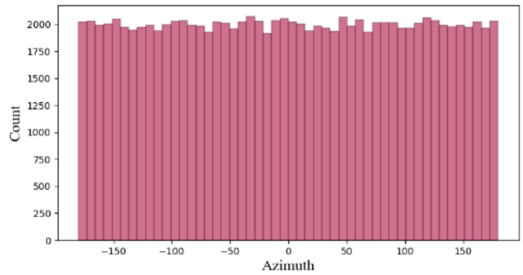


(c) Uniform distribution of elevation scan

Radar D: antenna height = 8 m, receiver noise figure = 2.7 dB, horizontal scan: -180° to 180°

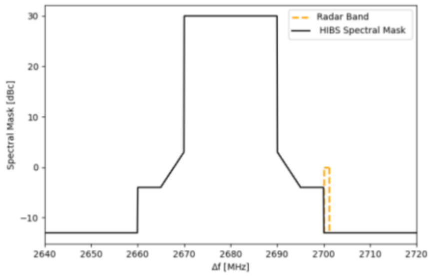


(a) Adjacent channel analysis

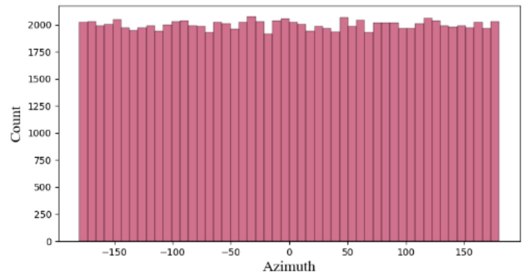


(c) Uniform distribution of azimuth scan

Radar E: antenna height = 8 m, receiver noise figure = 2.1 dB, horizontal scan: -180° to 180°

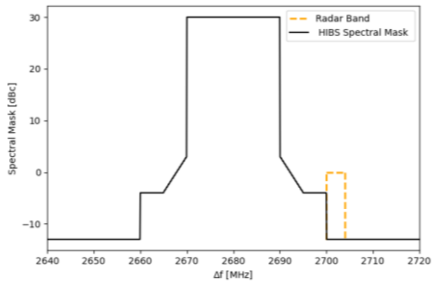


(a) Adjacent channel analysis

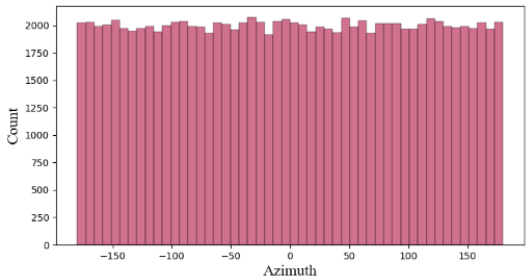


(b) Uniform distribution of azimuth scan

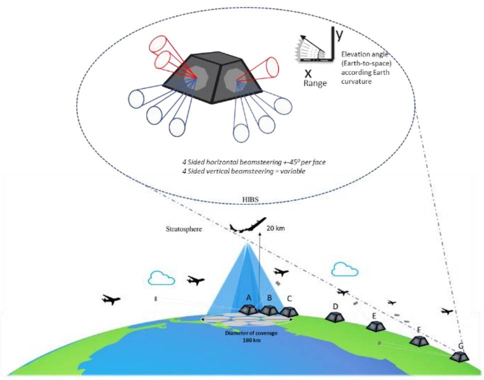
Radar F: antenna height = 24 m, receiver noise figure = 2 dB, horizontal scan: -180° to 180°



(a) Adjacent channel analysis



(b) Uniform distribution of azimuth scan



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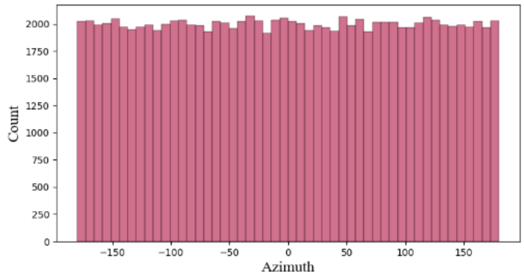
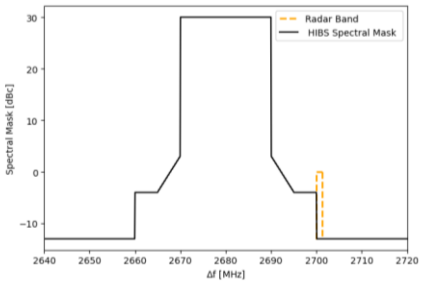
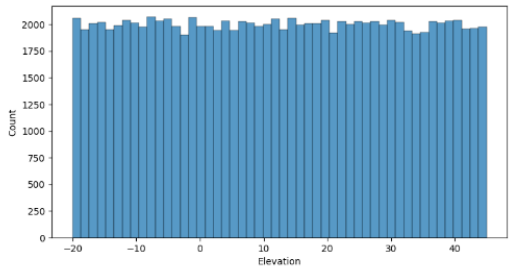
Radar F1: antenna height = 24 m, receiver noise figure = 6 dB, horizontal beamsteering scan per face: -45º to 45º, vertical beamsteering scan per face: -20º to 45º



(b) Uniform distribution of azimuth scan

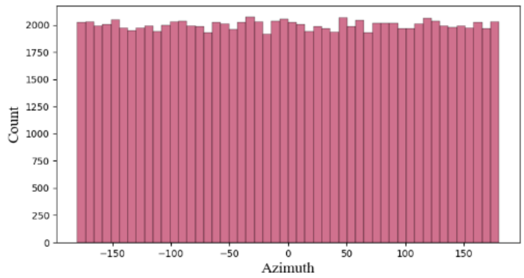


(a) Adjacent channel analysis

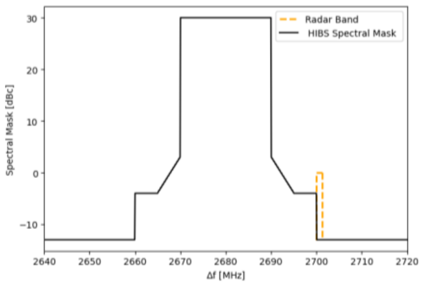


(c) Uniform distribution of elevation scan

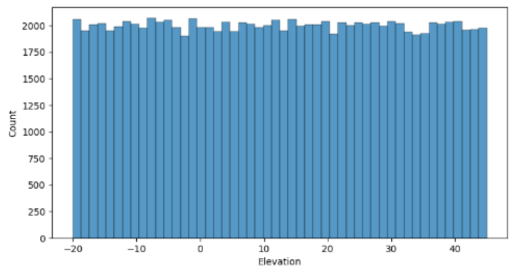
Radar F2: antenna height = 24 m, receiver noise figure = 6 dB, horizontal beamsteering scan per face: -45º to 45º, vertical beamsteering scan per face: -20º to 45º



(b) Uniform distribution of azimuth scan



(a) Adjacent channel analysis



(c) Uniform distribution of elevation scan

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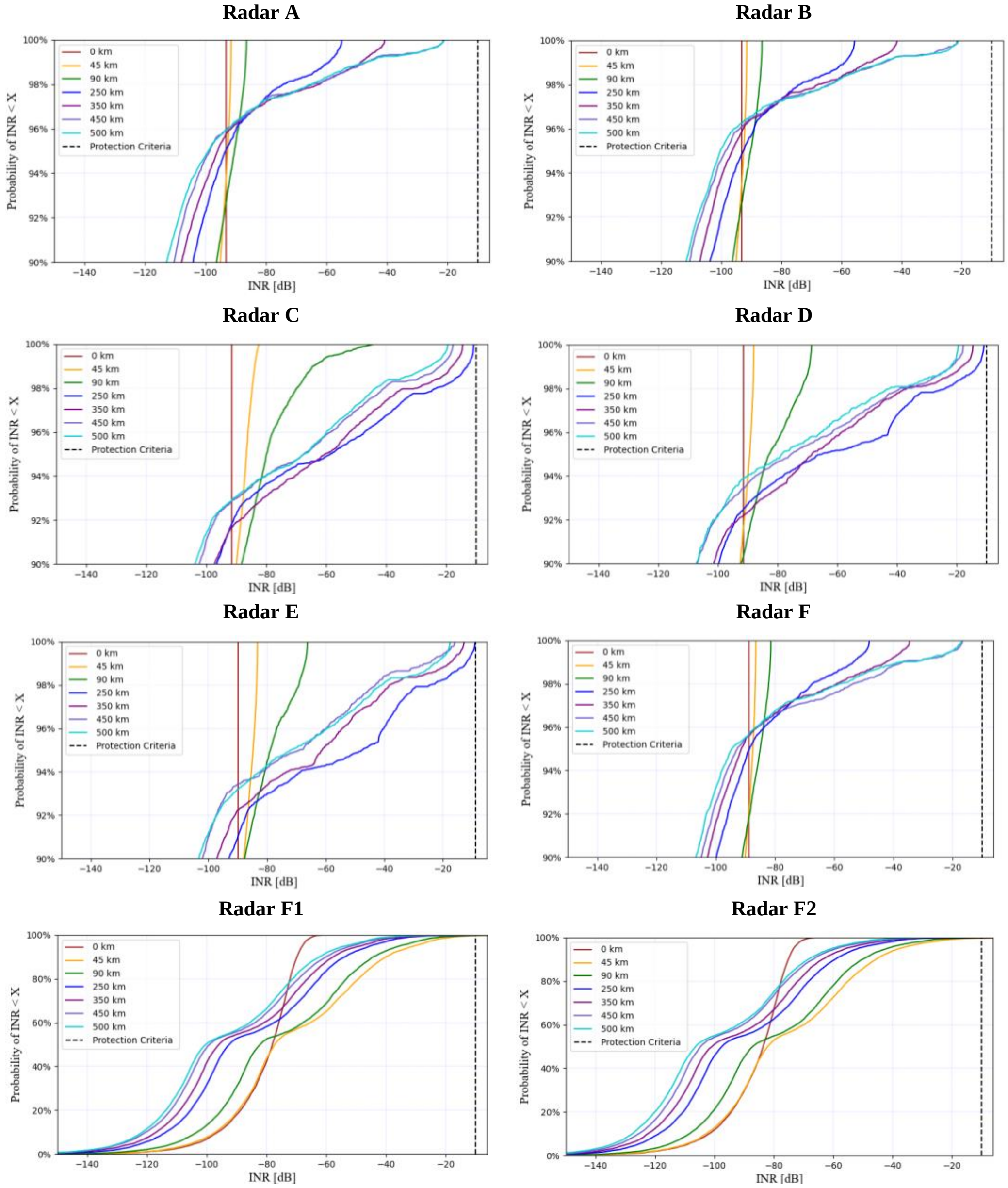
The results of the simulations, as shown in Figure A4.6.2.4, indicates the probability of the achieved protection criteria (*I/N*) for each of the distances described above. In all cases, the achieved *I/N* is always lower than the protection criteria of -10 dB.

FIGURE A4.6.2.4HIBS - Ground ATC radars adjacent channel simulation results



Additionally, simulations with Radar F for adjacent channel compatibility analysis were done considering a sensitivity analysis, by varying the altitude of the HIBS platform from 20 km to 18

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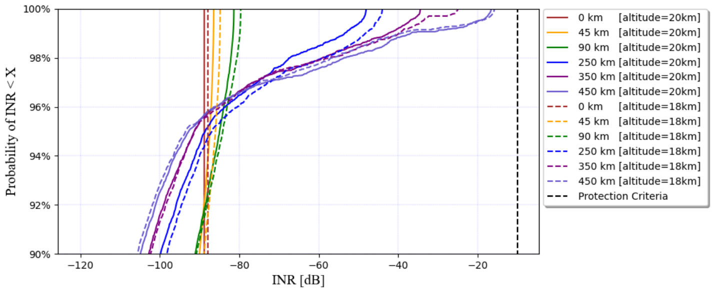
km, as shown in Figure A4.6.2.5. The achieved I/N for a HIBS platform altitude of 18 km continued to be lower than the protection criteria of -10 dB.

FIGURE A4.7.2.5

HIBS - Ground ATC radars adjacent channel simulation results (sensitivity analysis with Radar F)



A4.6.2.6 Summary and analysis of the results of Study B

Considering a HIBS single element AAS antenna pattern for adjacent analysis, the use of propagation model in Recommendation ITU-R P.619, a 3 dB of polarization loss, and a radar protection criteria I/N of -10 dB, the results of this study show that for HIBS operating in the 2 500-2 690 MHz frequency range the compatibility with aeronautical radionavigation service operating in adjacent 2 700-2 900 MHz frequency range is feasible. In all the possible cases, with all types of radar, the protection criteria is met. Additionally, the sensitivity analysis of varying the altitude of the HIBS platform from 20 km to 18 km has shown that the radar protection criteria continue to be met.

A4.7 Compatibility studies with meteorological radar service in the adjacent 2 700-2 900 MHz band and HIBS operating in the 2 500-2 690 MHz frequency range

A4.7.1 Study A - High Altitude IMT Base Station compatibility with ground-based radars used for meteorological purposes operating under the radiolocation service under No. 5.423 in the 2 700-2 900 MHz frequency band

A4.7.1.1 Technical characteristics

A4.7.1.1.1 Technical and operational characteristics of HIBS systems operating in the frequency band 2 500-2 690 MHz

This section includes the technical and operational characteristics used in this study to model HIBS operations in the 2 500-2 690 MHz band.

Table A4.7.1.1 shows specification related parameters to be used in this analysis for HIBS that serve associated UEs. The HIBS in this analysis use Frequency Division Duplex (FDD) with the transmitter centered at 2 680 MHz and a channel bandwidth of 20 MHz such that the upper edge of the channel is at 2 690 MHz.

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TABLE A4.7.1.1

Specification related parameters of HIBS (Base Station)

No.	Parameter	Band 3 (2 500-2 690 MHz)
1	Duplex method	FDD
2	Channel bandwidth (MHz)	20 MHz
3	Signal bandwidth (MHz)	18 MHz @ −3 dB
4	Transmitter characteristics	
4.1	Power dynamic range (dB)	0 dB conducted BS output power
4.4	Spurious emissions	−13 dBm/MHz

Table A4.7.1.2 shows deployment-related HIBS parameters for this analysis.

TABLE A4.7.1.2

Deployment related parameters of HIBS (Base Station)

No.	Parameter	Band 3 (2 500-2 690 MHz)
1	Network topology and characteristics	
1.1	BS density or ISD	1 BS/HIBS area
1.2	HIBS area radius (based on 20 km platform altitude)	90 km
1.3	HIBS network configuration (Duplex Mode)	FDD
2	Base station characteristics/Cell structure	
2.1	HIBS Platform Altitude	20 km
2.2	Number of cells/HIBS	7
2.3	Frequency reuse	1
2.5	HIBS Platform Antenna pattern	Recommendation ITU-R M.2101
	Element gain	8 dBi
	Horizontal/vertical 3 dB beamwidth of single element	65° for both H/V
	Horizontal/vertical front-to-back ratio	30 dB for both H/V
	Antenna polarization	Linear/±45 degrees
	Antenna array configuration (Row × Column)	2 × 2 elements (1st layer cell), 4 × 2 elements per cell (2nd layer cell)?
	Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
	Ohmic losses	2 dB
2.7	HIBS platform antenna tilt	90º (1st layer cell), 23º (2nd layer cell)

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No.	Parameter	Band 3 (2 500-2 690 MHz)
2.8	HIBS conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
2.9	HIBS platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)
2.10	HIBS platform e.i.r.p. spectral density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)

Because the HIBS is interfering with the radar operating in the adjacent band, the analysis models the HIBS antenna pattern using the single element equations from Table A4.8.1.3, in accordance with Recommendation ITU-R M.2101. The parameters for horizontal and vertical 3 dB beamwidths, front-to-back ratio, and element gain are taken from Table A4.7.1.2.

TABLE A4.7.1.3

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 3 dB beamwidth of single element / deg (φ_{3dB})	65°
Front-to-back ratio: A_m and SLA_v	30 dB
Vertical radiation pattern	$A_{E,V}(\theta) = -min\left[12\left(\frac{\theta - 90}{\theta_{3dB}}\right)^2, SLA_v\right]\ dB$
Vertical 3 dB beamwidth of single element / deg (θ_{3dB})	65°
Single element pattern	$A_E(\varphi,\theta) = G_{E,max} - min\{-\lfloor A_{E,H}(\varphi) + A_{E,V}(\theta)\rfloor, A_m\}\ dB$
Element gain (dBi), $G_{E,max}$	8 dBi

Table A4.7.1.4 describes the spectrum mask for out-of-band and spurious emissions associated with the HIBS transmitter. The HIBS spectrum mask is shown in Figure A4.7.1.1. This mask is used in conjunction with the radar receiver IF selectivity response in Figure 3 to calculate the frequency dependent rejection (FDR) as described in A.4.8.1.1.3.

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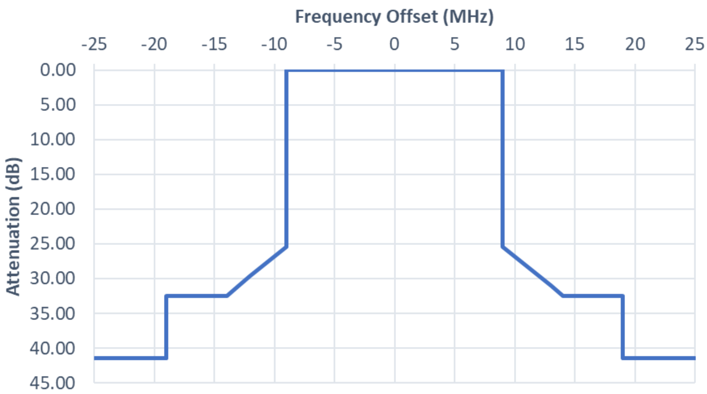
TABLE A4.7.1.4

Spectrum Mask – HIBS (BS)

Frequency offset from "edge of transmission" Δf	**Emission limit**	**Measurement bandwidth**
0 MHz ≤ Δf < 5 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < 10 MHz	−14 dBm	100 kHz
10 MHz ≤ Δf	−13 dBm	1 MHz

FIGURE A4.7.1.1

HIBS Transmitter Spectrum Mask



A4.7.1.1.2 Technical and operational characteristics of Meteorological Radars operating in the frequency band 2 700-2 900 MHz

Characteristics of meteorological radars operating in the 2 700-2 900 MHz band are found in Annex 18 to Working Party 5B Chairman's Report titled, "Working document towards preliminary draft revised Recommendation ITU-R M.1849-2, Technical and operational aspects of ground-based meteorological radars" (Document 5B/TEMP/95, 3 June 2021). Table A4.7.1.5 provides the technical and operational characteristics used in this analysis for the meteorological radar.

TABLE A4.7.1.5

Technical characteristics of meteorological radar

Characteristics	**Radar 1***
Frequency (MHz)	2 705
Antenna pattern type (pencil, fan, cosecant-squared, etc.)	Pencil
Antenna type reflector, phased array, slotted array, etc.	Parabolic reflector

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Characteristics	Radar 1*
Antenna polarization	Horizontal and vertical, simultaneous transmit/receive
Antenna main beam gain (dBi)	45.0
Antenna elevation beamwidth (degrees)	0.92
Antenna azimuthal beamwidth (degrees)	0.92
Antenna horizontal scan type (continuous, random, 360°, sector, etc.)	360°
Antenna vertical scan type (degrees) (continuous, random, 360°, sector, etc.)	Fixed steps: 0.5-20
Antenna height (m)	30
Receiver IF bandwidth (MHz)	0.714 at –3 dB
Receiver noise figure (dB)	2.7
Geographical distribution	Worldwide
Fraction of time in use (%)	100

The meteorological radar antenna pattern to be used in the analysis is shown in Figure A4.7.1.2, adopted from Recommendation ITU-R M.1851. In this analysis of compatibility of meteorological radars with HIBS, the pattern will be modelled as rotationally symmetric around the antenna's main beam and composite off-axis angles will be computed to determine the antenna gain in the direction of the HIBS.

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FIGURE A4.7.1.2

Meteorological Radar Antenna Pattern

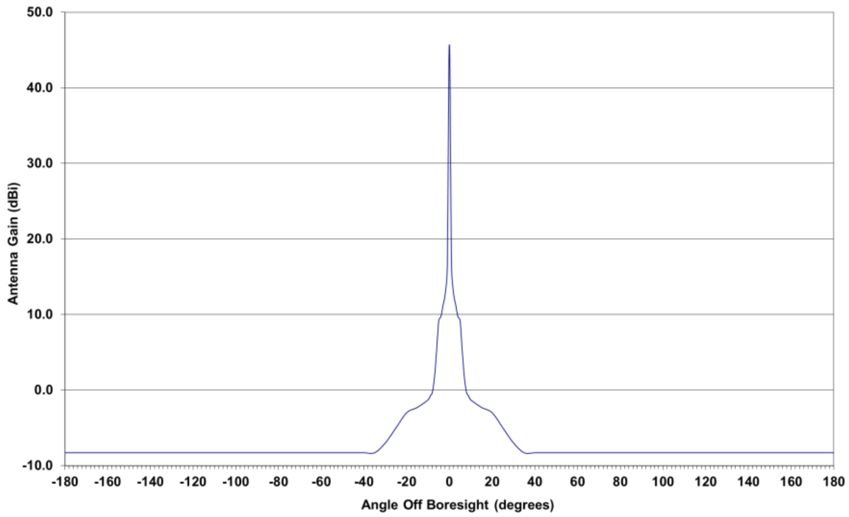
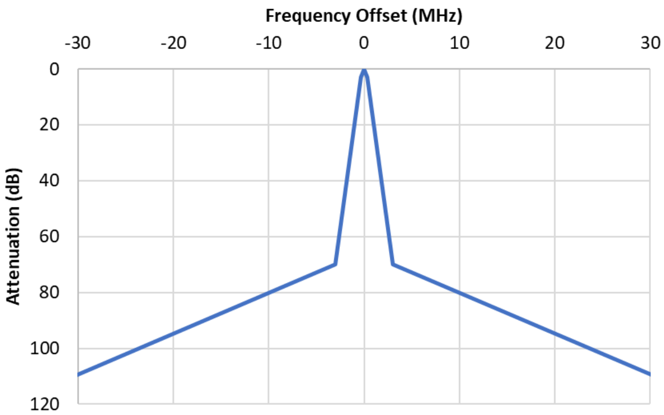


Figure A4.8.1.3 depicts the radar receiver IF selectivity response in accordance with the process described in Recommendation ITU-R M.1461, using a roll-off of 40 dB per decade beyond the 70 dB selectivity threshold. This curve is used in conjunction with the HIBS Spectrum Mask in and Figure A4.7.1.1 to calculate FDR.

FIGURE A4.7.1.3

Radar IF Selectivity Response



A4.7.1.2 Propagation Models

In accordance with guidance from Study Group 3, Recommendation ITU-R P.528 can be used to predict basic transmission loss (i.e., propagation loss) for a range of time percentage values. This

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analysis used a 5% value; however, noting that other values could also be considered, future updates of this study may consider additional percentage values, as appropriate.

Clutter loss is considered to be 0 dB for this study. Future updates of this study will consider Recommendation ITU-R P.2108 “Prediction of clutter loss” noting the location of these radars, and HIBS usually operate in areas with limited clutter.

A4.7.1.3 Analysis Methodology

Analysis will be performed to calculate the minimum distance required to preclude harmful interference from a HIBS base station operating in the 2 500-2 690 MHz band into a meteorological radar operating in the nearby adjacent band 2 700-2 900 MHz. The analysis scenario is such that the meteorological radar is at a fixed location; the HIBS is also fixed, but it will be analysed at incremental distances away from the radar along a single azimuthal direction.

Interference

Interference from a single HIBS base station cell is calculated using:

$$Ik = PT + GTk(\theta, \phi) - Lp - L_{Cl} + Gr(\alpha, \gamma) - Lpol - Ls - FDR(\Delta f)$$

where:

Ik = predicted interfering signal level at the receiver input due to cell k, dBm;

k = number of base station cells, 7;

PT = transmitter power from a HIBS cell, dBm;

GTk(θ, ϕ) = kth transmitter antenna gain in the direction of the victim receiver, dBi;

Lp = interference path propagation loss, dB;

L_{Cl} = Clutter loss, dB;

Gr(α, γ) = receiver antenna gain in the direction of the interferer transmitter, dBi;

Lpol = antenna polarization mismatch loss, dB;

Ls = system losses, dB;

FDR(Δf) = Frequency Dependent Rejection, dB.

The total interference from the HIBS base station is:

$$i_{total} = \sum_{k=1}^{7} 10^{\frac{I_k}{10}}$$

where:

itotal = total interference power, mW;

Ik = Interference power from base station cell k, dBm.

The noise power is calculated using:

$$N = -114 + 10\log_{10} B + NF$$

where:

N = receiver noise power, dBm;

B = −3 dB bandwidth of receiver, MHz;

NF = receiver noise figure, dB.

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Frequency Dependent Rejection

FDR was calculated using the HIBS emission mask shown in Figure A4.7.1.1, centred at 2 680 MHz, and the radar IF selectivity response shown in Figure A4.7.1.3, centred at 2 705 MHz. For the frequency difference of 25 megahertz, the FDR was determined to be 53.7 dB.

Radar Antenna Scanning

The radar antenna uses multiple patterns that create scan volumes as the antenna rotates throughout 360 degrees in azimuth but moves to several discrete elevation angles. For this study, the entire scan volume between 0.5 and 20 degrees elevation is considered

A4.7.1.4 Analysis

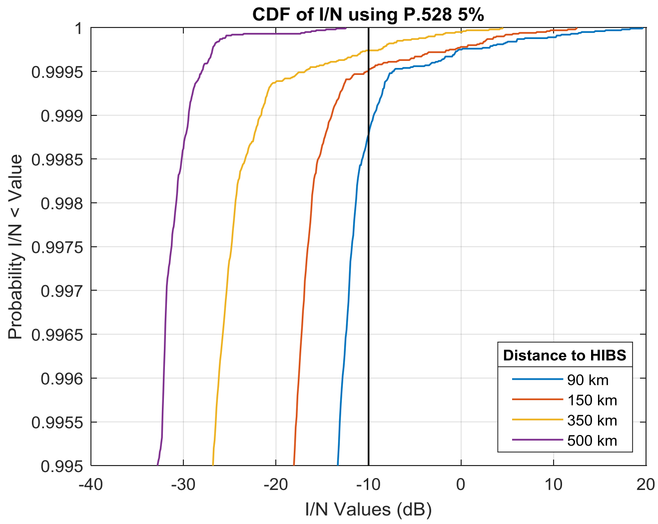
[*TBD*]

A4.7.1.5 Preliminary results of Study A

Results are presented in the form of cumulative distribution functions representing the probability of *I/N* values at the separation distances simulated. Figure 4 shows preliminary results of the study conducted with the HIBS 45 km (ground distance) and 500 km from the radar. The plot displays the *I/N* calculated at the radar using the Recommendation ITU-R P.528 5% propagation loss.

FIGURE A4.7.1.4

CDFs of I/N at Radar using 5% P.528



A4.7.2 Study B

A4.7.2.1 Technical and operational characteristics of HIBS operating in the 2 500-2 690 MHz frequency range

The technical and operational characteristics of HIBS are those for Band 3 in the working documents towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS],

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including Tables 2, 2-A, 3, 3-A, and 5. The platform altitude is considered at 20 km, with additional sensitivity analysis with an altitude of 18 km.

FIGURE A4.7.2.1

HIBS antenna pointing and network topology

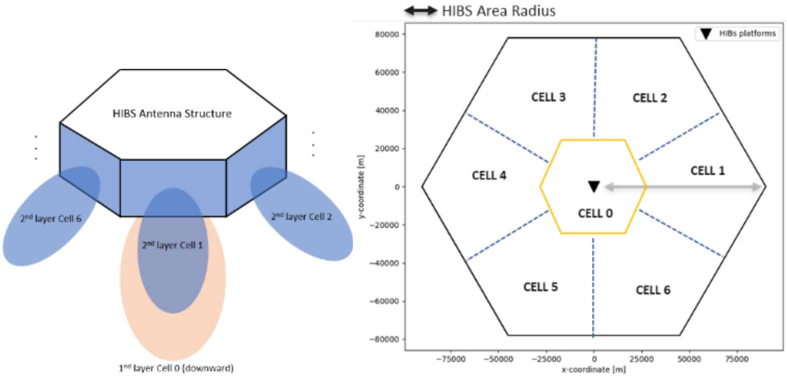
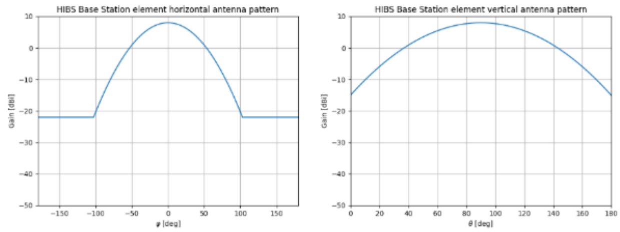


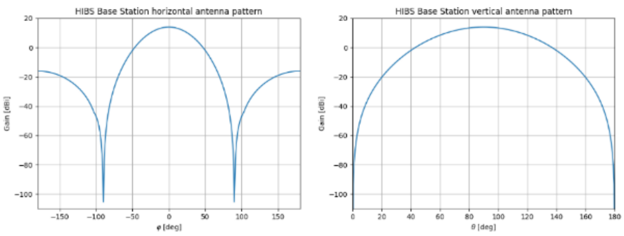
FIGURE A4.7.2.2

HIBS antenna pattern (Recommendation ITU-R M.2101)

(a) Single element (for adjacent case)



(b) 1st layer (2 x 2)



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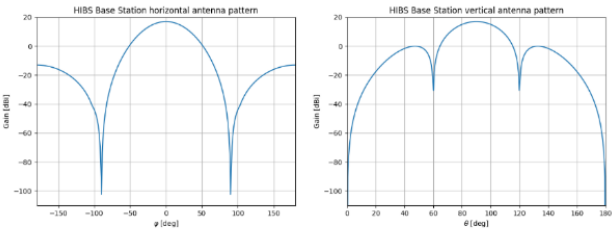
(c) 2nd layer (4 x 2)



A4.7.2.2 Technical and operational characteristics of meteorological radar service operating in the 2 700-2 900 MHz frequency range

The characteristics for meteorological radar service are based on the information contained in the Recommendation ITU-R M.1849, as well as the antenna patterns in Recommendation ITU-R M.1851, as summarized below.

TABLE A4.7.2.1

Characteristics of ground meteorological radars

Parameter	Unit	Radar 1	Radar 2	Radar 3	Radar 4
Tuning range (MHz)	MHz	2 700-3 000	2 700-3 000	2 700-3 000	2 700-3 000
Transmitter power	kW	500	400 or 556	40	160
Pulse width	Ms	1.6 (short pulse) 4.7 (long pulse)	1.0 (short pulse) 4.0 (long pulse)	1.0 (short pulse) 60.0 (long pulse)	1.0 (short pulse) ≤ 250 (long pulse)
Pulse repetition	Pps	318 – 1 304 (short pulse) 318-452 (long pulse)	318 – 1 304 (short pulse) 318-452 (long pulse)	320 – 6 100 (short pulse) 320-1 300 (long pulse)	320 – 4 300 (short pulse) 320-1 500 (long pulse)
Output device		Klystron	Coaxial magnetron	Solid state	
Antenna pattern	degrees	Pencil	Pencil	Pencil beam	Pencil beam
Antenna type		Parabolic reflector		Phased array (4 meter diameter phased array per face)	Phased array (8 meter diameter phased array per face)
Antenna main beam gain	dBi	45.7	38	41	46
Antenna elevation beamwidth	degrees	0.92	2	1.6-2.7	0.9-1.5
Antenna azimuthal beamwidth	degrees	0.92	2	1.6-2.7	0.9-1.4
Antenna side lobe (SL)	dB	20	15	17	17
Antenna horizontal scan		360^0 and sector	360^0 and sector	Irregular to cover 360^0	
Antenna vertical scan	degrees	0.5-20	-2.0 to +60	Irregular to cover required volume	
Receiver RF 3 dB bandwidth	MHz	18	0.5 (long pulse) 1.5 (short pulse)	200	300
Receiver IF bandwidth	MHz	0.714 at -3 dB	0.25 at -3 dB	1.2 at – 6 dB	1.2 at – 6 dB

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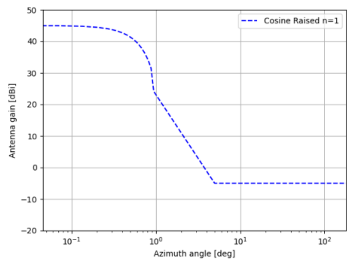
Parameter	Unit	Radar 1	Radar 2	Radar 3	Radar 4
			(long pulse) 0.5 at -3 dB (short pulse)	(short pulse) 1.8 at – 6 dB (long pulse)	(short pulse) 1.8 at – 6 dB (long pulse)
Receiver noise figure	dB	2.7	9.0	< 6	
Antenna height	-	30		variable	
Geographical distribution		Worldwide			
Protection criteria	dB	-10			

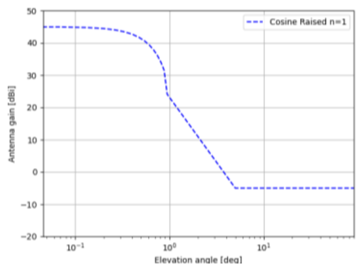
FIGURE A4.7.2.3

Ground meteorological radars antenna patterns

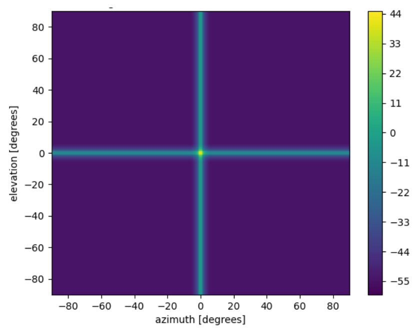
Radar 1: antenna gain = 45 dBi, beamwidthφ = 0.92º, beamwidthθ = 0.92º



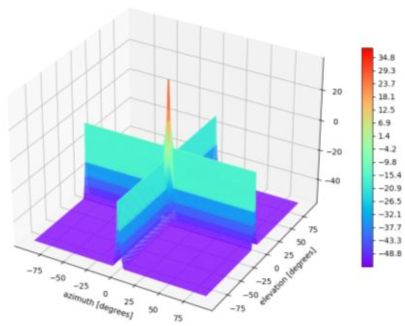
(a) Azimuth antenna pattern



(b) Elevation antenna pattern

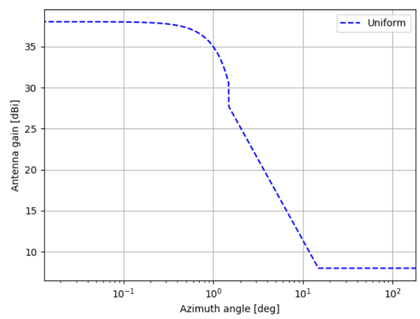


(c) 3D antenna pattern

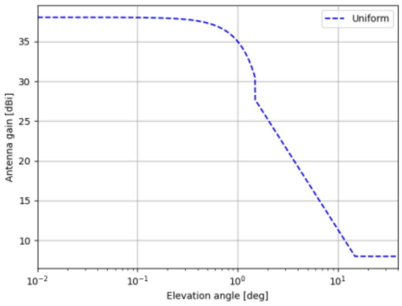


(d) 3D antenna pattern

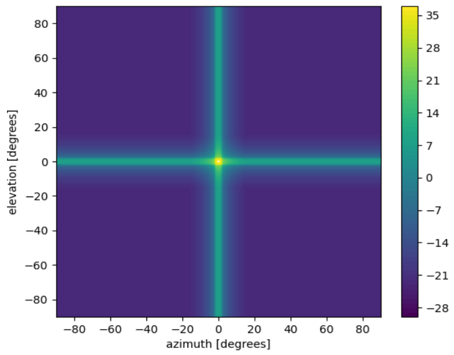
Radar 2: antenna gain = 38 dBi, beamwidthφ = 2º, beamwidthθ = 2º



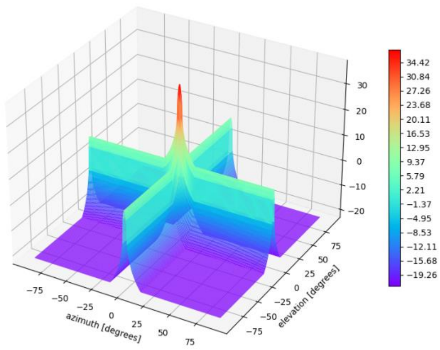
(a) Azimuth antenna pattern



(b) Elevation antenna pattern

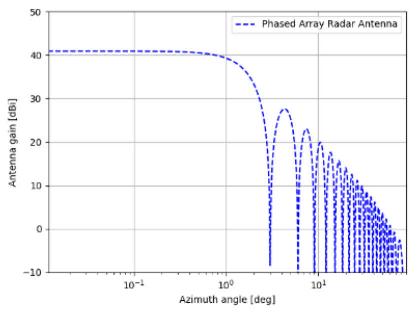


(c) 3D antenna pattern

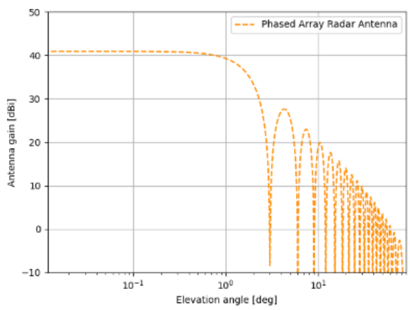


(d) 3D antenna pattern

Radar 3: antenna gain = 41 dBi, beamwidthφ = 2.7º, beamwidthθ = 2.7º, element space: 0.5 λ



(a) Azimuth antenna pattern



(b) Elevation antenna pattern

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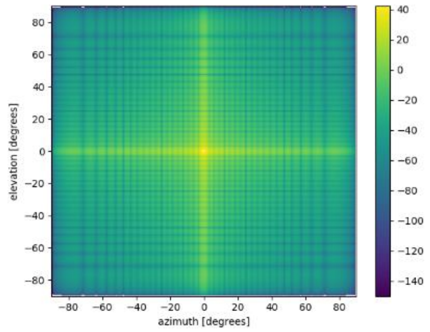
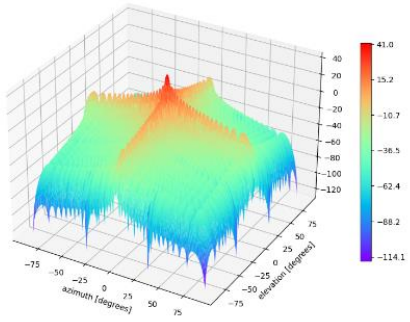
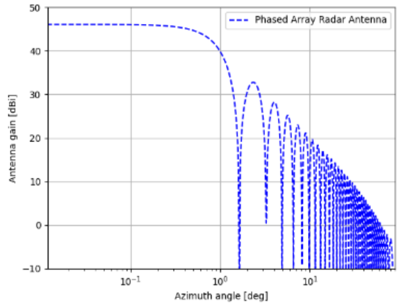


(c) 3D antenna pattern

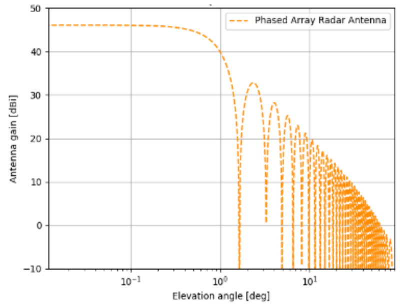


(d) 3D antenna pattern

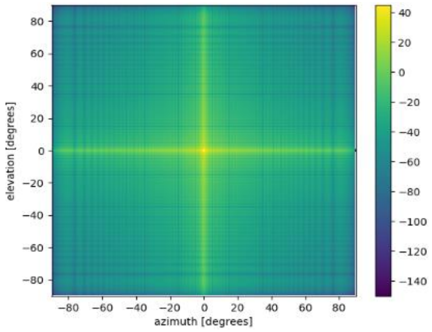
Radar 4: antenna gain = 46 dBi, beamwidthφ = 1.4º, beamwidthθ = 1.4º, element space: 0.5 λ



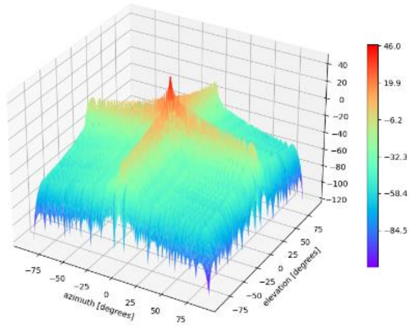
(a) Azimuth antenna pattern



(b) Elevation antenna pattern



(c) 3D antenna pattern



(d) 3D antenna pattern

A4.7.2.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at -15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. Finally, the HIBS visible horizon when

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deployed at 20 km of altitude is approximately 500 km from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A4.7.2.4 Methodology

The Brazilian administration continues to use and develop, in cooperation with partners in the industry and academia, an open-source simulation tool, named SHARC, to support Sharing and Compatibility studies between IMT and other radio communication systems, according to the framework proposed by Recommendation ITU-R M.2101. SHARC is a coexistence static system-level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa. In this study the interference-to-noise ratio is calculated and compared with the protection criteria for their specific frequency range.

A4.7.2.5 Scenarios and results of the study

The study was implemented in accordance with the scenarios described in Figure A4.7.2.4, with the radars positioned at different distances from the HIBS nadir, as described in Table A4.7.2.2. The simulations were done with 10 000 snapshots.

TABLE A4.7.2.2

Geographical coordinates of the meteorological radar stations in the simulation

Position	Distance from point A	Latitude	Longitude
A(1)	-	-15.809422°	-47.866732°
B	45 km	-15.396298°	-47.866732°
C	90 km	-14.991080°	--47.866732°
D	250 km	-13.560102°	-47.866732°
E	350 km	-12.660001°	-47.866732°
F	450 km	-11.760120°	-47.866732°
G	500 km	-11.310301°	-47.866732°

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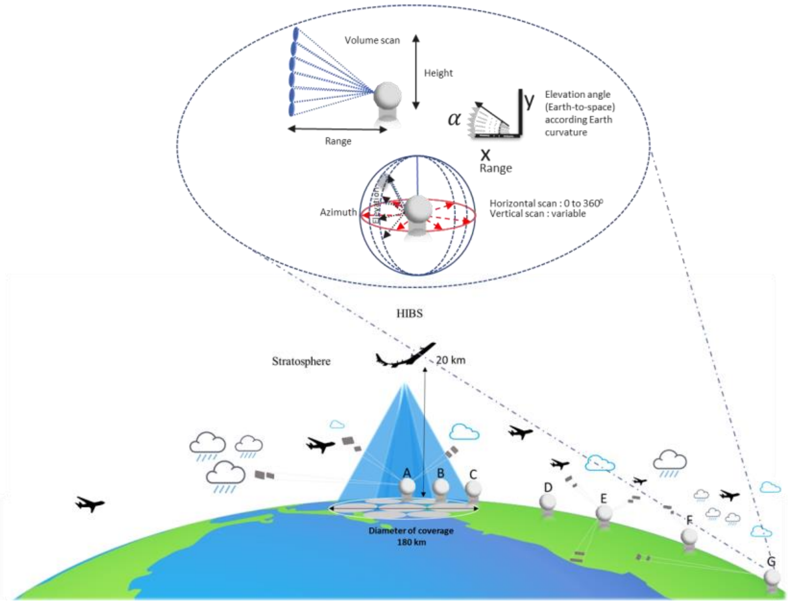
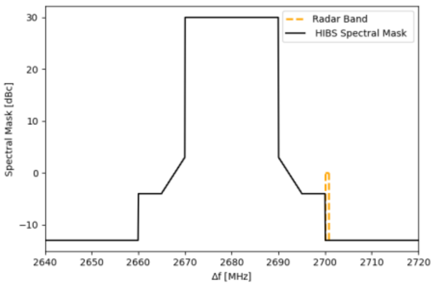
FIGURE A4.7.2.4

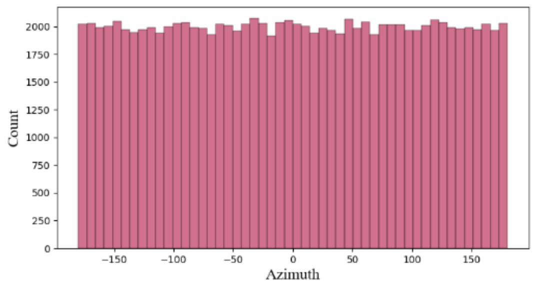
Ground meteorological radars simulation scenarios



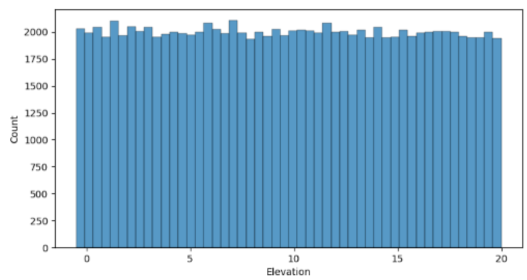
Radar 1: antenna height = 30 m, receiver noise figure = 2.7 dB, horizontal scan: -180º to 180º, vertical scan: -0.5º to 20º



(a) Adjacent channel analysis



(b) Uniform distribution of azimuth scan



(c) Uniform distribution of elevation scan

Radar 2: antenna height = 30 m, receiver noise figure = 9 dB, horizontal scan: -180º to 180º, vertical scan: -2º to 60º

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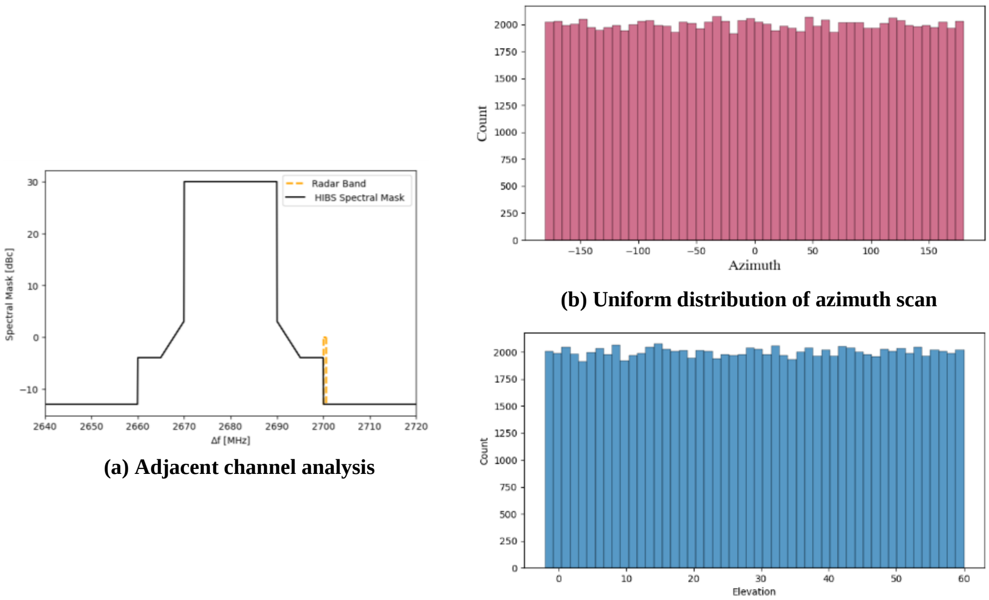

(a) Adjacent channel analysis

(b) Uniform distribution of azimuth scan

(c) Uniform distribution of elevation scan

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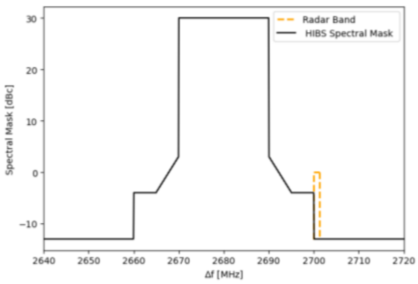
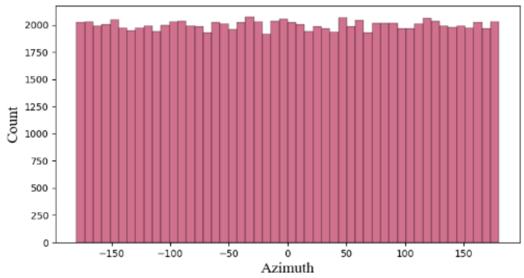
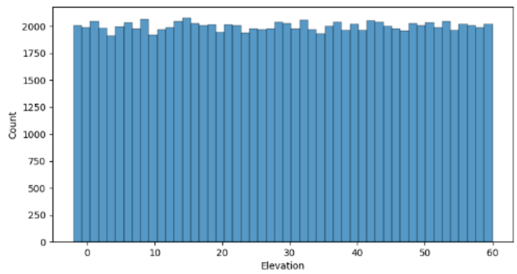
Radar 3: antenna height = 24 m, receiver noise figure = 6 dB, horizontal beamsteering scan per face: -45º to 45º, vertical beamsteering scan per face: -2º to 60º



(a) Adjacent channel analysis

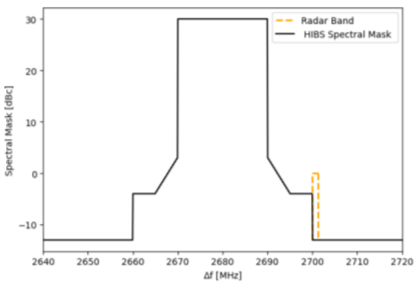


(b) Uniform distribution of azimuth scan

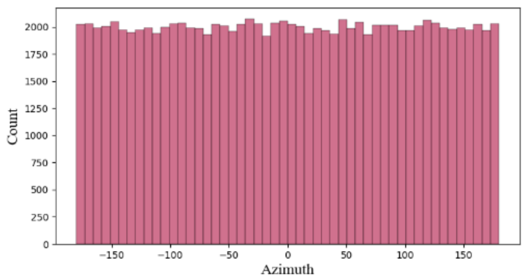


(c) Uniform distribution of elevation scan

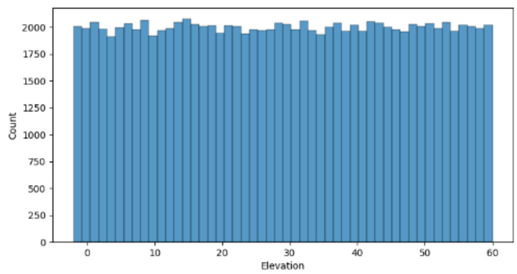
Radar 4: antenna height = 24 m, receiver noise figure = 6 dB, horizontal beamsteering scan per face: -45º to 45º, vertical beamsteering scan per face: -2º to 60º



(a) Adjacent channel analysis



(b) Uniform distribution of azimuth scan

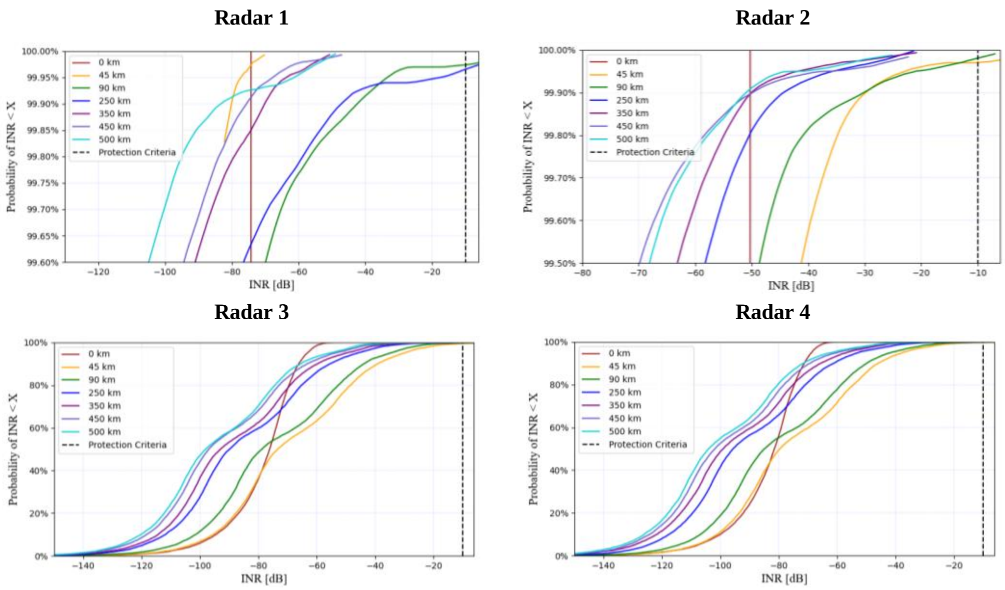


(c) Uniform distribution of elevation scan

The results of the simulations, as shown in Figure A4.7.2.4, indicates the probability of the achieved protection criteria (I/N) for each of the distances described above. In all cases, the probability of the I/N not meeting the protection criteria of -10 dB is lower than 0.1%, which can be considered negligible.

FIGURE A4.7.2.4

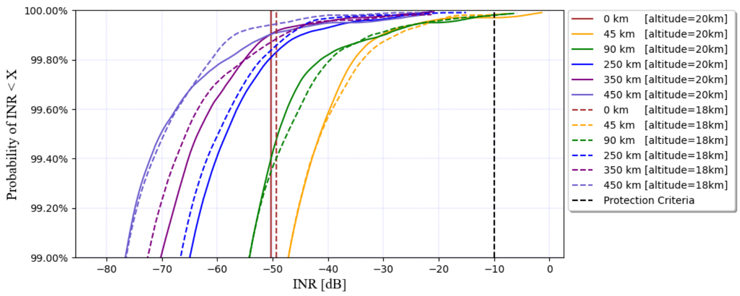
HIBS - Ground meteorological radars adjacent channel simulation results



Additionally, simulations with Radar 2 for adjacent channel compatibility analysis were done considering a sensitivity analysis, by varying the altitude of the HIBS platform from 20 km to 18 km, as shown in Figure A4.7.2.5. The achieved I/N for a HIBS platform altitude of 18 km continued to be lower than the protection criteria of -10 dB with a probability higher than 99.9%.

FIGURE A4.7.2.5

HIBS - Ground meteorological radars adjacent channel simulation results (sensitivity analysis with Radar 2)



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A4.7.2.6 Summary and analysis of the results of Study B

The results of this study show that for HIBS operating in the 2 500-2 690 MHz frequency range the compatibility with meteorological radar service operating in adjacent 2 700-2 900 MHz frequency range is feasible. In all the possible cases, with all types of radar, the protection criteria is met. Additionally, the sensitivity analysis of varying the altitude of the HIBS platform from 20 km to 18 km has shown that the radar protection criteria continues to be met.

A4.8 Compatibility studies with radio astronomy service in the adjacent 2 690-2 700 MHz band and HIBS operating in the 2 500-2 690 MHz frequency range

A4.8.1 Study A: Compatibility between the radio astronomy service operating in the band 2 690-2 700 MHz and HIBS BS operating in the 2 500-2 690 MHz frequency range

A4.8.1.1 General description

The study was conducted using parameters from relevant references as described in Tables A4.9.1.1 – A4.9.1.4. One HIBS system was assumed to consist of two layers, with 1 central and 6 surrounding cells as described in WDPDN REPORT ITU-R M.[HIBS-CHARACTERISTICS], with BS transmitting in the adjacent channel up to 2 690 MHz, from a HAPS platform at nominal altitude 20 km. The study calculated the mean power flux density (pfd) of unwanted emissions arriving at a radio telescope in the frequency band 2 690-2 700 MHz, varying the nadir distance to the HIBS platform in a spherical Earth geometry.

The frequency band 2 690-2 700 MHz is allocated to the radio astronomy service on a primary basis and subject to RR No. **5.340**.

Radio telescopes are sited in remote locations having a clear horizon down to a few degrees elevation, rendering HIBS visible in line of sight at large distances. Site characteristics have little influence on the study results but, for definiteness, this study took as an example a radio telescope operating at an elevation of 7000 feet (Table A4.8.1.1) like the Karl Jansky Very Large Array (VLA) in New Mexico, USA. The VLA and the Meerkat Telescope in South Africa are shown in Figure A4.X.1. They are registered at a single central coordinate.

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FIGURE A4.8.1.1

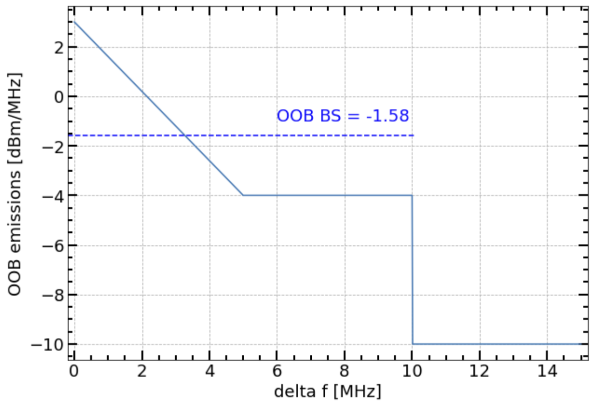
Two radio telescopes operating at 2 695 MHz. Left: The Jansky Very Large Array in New Mexico, USA. Right: The Meerkat Telescope in South Africa.

A4.8.1.2 HIBS BS eirp density in the band 2 690-2 700 MHz allocated to radio astronomy

The unwanted emissions mask for HIBS BS is given in Tables 2 and 2-a of WDPDN REPORT ITU-R M.[HIBS-CHARACTERISTICS] and shown in Figure A4.8.1.2 where, in the case of this study, Δf = 0 corresponds to f = 2 690 MHz. Numerical integration over the frequency band 2 690-2 700 MHz was performed to determine the mean BS power density in the RAS band, –1.51 dBm/MHz, see Figure A4.8.1.2 and Table A4.8.1.3. Spurious emissions arising from HIBS operation in non-adjacent channels were not included in this study.

FIGURE A4.8.1.2

Unwanted emissions spectrum masks and mean power densities.



A4.8.1.3 Incident power flux density

The geometry of the study is illustrated in Figure A4.8.1.3 where it is shown that the line between the platform and the telescope defining the nadir distance passes between two outer-layer HIBS BS cells/beams and is not aligned with any one of them.

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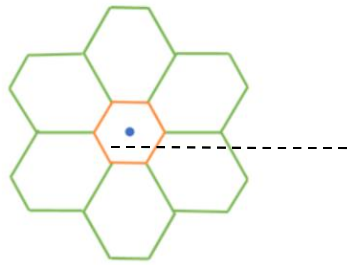
Shown in Figure A4.8.1.4 at left is the pfd received from HIBS transmitting aboard one platform as a function of the platform's nadir distance to the radio astronomy station. Shown at right is the apparent elevation of the HIBS station above the horizon at the telescope. Shown separately at left in Figure A4.8.1.4 are the total incident pfd from all BS serving the two-layer configuration and that from the individual contribution of the nadir-pointing BS serving the central cell directly beneath the platform. At larger separation the contribution from the outer layer is enhanced by the 67^{o} upward tilt from nadir of the radiating elements.

FIGURE A4.8.1.3

Geometrical configuration of the study.



As a check, note that the pfd at 0 nadir distance arising from the nadir-pointing BS is just that for a conducted power of –1.51 dBm/MHz affected by the element gain (8 dBi) and ohmic losses (–2dB) at 18 km line of sight distance, resulting in –181.6 dBW/m^2/Hz. The effect of the individual antenna element beam pattern is evident in Figure A4.8.1.4 because the incident pfd from the central BS drops much faster than the inverse square law distance dependence as the platform nadir distance increases away from the origin. By contrast, the upward tilt of the outer layer BS is more nearly oriented toward the telescope at larger nadir distance, compensating for increased spreading loss.

A4.8.1.4 Incident PFD compared with the protection threshold in Recommendation ITU-R RA.769

The total incident pfd exceeds the Recommendation ITU-R RA.769 threshold at all separations by 30-70 dB (see Figure A4.8.1.5). In this case, added attenuation of the unwanted emissions of whatever kind (see Section A4.8.1.7) would be required to operate compatibly with radio astronomy. The added attenuation that will lower the incident pfd to the Recommendation ITU-R RA.769 threshold will be denoted X_{block}. Once that is added and the threshold pfd in Recommendation ITU-R RA.769 is met, compatibility becomes a question of sky blockage, as discussed in A4.8.1.6.

A4.8.1.5 Clutter loss

Over the range of nadir distances shown in Figures A4.8.1.4 and A4.8.1.5, the line of sight between the HIBS and the VLA does not pass low enough to encounter ground clutter except in the very

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immediate vicinity of the telescope where the only "clutter" is other antennas that by design do not obstruct each other.

FIGURE A4.8.1.4

Left: Received power flux density vs. HIBS platform nadir distance. The total pfd and the contribution of the nadir-pointing central antenna element are shown. The horizontal dashed line at bottom left represents the protection threshold -247 dB W/m^2/Hz in Table 1 of Rec. ITU-R RA.769 at 2 695 MHz. Right: Elevation angle of the HIBS at the RAS station.

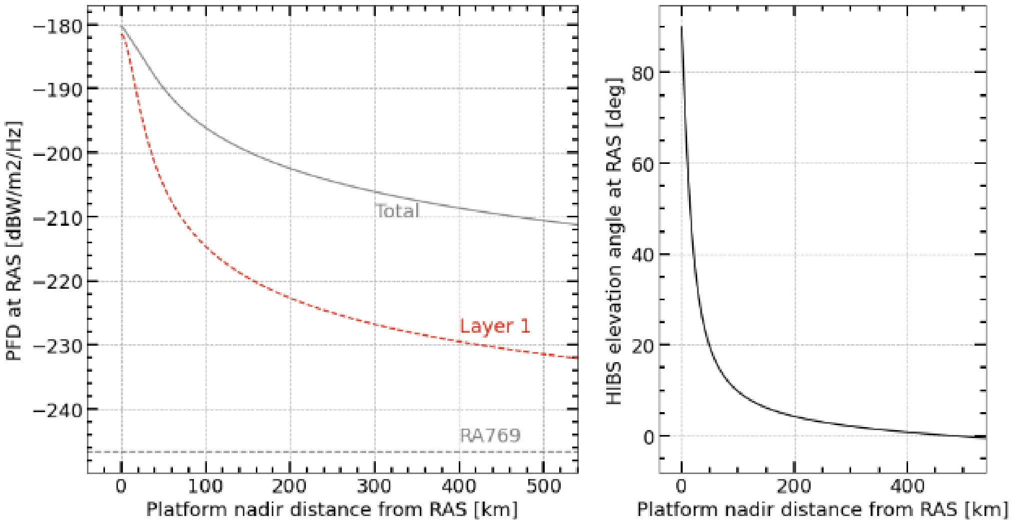

TABLE A4.8.1.1

RAS operating characteristics and protection threshold

RAS Parameters	Value	Reference
PFD threshold	-247 dB W/m^2/Hz	Rec. ITU-R RA.769, Table 1
Antenna gain	0 dBi	Rec. ITU-R RA.769
Site altitude	2.13 km (7000')	Karl Jansky VLA (USA)
Max data loss from HIBS	2%	Rec. ITU-R RA.1513
Allocated Frequency Band	2 690 – 2 700 MHz	RR. 5.340

TABLE A4.8.1.2

Platform operating characteristics

HAPS Parameters	Value	Reference
Altitude (nominal)	20 km	RR. 1.66A
Horizontal circulation radius	5 km	Rep. ITU-R F.2439
Altitude deviation	+5 km (20 – 25 km)_	Rep. ITU-R F.2439

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TABLE A4.8.1.3

HIBS operational characteristics

HIBS/BS Parameters	Value or Description	Reference in WDPDN Report ITU-R M.[HIBS-CHARACTERISTICS]
Spectrum mask per beam	–1.51 dBm/MHz	Numerical integration of the mask in Table 2-A, see Figure A4.X.2
Single element gain	8 dBi	Parameters from Table 5
Ohmic losses	2 dB	Parameters from Table 5
Antenna pattern	Single element as per Rec. ITU-R M.2070	Parameters from Table 5
Beams considered	1x1st layer toward nadir 6x2nd layer 67° off-nadir	Section 6.1.3.2 2nd layer offset +/- 30°, 90°, 150° in azimuth relative to the RAS antenna

TABLE A4.8.1.4

Propagation characteristics

Propagation loss	Value or Description	Reference
Free space loss	Inverse square law	
Atmospheric attenuation	Numerical integration of 0.006 dB/km * exp (-h/6 km) at height h along path to RAS	P.619, P.676, P.835
Ducting, Scintillation	Negligible	P.619, P.676, P.835
Clutter loss	None	See Section A4.X.5

A4.8.1.6 Sky blockage as data loss

As noted in A4.8.1.4, the pfd incident on the radio telescope from only one platform exceeds the threshold in Rec. ITU-R RA.769 and an added attenuation denoted X_{block} in the direction of the radio telescope would be required to lower the incident pfd to the Recommendation ITU-R RA.769 level.

The larger point is that the protection thresholds in the tables of Recommendation ITU-R RA.769 are calculated for 0 dBi RAS gain, and, as noted in Rec. ITU-R RA.1513, ensuring 0 dBi gain requires an angular offset from a persistent interferer like HIBS that remains in direct line of sight. Pointing too close to the HIBS would imply an RAS gain greater than 0 dBi, raising the received power above the protection threshold. In this way, a portion of the sky may be permanently blocked, resulting in data loss. As an example, sky blockage by the GSO belt is discussed in Rec. ITU-R RA.769 where the protection thresholds are tightened by 15 dB to allow RAS stations to point within 5° of the belt. Another instance of data loss associated with sky blockage is encountered in the case of HAPS, as described below, where X_{block} = 30 dB was adopted to solve issues of compatibility.

For the antenna pattern used in sharing and compatibility studies, defined in Rec. ITU-R SA.509, an antenna gain of 0 dBi is reached at 19° from the boresight. An angular cone of radius θ subtends a solid angle 2π(1-cos(θ)) steradians or, for θ = 19°, 5.4% of the sky above the horizon.

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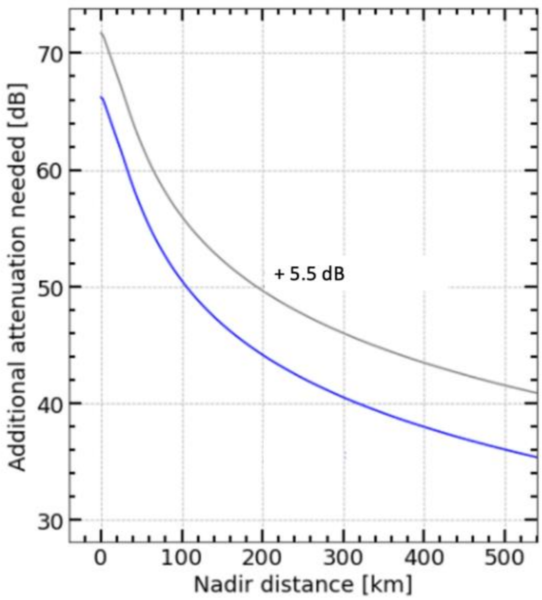
Such sky blockage exceeds the allowable 2% data loss from one network according to Rec. ITU-R RA.1513. Limiting the area of a cone of avoidance below 2% of the sky requires $\theta \leq 11.5^o$, in which case the RAS antenna gain, independent of antenna diameter in Rec. ITU-R SA.509, is at least 5.5 dBi. This increases the value of X_{block} needed to protect radio astronomy operations.

FIGURE A4.8.1.5

Additional attenuation X_{block} needed to reach the Recommendation ITU-R RA.769 levels for 0 dBi RAS antenna gain and for an 11.5^o avoidance cone where X_{block} is increased by 5.5 dB.



Calculation of the size of the angular regions of avoidance and the value of X_{block} is complex because to maintain the 2% data loss, each additional HIBS in line of sight reduces the required size of all cones of avoidance, implying higher RAS gain and increased X_{block}. This could greatly complicate compatibility if several HIBS in line of sight to the same radio telescope are deployed by different operators or in different administrations. In previous studies of a full HAPS network buildout, compatibility with RAS operations at 23.6-24 GHz required X_{block} = 30 dB in the direction of radio astronomy stations as discussed in Rep. ITU-R F.2472-0. This allowed the cones of avoidance to have radii $\theta = 3^o$ and to occupy 2% of the sky in the aggregate.

As an additional challenge, the X_{block} value calculated above ignores an additional source of sky blockage associated with circulation of the platform and the consequent positional uncertainty that must be factored into calculation of the size of the region of avoidance. HIBS will follow the motion of the platform with vertical and horizontal excursions of 5 km and +/–5 km, respectively, as noted in Table A4.9.1.2 drawn from Rep. ITU-R F.2439. An excursion of 5 km across the line of sight subtends an angle of 1.4^o at a platform distance of 200 km At shorter distances, for instance 50 km, this angle increases to 5.7^o.

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A4.8.1.7 Summary

With the parameters considered in this study, for a single HIBS and a RAS station, and the deployment scenario considered, achieving compatibility requires further measures.

To achieve compatibility of a single HIBS using a frequency channel adjacent to 2 690 MHz and a RAS station operating in the 2 690-2 700 MHz band, the following measures can be considered:

The RAS operator will avoid pointing too directly at the HIBS to avoid receiving harmful interference, with the size of the zone of avoidance dependent on HIBS deployment and measures taken by HIBS operators. The dynamic movement of the HIBS may be an important consideration in this avoidance.

A combination of the following measures could be employed by the HIBS operator:

a) Avoid using the IMT channels nearest in frequency so that the spurious emissions in the RAS band drops to -13 or –30 dBm/MHz rather than –1.51 dBm/MHz.

b) As assumed in this work, avoid the situation where HIBS BS are oriented in azimuth directly toward the radio telescope.

c) Filter or otherwise attenuate unwanted emissions in the direction of the RAS station. According to Figure A4.8.5, the required additional attenuation for one HIBS (in a 2-layer 7 cell HIBS system) at 90 km nadir distance from a RAS station is X_{block} = 56 dB, (see Section A4.8.4 and A.4.8.6) including the additional 5.5 dB attenuation that limits the fractional sky blockage of the region of avoidance about the HIBS to 2%.

d) Geographic separation.

A4.8.2 Study B

A4.8.2.1 Technical and operational characteristics of HIBS operating 2 500-2 690 MHz frequency range

The technical and operational characteristics of HIBS are those for Band 3 from the working document towards a preliminary draft new Report ITU-R M.[HIBS-CHARACTERISTICS], including Table 2, Table 2-A, Table 3, and Table 5. It should be emphasized that the analysis is needed only with the HIBS (BS), as the user equipment is the same as the IMT ground-based network.

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FIGURE A4.8.2.1

HIBS antenna pointing and network topology

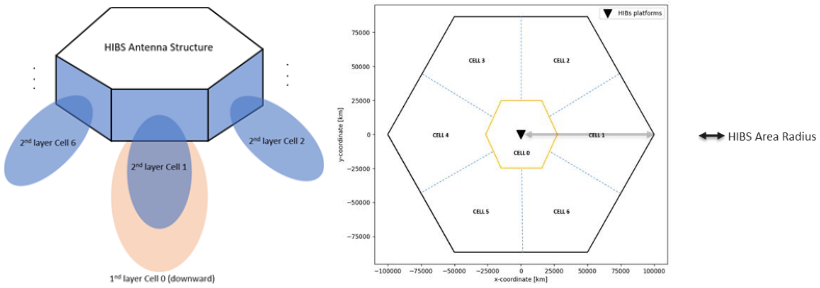
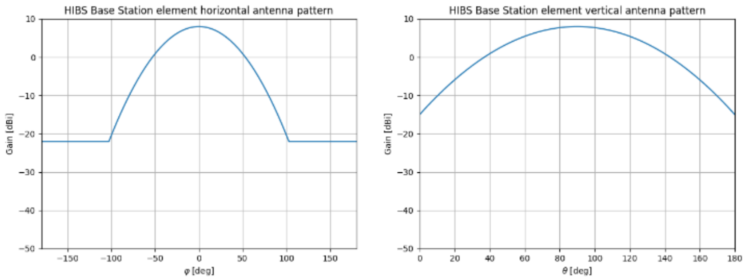
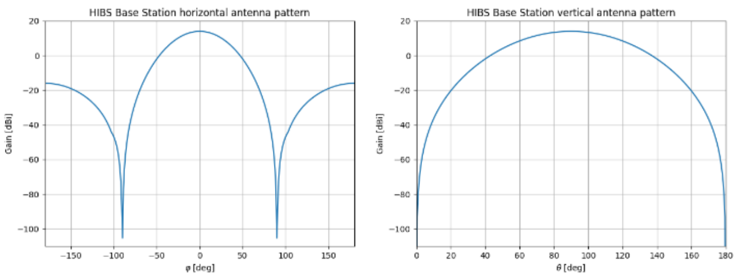


FIGURE A4.8.2.2

HIBS antenna pattern (Recommendation ITU-R M.2101)
(a) Single element (for adjacent case)



(b) 1st layer (2 × 2)



(c) 2nd layer (4 × 2)

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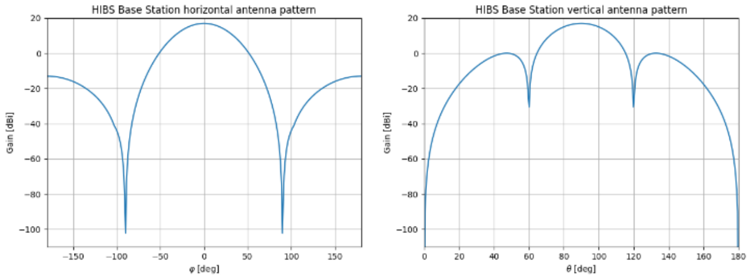

A4.8.2.2 Technical and operational characteristics of radio astronomy service operating in the 2 690-2 700 MHz frequency range

The 2 690-2 700 MHz band is primarily used for the study of continuum emission of radio sources. Many extragalactic radio sources show a "break" in thein non-thermal spectrum in the region between 1 to 3 GHz and continuum measurement at approximately 2.7 GHz is essential to define such a spectral characteristic. Also, the 2 690-2 700 MHz frequency band is important for polarization measurement of the radiation that is observed from radio sources. The radio astronomy service (RAS) receivers are designed to have the lowest receiver noise figures allowing a large case of studies involving many astronomical signal levels. Receiver input stage couples directly to the antenna without input filters or coupling components that could rise the loss and consequently the input noise temperature.

The characteristics for RAS are based on the information contained in the Recommendation ITU-R RA.769, as summarized below.

TABLE A4.8.2.1

Characteristics of the RAS

Parameter	Value
Band of operation	2 690-2 700 MHz
Bandwidth	10 MHz
Antenna height	15 m
Antenna pattern	Isotropic
Antenna gain	0 dBi
Antenna noise temperature	12 K
Receiver noise temperature	10 K
Protection criteria	−207 dBW

Recommendation ITU-R RA.769 specifies the protection criteria for radio astronomical observations and gives threshold levels of detrimental interference for primary radio astronomy bands. In the 2 690-2 700 MHz band, for single-dish continuum observations making use of the entire 10 MHz bandwidth, the threshold power flux density (pfd) limit is −177 dB(W/(m^2)).

This band is used exclusively for continuum observations, not for spectral line observations. In addition, for Very Long Baseline Interferometry (VLBI) observations, where the separation of the antennas are greater, the signals are recorded and correlated after the observations, and, the chance of occurrence of correlated interference is very small.

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In order to simulate the interference arriving at the side-lobe, an isotropic antenna pattern with 0 dBi of gain is considered in accordance with Recommendation ITU-RA.769.

A4.8.2.3 Propagation model

Recommendation ITU-R P.1409, item 2.3, indicates that Recommendation ITU-R P.619 should be used for studies of frequency sharing between high-altitude platform networks and other terrestrial stations. Furthermore, Recommendation ITU-R P.835 is used for reference atmosphere, and a latitude < 22º (Brasilia, Brazil is at −15.8º) was considered, which has no significant seasonal variations, and thus a single annual atmosphere profile can be used.

The total propagation loss considered is the sum of free space loss, atmospheric gasses loss, beam spreading attenuation, and tropospheric scintillation loss. Additionally, the study considered 3 dB of average polarization discrimination loss. The diffraction loss, building loss, and clutter loss were not considered as the HIBS is in a line-of-sight scenario. Finally, the HIBS visible horizon when deployed at 18 km and 20 km of altitude is approximately 478 km and 500 km, respectively, from its nadir, after which it can no longer be considered in a line-of-sight scenario due to heavy attenuation.

A4.8.2.4 Methodology

The SHARC open-source simulation tool is used, which is a coexistence static system-level simulator using the Monte Carlo method. It has the main features required for a common system-level simulator, such as antenna beamforming, power control, resource blocks allocation, among others. The simulator is written in Python and the source code is available at GitHub https://github.com/SIMULATOR-WG/SHARC.

At each simulation snapshot, the UE are randomly generated and located within a cell cluster. The coupling loss is calculated between the UE and their nearest BS. The simulation then performs resource scheduling and power control, enabling the interference calculation among the systems. Finally, system performance indicators are collected, and this procedure is repeated for a fixed number of snapshots.

With SHARC, it is possible to study the coexistence between HIBS, IMT, and other services and applications. The main key performance indicator obtained from these simulations is the aggregate interference generated by the HIBS into the other system, and vice-versa.

A4.8.2.5 Scenarios and results of the study

The study was implemented in accordance with the scenarios described in Figure A4.9.2.3, with the RAS stations positioned at different distances from the HIBS nadir, as described in Table A4.9.2.2. The simulations were done with 10 000 snapshots.

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FIGURE A4.8.2.3

HIBS-RAS simulation scenario

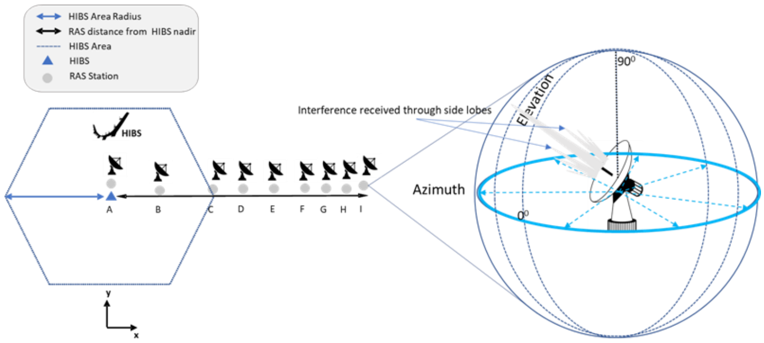

TABLE A4.8.2.2

Geographical coordinates of the RAS stations in the simulation

Position	Distance from point A	Latitude	Longitude
A[(1)]	–	−15.809422°	−47.866732°
B	45 km	−15.396298°	−47.866732°
C	90 km	−14.991080°	−47.866732°
D	150 km	−14.458172°	−47.866732°
E	250 km	−13.560102°	−47.866732°
F	350 km	−12.660001°	−47.866732°
G	450 km	−11.760120°	−47.866732°
H	478 km	−11.510010°	−47.866732°
I	500 km	−11.310301°	−47.866732°

[(1)] HIBS nadir.

The simulation for adjacent compatibility analysis was done considering HIBS central frequency at 2 680 MHz, and the RAS at 2 695 MHz, as shown in Figure A4.8.2.4.

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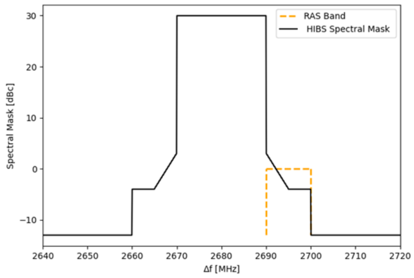
FIGURE A4.8.2.4

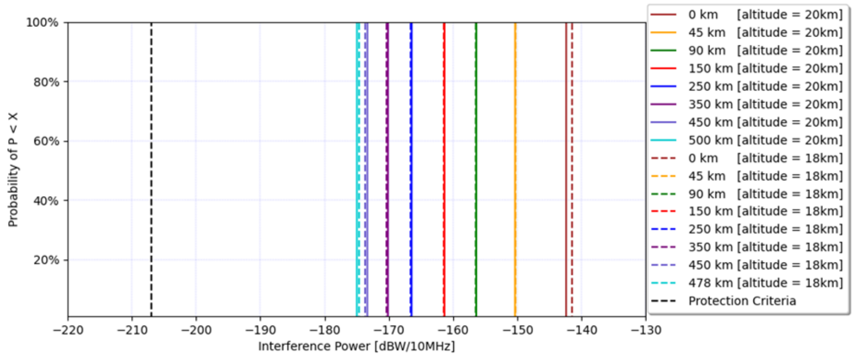
HIBS-RAS adjacent analysis



The results of the simulations, as shown in Figure A4.8.2.5, indicate the probability of the achieved interference power for each of the distances described above. Furthermore, a sensitivity analysis was performed considering HIBS at an altitude of 18 km.

FIGURE A4.8.2.5

HIBS-RAS adjacent simulation results



In case no additional measures are implemented for the HIBS station, the results show that the achieved interference power will not meet the RAS protection criteria.

There are different mitigation methods that can be considered on the national level, and which can reduce the unwanted emissions from HIBS towards RAS stations, and thus ensure the compatibility:

– Antenna side-lobe suppression: The side-lobe suppression aims to decrease HIBS space-earth radiation entering through RAS antenna side-lobes. This technique has the benefit of decreasing possible interference into the sidelobes from 30 to 50 dB.

– Guard-band: This technique provides an adequate separation in frequency between operating services and can be used in conjunction with adequate RF filter rejection.

– RF Filters: RF Filters can be implemented into the interferer system. Notch filters with zero poles into RAS band can be useful to maintain a good trade-off between insertion loss and selectivity to prevent interferences from HIBS.

– Geographical separation: Most RAS stations are located in isolated areas and surrounded by clutter. In Brazil, one example is the Itapetinga station, which is

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surrounded by mountains to reduce possible interference from its surroundings. In addition, the geographical separation between systems can be useful in achieving the protection criteria limits.

A4.8.2.6 Summary and analysis of the results of Study B

The results of this study show that for HIBS operating in the 2 500-2 690 MHz frequency range the compatibility with RAS in adjacent channel is only feasible if additional measures are implemented for the HIBS stations. For compatibility between HIBS and RAS one or more mitigation techniques can be implemented on the national level to ensure the protection of RAS stations, including, among others: antenna side-lobe suppression, guard-bands, RF filters, and geographical separation.

A4.8.3 Study C

A4.8.3.1 General description

The use of the frequency band 2 655 – 2 690 MHz for radio astronomy service is under No. **5.149** of the Radio Regulations. In making assignments to the HIBS base station in the band 2 655-2 690 MHz, administrations are urged to take all practicable steps to protect radio astronomy service from harmful interference. **No. 5.149** further emphasises that emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service.

The spectral region 2 655-2 700 MHz is important for RAS continuum measurements due to the low galactic background radiation and the excellent quality of the receivers operating at this frequency with very low noise. The band is also useful for galactic studies; i.e. the state of matter and the possibilities of the existence of blackholes in galactic nuclei, the explosive activities and the production of intense double radio sources, the formation of galaxies and quasars and many other major astrophysical subjects

The study was conducted using parameters from references provided in the working WDPDNR ITU-R M.[HIBS-CHARACTERISTICS]

TABLE A4.8.3.1

Possible HIBS frequency arrangement in the frequency range 2 500-2 690 MHz (ITU-R M.1036)

No.	Frequency band		Duplex mode
	Mobile station transmitter (MHz)	Base station transmitter (MHz)	
C1	2 500-2 570	2 620-2 690	FDD
C1	2 570-2 620		TDD
C2	2 500-2 570 External	2 620-2 690 2 570-2 620	FDD
C3	2 500-2 690		Flexible FDD/TDD

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TABLE A4.8.3.2

Deployment related parameters of HIBS BS in the frequency band 2 500-2 690 MHz

Parameter	Band (2 500-2 690 MHz)
Network topology and characteristics	
BS density or ISD	1 BS/HIBS area
HIBS area radius	90 km
HIBS Network Configuration (Duplex Mode)(1)	FDD/TDD
Base station characteristics/Cell Structure	
HIBS Platform Altitude	20-50 km(1)
Number of cells/HIBS	7
Frequency reuse	1
HIBS Platform Antenna pattern	Recommendation ITU-R M.2101(2)(3)
Element gain	8 dBi
Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V
Horizontal/vertical front-to-back ratio	30 dB for both H/V
Antenna polarization	Linear/±45 degrees
Antenna array configuration (Row × Column)	2 x 2 elements (1st layer cell), 4 x 2 elements per cell (2nd layer cell)
Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V
Ohmic losses	2 dB
HIBS Platform Antenna tilt	90º (1st layer cell), 23º (2nd layer cell)
HIBS Conducted power per antenna element	37 dBm (1st layer cell), 34 dBm (2nd layer cell)
HIBS Platform e.i.r.p./cell	55 dBm (1st layer cell), 58 dBm (2nd layer cell)
HIBS Platform e.i.r.p. Spectral Density/cell	42 dBm/MHz (1st layer cell), 45 dBm/MHz (2nd layer cell)

Notes to the Table:

(1) Additional consideration may be given to parameters that deviate from established regulatory conditions for high altitude platform stations and may require a sensitivity analysis. This sensitivity analysis could include deployment scenarios involving an altitude that could go down to 18 km for the purpose of determining appropriate sharing and compatibility measures to protect existing services.

(2) The values are representative of HIBS extracted from the deployment related parameters of the ground component of IMT.

(3) Considering the relevant normalization factor, if needed.

TABLE A4.8.3.3

Deployment related parameters of a radio astronomy station in the frequency band 2 655 – 2 690 MHz

RAS Parameters	Value	Reference
PFD threshold	-247 dB W/m^2/Hz	Rec. ITU-R RA.769, Table 1

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Antenna gain	0 dBi	Rec. ITU-R RA.769
Site altitude	1.38 km	HartVGS (South Africa)
Max data loss from HIBS	2%	Rec. ITU-R RA.1513
Allocated Frequency Band	2 690-2 700 MHz	RR. No. **5.340**

A4.8.3.2 Propagation Model

The propagation model that will be used for this analysis is ITU-R P.619

A4.8.3.2 Methodology

Analysis will be performed to calculate the mitigation required to protect radio astronomy service undertaking observations in the frequency range 2 655-2 690 MHz from harmful interference from a HIBS base station operating in the frequency band 2 500-2 690 MHz.

[*Editor's note : TBD*]

A4.8.3.3 Analysis

[*Editor's note : TBD*]

A4.8.3.3 Summary and analysis of the results of the study

[*Editor's note : TBD*]

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APPENDIX

Comparison of interference from HIBS and ground-based IMT base station to space station

[*Editor's Note: Different opinions were expressed regarding the applicability of the information in the Appendix, and thus further discussion is required at the following WP 5D meetings. It should be highlighted that WRC-23 agenda item 1.4, as per Resolution* ***247 (WRC-19)****, strictly limits the sharing and compatibility studies of frequency bands for HIBS and not for ground-based IMT. Thus, the results of the studies should not impose any constraints in any existing service, including IMT systems. As the current version of text of the Appendix may raise concerns regarding the use of ground-based IMT in these bands, the proponents are invited to review the relevance of the information contained herein, noting that currently it should be considered for informational purposes only and not intended to be included as part of the summary of studies for this agenda item.*]

AA.1 Introduction

This study conducted the comparison of interference level at the orbits of space station (GSO/NGSO) from HIBS and ground-based IMT base station in the frequency bands subject to sharing and compatibility studies with space stations under WRC-23 agenda item 1.4 in both co-channel and adjacent-channel cases in order to evaluate whether HIBS specific mitigation measures would be necessary to protect space stations.

It is noted that this analysis aims only for the comparison of interference level at the orbits of space stations from HIBS and ground-based IMT base stations in order to evaluate whether HIBS specific mitigation measures would be necessary to protect space stations and the conclusion of this analysis does not provide any constraints to the existing IMT identification in accordance with Resolution **247 (WRC-19)**.

AA.2 Technical and operational characteristics

AA.2.1 Technical and operational characteristics of HIBS

Table AA.1 is the technical and operational characteristics of HIBS based on the working document towards a PDN Report ITU-R M.[HIBS-CHARACTERISTICS]. With regard to Platform Altitude, this study considers at 18 km in addition to 20 km and 50 km in order to perform the sensitivity analysis on the interference from HIBS operating at altitude below 20 km.

TABLE AA.1

Technical and operational characteristics of HIBS

Parameter	**Band 2** **(1 710-1 980 MHz** **2 010-2 025 MHz** **2 110-2 170 MHz)**	**Band 3** **(2 500-2 690 MHz)**
Channel bandwidth	20 MHz	20 MHz
Network topology and characteristics		

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Parameter	**Band 2** **(1 710-1 980 MHz** **2 010-2 025 MHz** **2 110-2 170 MHz)**	**Band 3** **(2 500-2 690 MHz)**
BS density or ISD	1 BS/HIBS area	1 BS/HIBS area
HIBS area radius	100 km	90 km
Base station characteristics/Cell Structure		
Platform Altitude	18/20/50 km	18/20/50 km
Number of cells/HIBS	7	7
Frequency reuse	1	1
Platform Antenna pattern	Recommendation ITU-R M.2101	Recommendation ITU-R M.2101
Element gain	8 dBi	8 dBi
Horizontal/vertical 3 dB beamwidth of single element	65º for both H/V	65º for both H/V
Horizontal/vertical front-to-back ratio	30 dB for both H/V	30 dB for both H/V
Antenna polarization	Linear/±45 degrees	Linear/±45 degrees
Antenna array configuration (Row × Column)	2 x 2 elements (1st layer cell), 4 x 2 elements per cell (2nd layer cell)	2 x 2 elements (1st layer cell), 4 x 2 elements per cell (2nd layer cell)
Horizontal/Vertical radiating element spacing	0.5 of wavelength for both H/V	0.5 of wavelength for both H/V
Ohmic losses	2 dB	2 dB
Platform Antenna tilt	90º (1st layer cell), 23º (2nd layer cell)	90º (1st layer cell), 23º (2nd layer cell)
Conducted power per antenna element	37 dBm (1st layer cell) 34 dBm (2nd layer cell)	37 dBm (1st layer cell) 34 dBm (2nd layer cell)
OOBE level per antenna element	Table 1-A	Table 1-A

TABLE AA.1-A

Spectrum mask - HIBS (BS)

Frequency offset from “edge of transmission” Δf	**Emission limit**	**Measurement bandwidth**
0 MHz ≤ Δf < 5 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < 10 MHz	−14 dBm	100 kHz
10 MHz ≤ Δf	−13 dBm	1 MHz

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Note: For AAS BS, the Over-The-Air (OTA) emission requirements measured as Total Radiated Power (TRP) are defined as the basic limits described in the table plus 9 dB.

AA.2.2 Technical and operational characteristics of ground-based IMT base station

Since all of the subject frequency bands under Resolution **247 (WRC-19)** have already been identified for IMT, it would be assumed that IMT-Advanced base stations have been implemented worldwide in these frequency bands. Therefore, this study used Macro rural (1-3 GHz) in Report ITU-R M.2292 as the technical and operational characteristics of ground-based IMT base station.

AA.3 Methodology

Table 2 shows the interference scenarios. Altitude of space stations was assumed as 36 000 km (GSO) and 7 000 km (NGSO) for each frequency range of 1 710-1 885 MHz, 1 885-1 980 MHz/2 010-2 025 MHz/2 110-2 170 MHz and 2 500-2 690 MHz, which are subject to sharing and/or compatibility studies under WRC-23 agenda item 1.4.

TABLE AA.2

Interference scenarios

Scenario	Frequency range	Co-channel/Adjacent-channel	Space station altitude	HIBS platform altitude
A-1	1 710-1 885 MHz	Co-channel	36 000 km (GSO)/ 700 km (NGSO)	18/20/50 km
A-2	1 710-1 885 MHz	Adjacent-channel	36 000 km (GSO)/ 700 km (NGSO)	18/20/50 km
B-1	1 885-1 980 MHz/ 2 010-2 025 MHz/ 2 110-2 170 MHz	Co-channel	36 000 km (GSO)/ 700 km (NGSO)	18/20/50 km
B-2	1 885-1 980 MHz/ 2 010-2 025 MHz/ 2 110-2 170 MHz	Adjacent-channel	36 000 km (GSO)/ 700 km (NGSO)	18/20/50 km
C-1	2 500-2 690 MHz	Co-channel	36 000 km (GSO)/ 700 km (NGSO)	18/20/50 km
C-2	2 500-2 690 MHz	Adjacent-channel	36 000 km (GSO)/ 700 km (NGSO)	18/20/50 km

The following steps were performed to calculate the interference level at the orbit of space station from HIBS and ground-based IMT base stations with elevation angle between 0° and 90°. It should be noted that this study compared the interference level from 1 HIBS and multiple ground-based IMT base stations equivalent to area coverage per 1 HIBS.

Step 1: Calculate the interference level at the orbit of space station from 1 HIBS:

$$I_{HIBS} = 10\log\left(\sum_{n=1}^{N} \frac{EIRP_{HIBS}(n)}{ADL_{HIBS}(\theta, n)}\right) - FSL$$

where:

$EIRP_{HIBS}(n)$: HIBS maximum e.i.r.p (W/MHz) in cell n

N: number of cells

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θ: elevation angle (degrees) at HIBS towards space station (angle of arrival above the horizontal plane)

$ADL_{HIBS}(\theta, n)$: angular discrimination loss of HIBS in cell n at elevation angle θ

FSL: free space loss (dB) between HIBS and space station

Step 2: Calculate the interference level at the orbit of space station from multiple ground-based IMT base stations:

$$I_{ground\_IMT} = 10\log(\sum_{n=1}^{N} \frac{EIRP_{ground\_IMT}(n)}{ADL_{ground\_IMT}(\theta, n)}) - FSL + ABA + 10\log\frac{C_{HIBS}}{C_{ground\_IMT}}$$

where:

$EIRP_{ground\_IMT}(n)$: ground-based IMT base station maximum e.i.r.p (W/MHz) in sector n

N: number of sectors

θ: elevation angle (degrees) at ground-based IMT base station towards space station (angle of arrival above the horizontal plane)

$ADL_{ground\_IMT}(\theta, n)$: angular discrimination loss of ground-based IMT base station in sector n at elevation angle θ

FSL: free space loss (dB) between ground-based IMT base station and space station

ABA: average base station activity (dB)

C_{HIBS}: area coverage (km2) per HIBS

C_{ground_IMT}: area coverage (km2) per HIBS ground-based IMT base station

Step 3: Calculate the difference of interference level from HIBS and ground-based IMT base stations:

$$\Delta I = I_{ground\_IMT} - I_{HIBS}$$

AA.4 Calculation results

Figures AA.1 to AA.6 show the calculation results of the difference in the interference level from HIBS and ground-based IMT base stations in each scenario. In all scenarios, the interference level at the orbit of space station from HIBS is at least 15 dB lower than that from ground-based IMT base stations at every elevation angle.

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FIGURE AA.1

Difference in the interference level from HIBS and ground-based IMT base stations in scenario A-1 (Co-channel case in 1 710-1 885 MHz)

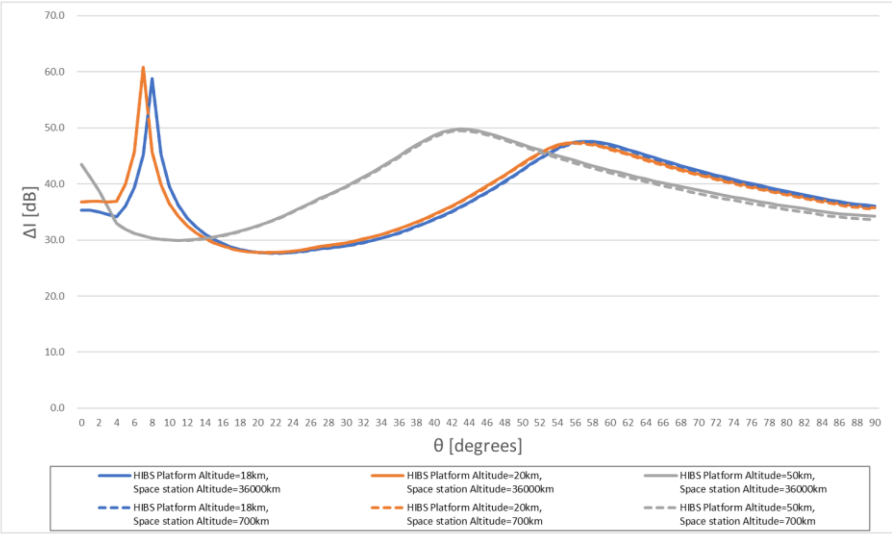

FIGURE AA.2

Difference in the interference level from HIBS and ground-based IMT base stations in scenario A-2 (Adjacent-channel case in 1 710-1 885 MHz)

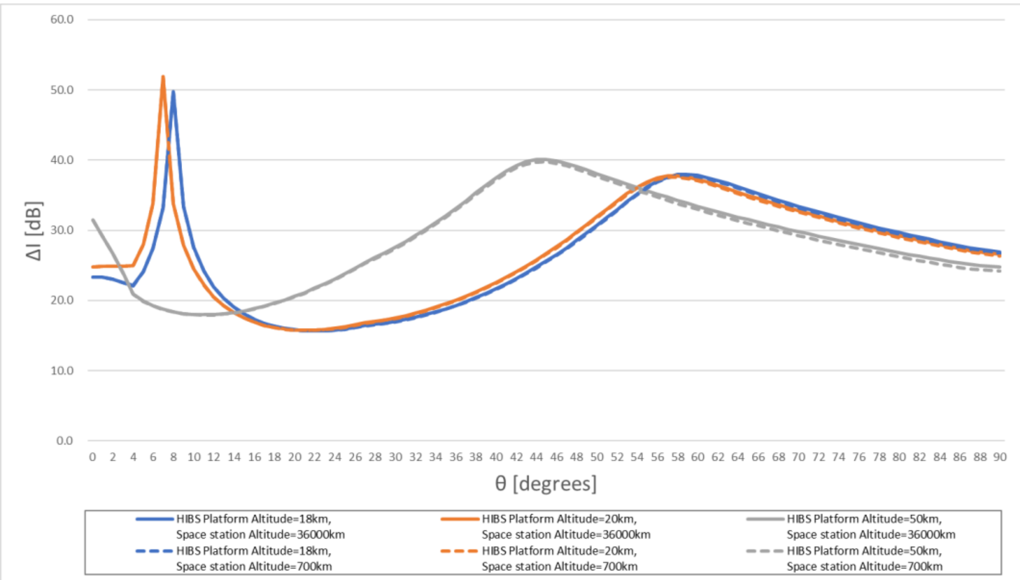

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FIGURE AA.3

Difference in the interference level from HIBS and ground-based IMT base stations in scenario B-1 (Co-channel case in 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz)

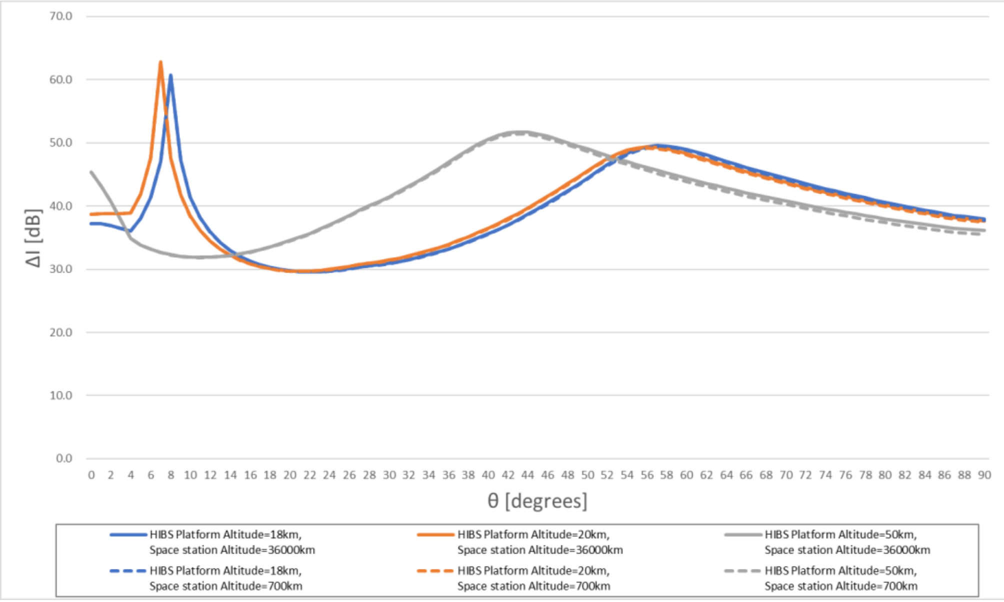

FIGURE AA.4

Difference in the interference level from HIBS and ground-based IMT base stations in scenario B-2 (Adjacent-channel case in 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz)

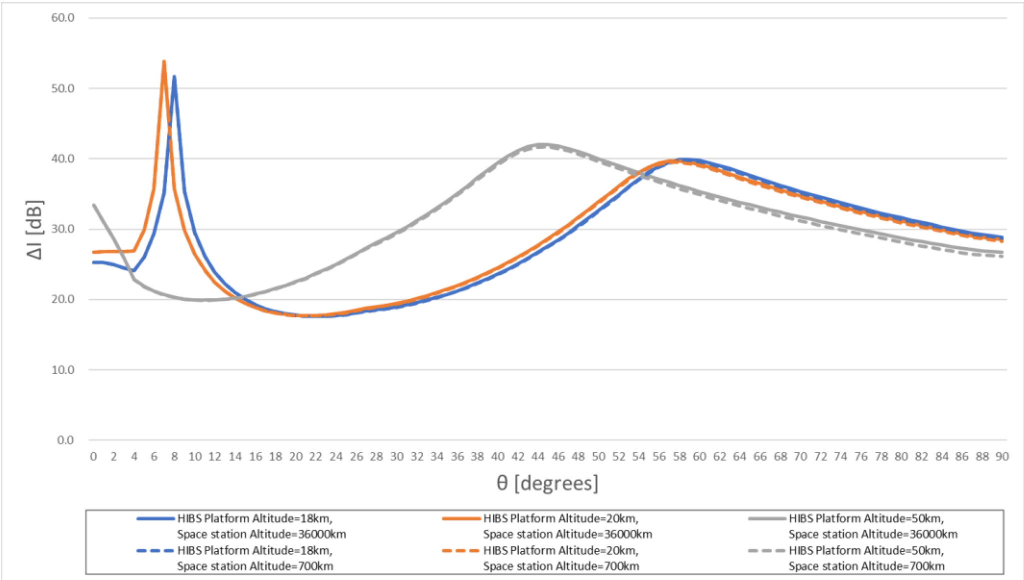

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FIGURE AA.5

Difference in the interference level from HIBS and ground-based IMT base stations in scenario C-1 (Co-channel case in 2 500-2 690 MHz)

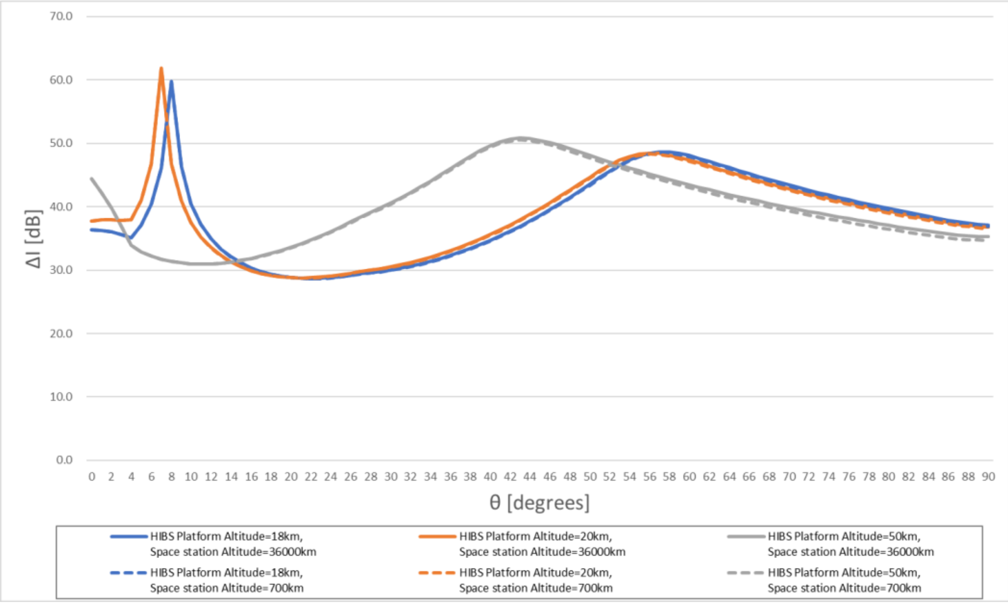
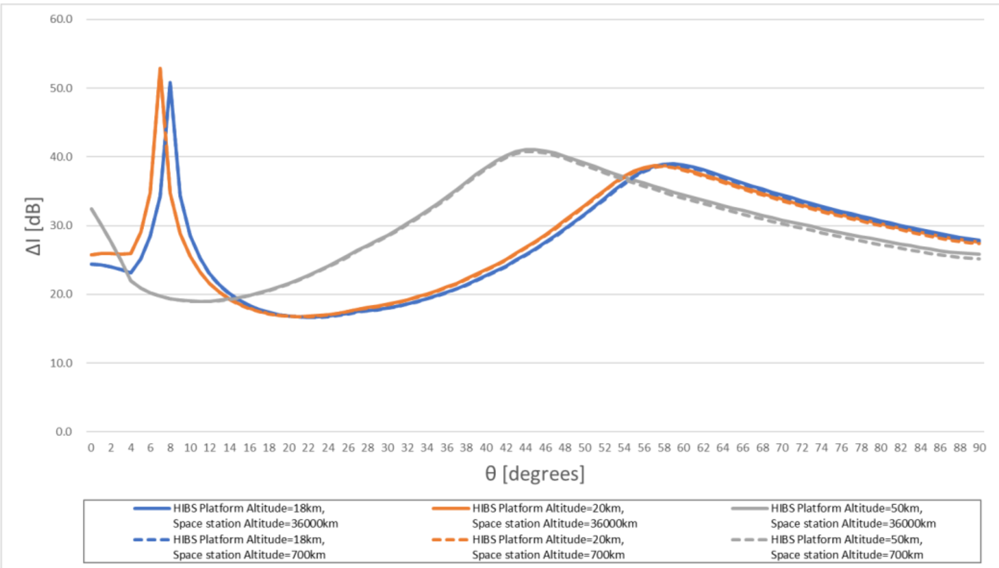


FIGURE AA.6

Difference in the interference level from HIBS and ground-based IMT base stations in scenario C-2 (Adjacent-channel case in 2 500-2 690 MHz)



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Furthermore, interference from UE communicating with HIBS to space station is also much lower than that from existing ground-based IMT based station in both co-channel and adjacent-channel cases as the following calculation examples in the 2 655-2 690 MHz frequency range.

Co-channel case

– The maximum interference power from one UE communicating with HIBS to at the orbit of GSO space station is calculated as “23 dBm/5 MHz (Maximum UE transmitter output power) + (−3 dB) (Typical antenna gain for UE) – 192 dB (Free space loss/Distance: 36 000 km) – 4 dB (Body loss) = –176 dBm/5 MHz”.

– The maximum interference power from ground-based IMT base stations in 1 HIBS area based on the calculations in section AA.3 is “–153 dBW/MHz (= –116 dBm/5 MHz)”.

– The difference of the maximum interference power between one UE communicating with HIBS and ground-based IMT base stations in 1 HIBS area is 59 dB. The result of this calculation shows that interference level from 941 632 UEs (= 59 dB) communicating with HIBS is same as that from ground-based IMT base stations in 1 HIBS area. This means that around 130 000 UEs per cell (total 7 cells) communicating with HIBS are operated within 5 MHz bandwidth and such situation would be technically difficult.

Adjacent-channel case

– If the OOBE levels of UE communicating with HIBS and ground-based IMT base stations are used and the same calculations with co-channel cases are performed, the maximum interference power from one UE communicating with HIBS is “–212 dBm/200 kHz” and that from ground-based IMT base stations is “–183 dBW/MHz (= –160 dBm/200 kHz)”.

– The difference of the maximum interference power between one UE communicating with HIBS and ground-based IMT base stations is 52 dB. This result shows that around 22 000 UEs per cell communicating with HIBS are operated and such situation would be technically difficult.

AA.5 Summary and analysis of the results of Study

The result of this study shows that the interference level from HIBS and UE communicating with HIBS to space station is much lower than that from ground-based IMT base stations at every elevation angle in both co-channel and adjacent-channel cases. This means that any HIBS specific mitigation measures to protect space stations would not be necessary. It is noted that the results of this analysis do not provide any constraints to the existing IMT identification in accordance with Resolution **247 (WRC-19)**.

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