

RESOLUTION 123 (WRC-23)

Use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by aeronautical and maritime earth stations in motion communicating with non-geostationary space stations in the fixed-satellite service

The World Radiocommunication Conference (Dubai, 2023),

recalling

the Preamble to the ITU Constitution,

considering

a) that there is some interest in global broadband satellite communications, and that some of this need could be met by allowing aeronautical and maritime earth stations in motion (A-ESIMs and M-ESIMs, respectively) to communicate with non-geostationary-satellite (non-GSO) fixed-satellite service (FSS) systems operating in the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth), and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space);

b) that the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) are allocated to space services, and that the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz, and 27.5-29.1 GHz are allocated to terrestrial services on a primary basis worldwide;

c) that, in the countries identified in No. 5.524, the frequency band 19.7-20.2 GHz is allocated to the fixed and mobile services on a primary basis; and that, in the countries identified in No. 5.542, the frequency band 29.5-30 GHz is allocated to the fixed and mobile services on a secondary basis;

d) that the frequency bands in *considering a)* above are used by a variety of different systems and that these existing services and their future development need to be protected without being adversely affected by the operation of non- GSO earth stations in motion (ESIMs)¹;

e) that the frequency band 18.6-18.8 GHz is allocated to the Earth exploration-satellite service (EESS) (passive) and space research service (SRS) (passive) and that these services need to be protected from the operation of those systems with which non-GSO ESIMs communicate;

f) that there is no regulatory procedure in the Radio Regulations for the coordination of non-GSO ESIMs relating to terrestrial assignments pertaining to a station of these services;

¹ Throughout this Resolution, aeronautical and maritime non-GSO ESIMs are referred to as non-GSO A-ESIMs and non-GSO M-ESIMs, respectively.

g) that regulatory procedures and interference management mechanisms, including necessary mitigation measures, are required for the operation of non-GSO ESIMs to protect other space and terrestrial services to which the frequency bands referred to in *considering a)* are allocated,

considering further

a) that there is no publicly available information on the conditions stipulated in coordination agreements reached among administrations with respect to non-GSO FSS satellite systems;

b) that, in order to enable sharing between transmitting non-GSO ESIMs and its terrestrial services, an administration intending to authorize the operation of non-GSO ESIMs on the territory under its jurisdiction, including territorial waters and national airspace, may consider adopting interference management procedures and/or mitigation measures different from those contained in this Resolution, as long as the provisions of this Resolution apply with respect to any other administration;

c) that the service area of the non-GSO FSS systems with which non-GSO ESIMs communicate may cover territories under the jurisdiction of multiple administrations;

d) that this Resolution in no way establishes or addresses any technical or regulatory provisions for the operation and use of land non-GSO ESIMs communicating with non-GSO FSS systems, and that any authorization of land non-GSO ESIMs is outside the scope of this Resolution (see *recalling* above),

recognizing

a) that an administration authorizing non-GSO ESIMs on the territory under its jurisdiction, including territorial waters and national airspace, has the right to require that the non-GSO ESIMs referred to above use only those assignments associated with non-GSO FSS systems that have been successfully coordinated, notified, brought into use and recorded in the Master International Frequency Register (MIFR) with a favourable finding under Articles 9 and 11, including No. 11.31, 11.32 or 11.32A, where applicable, with the exception of No. 11.41;

b) that, where assignments to non-GSO FSS systems recorded under No. 11.41 will be used for the operation of non-GSO ESIMs in the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-28.6 GHz and 29.5-30 GHz (Earth-to-space), such assignments may be used for non-GSO FSS ESIMs only in accordance with No. 11.42;

c) that for cases of incomplete coordination under No. 9.7B of the non-GSO FSS system with which non-GSO ESIMs communicate, the operation of non-GSO ESIMs in the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz (space-to-Earth) needs to be in accordance with the provisions of No. 11.42 with respect to any recorded frequency assignment which was the basis of an unfavourable finding under No. 11.38;

d) that the provisions of No. 22.2 apply to non-GSO FSS systems with which non-GSO ESIMs operate in the frequency band 17.7-17.8 GHz (space-to-Earth) with respect to geostationary-satellite (GSO) FSS and GSO broadcasting-satellite service (BSS) networks;

e) that, under the provisions of No. **22.2**, in the frequency bands 27.5-28.6 GHz and 29.5-30 GHz (Earth-to-space) non-GSO ESIMs shall not cause unacceptable interference to GSO FSS and BSS networks operating in accordance with the Radio Regulations, and shall not claim protection from them in the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz (space-to-Earth), and No. **5.43A** does not apply in this case;

f) that a non-GSO FSS system operating in the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-28.6 GHz and 29.5-30 GHz (Earth-to-space) in compliance with the provisions and equivalent power flux-density (epfd) limits set out in Nos. **22.5C**, **22.5D** and **22.5F** is considered as having fulfilled its obligations under No. **22.2** with respect to not causing unacceptable interference to any GSO network, provided that the operational limits given in Table **22-4B** are also met by the non-GSO FSS system;

g) that the use of the frequency bands 18.8-19.3 GHz (space-to-Earth) and 28.6-29.1 GHz (Earth-to-space) by non-GSO FSS systems is subject to No. **9.11A** (i.e. the provisions of Nos. **9.12** to **9.16** apply), and No. **22.2** does not apply in this case;

h) that, for the use of the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-GSO systems, No. **9.12** applies;

i) that, with respect to GSO FSS networks, in the frequency bands 18.8-19.3 GHz (space-to-Earth) and 28.6-29.1 GHz (Earth-to-space) Nos. **9.12A** and **9.13** apply, and No. **22.2** does not apply;

j) that there is no obligation for any administration to authorize any non-GSO ESIMs to operate within the territory under its jurisdiction, including territorial waters and national airspace,

recognizing further

a) that frequency assignments to non-GSO ESIMs need to be notified to the Radiocommunication Bureau;

b) that the notification by different administrations of frequency assignments to be used by the same non-GSO satellite system could create difficulties to identify the responsible administration in case of unacceptable interference;

c) that an administration authorizing the operation of non-GSO ESIMs within the territory under its jurisdiction may modify or withdraw that authorization at any time,

resolves

1 that, before using non-GSO A-ESIMs and non-GSO M-ESIMs in the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space), the notifying administration for the non-GSO FSS system in which the non-GSO ESIM is to be used shall send the Bureau the relevant Appendix 4 notification information relating to the characteristics of the non-GSO ESIM intended to communicate with the non-GSO FSS system, together with a commitment to operate the non-GSO ESIM in conformity with the Radio Regulations, including this Resolution;

1.1 that, upon receipt of the notification information and commitment referred to in *resolves* 1 above, the Bureau shall examine them to check conformity with Article 11, taking into account *recognizing a) and b)*, and with the provisions of this Resolution, and publish the results of its examination in its International Frequency Information Circular (BR IFIC);

2 that the characteristics of non-GSO ESIMs shall remain within the envelope characteristics, including any applicable coordination agreement, of typical earth stations associated with the non-GSO FSS system with which the ESIMs communicate;

3 that, with respect to space services in the frequency bands referred to in *resolves* 1 above, or portions thereof, non-GSO ESIMs shall comply with the following conditions:

3.1 non-GSO ESIMs communicating with space stations of a non-GSO FSS system shall not cause more interference or claim more protection than what is applicable to typical earth stations of that same non-GSO FSS system;

3.2 the notifying administration for the non-GSO FSS system with which a non-GSO ESIM communicates, together with the administration authorizing the use of that non-GSO ESIM within the territory under its jurisdiction, including territorial waters and national airspace, shall ensure that the operation of that ESIM complies with *resolves* 3.1 above and with the coordination agreements for the frequency assignments of the typical earth station of that non-GSO FSS system obtained under the provisions of Article 9, taking into account *recognizing a)* above;

3.3 taking into account *recognizing f)* above, the notifying administration for the non-GSO FSS system with which ESIMs communicate shall ensure that non-GSO ESIMs comply with the provisions and epfd limits set out in Nos. 22.5C, 22.5D and 22.5F, as well as the operational limits given in Table 22-4B;

3.4 non-GSO ESIMs shall not claim protection from BSS feeder-link earth stations operating in accordance with the Radio Regulations in the frequency band 17.7-18.4 GHz;

3.5 with respect to the protection of EESS (passive) operating in the frequency band 18.6-18.8 GHz, any non-GSO FSS system with an orbital apogee of less than 20 000 km operating in the frequency bands 18.3-18.6 GHz and 18.8-19.1 GHz with which non-GSO A-ESIMs and/or non-GSO M-ESIMs communicate and for which the complete notification information has been received by the Bureau after 1 January 2025 shall comply with the provisions indicated in Annex 3 to this Resolution;

3.6 for the implementation of *resolves* 3.5 above, the notifying administration for the non-GSO FSS system with which non-GSO ESIMs communicate shall send the Bureau the relevant Appendix 4 notification information, including a commitment that operation shall be in conformity with *resolves* 3.5 above and *further resolves* 1, 2, 3 and 4 below;

3.7 where the operation of the ESIM referred to in *resolves* 1 uses assignments to non-GSO FSS systems recorded under No. 11.41, such assignments may be used for non-GSO ESIMs only in accordance with No. 11.42;

3.7.1 for the implementation of *resolves* 3.7 above, the notifying administration for the non-GSO FSS system with which non-GSO ESIMs communicate shall send the Bureau a commitment that operation shall be in conformity with *resolves* 3.7 above and *further resolves* 1, 2, 3 and 4 below;

4 that, with respect to terrestrial services that operate in accordance with the Radio Regulations in the frequency bands referred to in *resolves* 1 above, or portions thereof, non-GSO ESIMs shall comply with the following conditions:

4.1 receiving non-GSO ESIMs in the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (see No. **5.524**) shall not claim protection from assignments in the terrestrial services to which those frequency bands are allocated;

4.2 transmitting non-GSO ESIMs in the frequency band 27.5-29.1 GHz shall not cause unacceptable interference to terrestrial services to which the frequency band is allocated, and Annex 1 to this Resolution shall apply;

4.3 transmitting non-GSO ESIMs in the frequency band 29.5-30 GHz shall not adversely affect the operations of terrestrial services to which that frequency band is allocated on a secondary basis, and the limits in Annex 1 to this Resolution shall apply with respect to those administrations mentioned in No. **5.542**;

4.4 the provisions in this Resolution, including Annex 1, set conditions for the purpose of protecting terrestrial services from unacceptable interference from non-GSO A-ESIMs and non-GSO M-ESIMs, in accordance with the provisions included in *resolves* 4.2 and 4.3 above; however, the requirement not to cause unacceptable interference to, or claim protection from, terrestrial services to which the frequency bands are allocated and that are operating in accordance with the Radio Regulations remains valid;

4.5 should an administration authorizing non-GSO A-ESIMs and/or non-GSO M-ESIMs agree to limits less stringent than those contained in Annex 1 to this Resolution within the territory under its jurisdiction, including territorial waters and national airspace, such agreement shall not adversely affect other countries that are not party to that agreement;

5 that the Bureau shall examine, in accordance with the provisions included in *resolves* 4.2 and 4.3 above and with the methodology included in Annex 2 to this Resolution, the characteristics of non-GSO A-ESIMs with respect to conformity with the power flux-density (pfd) limits at the Earth's surface specified in Part 2 of Annex 1 to this Resolution and publish the results of such examination in the BR IFIC;

5.1 should the results of the examination by the Bureau with respect to this Resolution, including *resolves* 5 above, be satisfactory, the assignments in question shall be published in the appropriate special section of the BR IFIC and recorded in the MIFR with a favourable finding; otherwise, the assignments in question shall be returned to the notifying administration with the reasons therefor;

6 that, in the event that unacceptable interference caused by non-GSO A-ESIMs and/or non-GSO M-ESIMs is reported:

6.1 the notifying administration for the non-GSO FSS system with which ESIMs communicate is responsible for eliminating the case of unacceptable interference; consequently, no other administration shall be held responsible for eliminating cases of unacceptable interference (see also *resolves* 6.3 below);

6.1.1 for the implementation of *resolves* 6.1 above, the system shall employ the minimum requirements specified in Annex 4 to this Resolution;

6.2 in the event that there is more than one administration involved in the notification of frequency assignments to the same operating non-GSO satellite system with which ESIMs communicate, those administrations shall nominate one administration as the notifying administration responsible to act on their behalf to eliminate any unacceptable interference cases, and inform the Bureau accordingly;

6.3 any authorizing administration, subject to its explicit agreement and to the extent of its ability, provide any available information that may help eliminate the case of unacceptable interference;

6.4 the administration responsible for the aircraft or vessel on which the ESIM operates shall, when requested, provide the affected administration with a point of contact to assist in identifying the notifying administration for the satellite with which the ESIM communicates, which is responsible for eliminating the case of unacceptable interference (see *resolves* 6.1 and 6.2 above);

7 that the notifying administration for the non-GSO FSS system with which non-GSO ESIMs communicate shall ensure that:

7.1 for the operation of non-GSO ESIMs, techniques are employed to maintain adequate antenna-pointing accuracy towards the associated non-GSO FSS satellite to avoid inadvertently tracking non-GSO satellites other than the associated non-GSO satellite;

7.2 measures are taken so that non-GSO ESIMs are subject to permanent monitoring and control by a network control and monitoring centre (NMC) in order to comply with the provisions in this Resolution, including the minimum requirements specified in Annex 4;

7.3 measures are taken so that non-GSO A-ESIMs and non-GSO M-ESIMs do not transmit from territory, including territorial waters and national airspace, under the jurisdiction of an administration situated inside the service area of the non-GSO FSS system with which those non-GSO A-ESIMs and non-GSO M-ESIMs communicate that has not authorized their use within its territory;

7.4 non-GSO ESIMs operate only in the territory, including territorial waters and national airspace, under the jurisdiction of administrations from which an authorization has been obtained, taking into account *recognizing further c)*;

7.5 a point of contact is designated and provided in the Appendix 4 submission by the notifying administration for the non-GSO FSS systems with which the non-GSO ESIMs communicate for the purpose of tracing any cases of unacceptable interference from non-GSO ESIMs and to respond immediately to requests from the focal point of the affected administration;

- 8 that non-GSO ESIMs shall not be used or relied upon for safety-of-life applications;
- 9 that the application of this Resolution does not provide regulatory status to non-GSO ESIMs different from that derived from the non-GSO FSS system with which they communicate, taking into account the provisions referred to in this Resolution (see *recognizing a) and b)*);
- 10 that any course of action taken under this Resolution has no impact on the original date of receipt of the frequency assignments to space and earth stations of the non-GSO FSS system with which non-GSO ESIMs communicate or on the coordination requirements of that system;
- 11 that compliance with this Resolution by non-GSO ESIMs does not, in any way whatsoever, release the notifying administration(s) from its/their obligation not to cause unacceptable interference to, or claim protection from, the incumbent services, as referred to in this Resolution;
- 12 that the operation of non-GSO A-ESIMs and M-ESIMs, including operation of the NCMC, the interference management system, and the mechanism and functioning of switching facilities, is subject to the availability of the ITU-R Recommendation referred to in *invites the ITU Radiocommunication Sector* below; in the meantime, *further resolves* 1, 2 and 3 shall strictly apply;
- 13 that the operation of non-GSO A-ESIMs and M-ESIMs using frequency assignments recorded under No. **11.41**, including operation of the NCMC, the interference management system, and the mechanism and functioning of switching facilities, is subject to the availability of the ITU-R Recommendation referred to in *invites the ITU Radiocommunication Sector* below, with the understanding that, in the meantime, *further resolves* 1, 2 and 3 strictly apply,

further resolves

- 1 that the notifying administration for the non-GSO system with which ESIMs communicate, when submitting Appendix 4 information, shall send a firm, objective, actionable, measurable and enforceable commitment that, in the event of unacceptable interference being reported, it undertakes to immediately eliminate the interference or reduce it to an acceptable level;
- 2 that, in the case of no action being taken with regard to the obligation referred to in *further resolves* 1 above, the Bureau shall send a reminder and request the notifying administration for the non-GSO system with which ESIMs communicate to comply with the requirements referred to in the commitment;
- 3 that, should the interference persist 30 days after the dispatch date of the above-mentioned reminder, the Bureau shall submit the case to the subsequent meeting of the Radio Regulations Board (RRB) for review and the necessary actions (including suppression of the frequency assignment in question), as appropriate;
- 4 that, for the implementation of *further resolves* 1 above, the notifying administration responsible for the operation of non-GSO A-ESIMs and non-GSO M-ESIMs shall also be responsible for observing and complying with all relevant regulatory and administrative provisions applicable to the operation of the ESIMs included in this Resolution or contained in the Radio Regulations;

5 that, in accordance with *instructs the Director of the Radiocommunication Bureau* 4 below, any notifying administration for a non-GSO system operating non-GSO A-ESIMs and non-GSO M-ESIMs, upon request by the Bureau regarding cases of unacceptable interference reported by an affected administration, shall provide the Bureau with a list of the administrations that have authorized non-GSO ESIM operations to communicate with that non-GSO FSS system and that are potentially related to a reported case of unacceptable interference,

instructs the Director of the Radiocommunication Bureau

1 to take all necessary actions to facilitate the implementation of this Resolution;

2 to report to future world radiocommunication conferences on any difficulties or inconsistencies encountered in the implementation of this Resolution, in particular with respect to the verification of compliance with the efd limits specified in Article 22;

3 not to examine, under No. 11.31, the conformity of non-GSO FSS systems with the provisions of *resolves* 3.5 of this Resolution with respect to the EESS (passive);

4 in the case of unacceptable interference:

4.1 based on information provided by the affected administration, to request the notifying administrations for non-GSO FSS systems with which non-GSO ESIMs communicate that could potentially be causing unacceptable interference to provide the affected administration promptly with the relevant list of administrations that have authorized non-GSO ESIM operations;

4.2 to provide the affected administration with a list of non-GSO FSS systems potentially related to the reported case of unacceptable interference;

4.3 if a notifying administration fails to provide the information required under *instructs the Director of the Radiocommunication Bureau* 4.1 above within 45 days from the date of dispatch of the Bureau's request as referred to in *instructs the Director of the Radiocommunication Bureau* 4.1, to send the notifying administration a reminder to provide the required list within 15 days from the date of that reminder;

4.4 if a notifying administration fails to provide the required information following the reminder under *instructs the Director of the Radiocommunication Bureau* 4.3 above, and if the affected administration has not confirmed to the Bureau that the case of unacceptable interference has been resolved, to submit the case to the subsequent meeting of the RRB for review and the necessary actions, as appropriate,

invites the ITU Radiocommunication Sector

to study, as a matter of urgency, with the objective of preparing a Recommendation to be adopted and approved in accordance with Resolution ITU-R 1, the functionalities and implementation of NCMCs for ESIMs,

instructs the Secretary-General

1 to bring this Resolution to the attention of the International Maritime Organization and the International Civil Aviation Organization;

2 to bring this Resolution to the attention of the ITU Council with a view to its considering whether cost recovery should be applied to non-GSO A-ESIMs and non-GSO M-ESIMs.

ANNEX 1 TO RESOLUTION 123 (WRC-23)

Provisions for maritime and aeronautical earth stations in motion communicating with non-geostationary-satellite systems to protect terrestrial services operating in the frequency band 27.5-29.1 GHz and for the frequency band 29.5-30 GHz with respect to administrations mentioned in No. 5.542

1 The parts below contain provisions to ensure that maritime and aeronautical earth stations in motion (ESIMs) communicating with non-geostationary-satellite (non-GSO) systems in the fixed-satellite service (FSS) do not cause unacceptable interference at any time in neighbouring countries to terrestrial service operations when such non-GSO ESIMs are operating in frequencies overlapping with those used by terrestrial services to which the frequency band 27.5-29.1 GHz is allocated and operating in accordance with the Radio Regulations. The provisions specified below also apply in the frequency band 29.5-30 GHz with respect to administrations mentioned in No. 5.542 (see *resolves* 4.2 and 4.3).

Part 1: Non-GSO maritime ESIMs

2 The notifying administration for the non-GSO FSS system with which maritime ESIMs (M-ESIMs) communicate shall ensure compliance of the non-GSO M-ESIM operating within the frequency bands, or parts thereof, indicated in § 1 above with the following conditions for the protection of terrestrial services to which the frequency bands are allocated within a coastal State:

2.1 The minimum distance from the low-water mark as officially recognized by the coastal State beyond which non-GSO M-ESIMs can operate without the prior agreement of any administration is 70 km within the frequency bands 27.5-29.1 GHz and 29.5-30 GHz. Any transmissions from non-GSO M-ESIMs within the minimum distance shall be subject to the prior agreement of the coastal State(s) concerned.

2.2 The maximum non-GSO M-ESIM equivalent isotropically radiated power (e.i.r.p.) spectral density towards the territory of any coastal State will be limited to 24.44 dBW in a reference bandwidth of 14 MHz. Transmissions from non-GSO M-ESIMs with higher e.i.r.p. spectral density levels towards the territory of any coastal state shall be subject to the prior agreement of the coastal State(s) concerned.

Part 2: Non-GSO aeronautical ESIMs

3 The notifying administration for the non-GSO FSS system with which a non-GSO aeronautical ESIM (A-ESIM) communicates shall ensure compliance of the non-GSO A-ESIM operating within the frequency bands, or parts thereof, indicated in § 1 above with all of the following conditions for the protection of terrestrial services to which the frequency band is allocated:

3.1 When within line-of-sight of the territory of an administration, and above an altitude of 3 km, the maximum power flux-density (pfd) produced at the surface of the Earth on the territory of an administration by emissions from a single non-GSO A-ESIM shall not exceed:

$\text{pfd}(\theta) = -124.7$	$\text{dB(W/(m}^2 \cdot 14 \text{ MHz))}$	for $0^\circ \leq \theta \leq 0.01^\circ$
$\text{pfd}(\theta) = -120.9 + 1.9 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 14 \text{ MHz))}$	for $0.01^\circ < \theta \leq 0.3^\circ$
$\text{pfd}(\theta) = -116.2 + 11 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 14 \text{ MHz))}$	for $0.3^\circ < \theta \leq 1^\circ$
$\text{pfd}(\theta) = -116.2 + 18 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 14 \text{ MHz))}$	for $1^\circ < \theta \leq 2^\circ$
$\text{pfd}(\theta) = -117.9 + 23.7 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 14 \text{ MHz))}$	for $2^\circ < \theta \leq 8^\circ$
$\text{pfd}(\theta) = -96.5$	$\text{dB(W/(m}^2 \cdot 14 \text{ MHz))}$	for $8^\circ < \theta \leq 90.0^\circ$

where θ is the angle of arrival of the radio-frequency wave (degrees above the horizon).

3.2 When within line-of-sight of the territory of an administration, and up to an altitude of 3 km, the maximum pfd produced at the surface of the Earth on the territory of an administration by emissions from a single non-GSO A-ESIM shall not exceed:

$\text{pfd}(\theta) = -136.2$	$\text{dB(W/(m}^2 \cdot 1 \text{ MHz))}$	for $0^\circ \leq \theta \leq 0.01^\circ$
$\text{pfd}(\theta) = -132.4 + 1.9 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 1 \text{ MHz))}$	for $0.01^\circ < \theta \leq 0.3^\circ$
$\text{pfd}(\theta) = -127.7 + 11 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 1 \text{ MHz))}$	for $0.3^\circ < \theta \leq 1^\circ$
$\text{pfd}(\theta) = -127.7 + 18 \cdot \log\theta$	$\text{dB(W/(m}^2 \cdot 1 \text{ MHz))}$	for $1^\circ < \theta \leq 12.4^\circ$
$\text{pfd}(\theta) = -108$	$\text{dB(W/(m}^2 \cdot 1 \text{ MHz))}$	for $12.4^\circ < \theta \leq 90.0^\circ$

where θ is the angle of arrival of the radio-frequency wave (degrees above the horizon).

3.3 A non-GSO A-ESIM operating within the frequency bands, or parts thereof, indicated in § 1 above within the territory of an administration that has authorized fixed-service and/or mobile-service operation in the same frequency bands shall not transmit in these frequency bands without the prior agreement of that administration (see also *resolves* 4.5).

3.4 The maximum power in the out-of-band domain should be attenuated below the maximum output power of the A-ESIM transmitter as described in the most recent version of Recommendation ITU-R SM.1541.

3.5 Higher pfd levels than those specified in §§ 3.1 and 3.2 above produced by A-ESIMs at the surface of the Earth in an area under the jurisdiction of any administration shall be subject to the prior agreement of that administration (see also *resolves* 4.5).

ANNEX 2 TO RESOLUTION 123 (WRC-23)

**Methodology and procedure to examine power flux-density
at the Earth's surface produced by aeronautical earth stations in motion
communicating with non-geostationary satellites in the fixed-satellite service
and conformity with power flux-density limits**

1 Overview

The methodology below is a functional description to conduct examination of aeronautical earth stations in motion (A-ESIMs) communicating with non-geostationary satellite (non-GSO) systems and their conformity with the power flux-density (pfd) limits specified in Part 2 of Annex 1 to this Resolution (see *resolves* 5).

2 A-ESIM parameters required for examination

To conduct the relevant examination of A-ESIMs and their conformity with respect to the pfd limits established in Part 2 of Annex 1, the following parameters are required:

- satellite system name;
- A-ESIM peak antenna gain;
- A-ESIM power density and bandwidth as given in Table 1; and
- fuselage attenuation mask expressed as a function of the angle below the horizon of the A-ESIM.

3 Examination methodology

3.1 Introduction

An A-ESIM can operate at different locations defined by latitude, longitude and altitude. This methodology determines the maximum allowable power P_j for an A-ESIM transmitter communicating with a non-GSO satellite system in the fixed-satellite service (FSS) to ensure compliance with the pre-established pfd limits to protect terrestrial services, at all positions, for a defined set of altitude ranges. The methodology derives P_j , taking into account the relevant loss and attenuation in the geometry considered.

The methodology then compares the computed P_j with the range of notified power for the A-ESIM emission. The minimum and maximum power values for emissions from the A-ESIM, $P_{min_emission,j}$ and $P_{max_emission,j}$, are calculated from the data included in the Appendix 4 notification information for the non-GSO FSS system with which the A-ESIM communicates and from the A-ESIM characteristics.

A-ESIMs are evaluated over a number of predefined altitude ranges in order to establish a number of P_j levels.

An examination by the Radiocommunication Bureau should apply this methodology for the defined altitude range to determine whether an A-ESIM operating under a given non-GSO satellite system complies with the pre-established pfd limits to protect terrestrial services.

3.2 Parameters and geometry

Considering a hypothetical non-GSO FSS system, Table 1 below provides an example of emissions that are included in one group associated with the A-ESIM non-GSO FSS class of earth station transmitting in the frequency bands 27.5-29.1 GHz and 29.5-30 GHz. Tables 2 to 4 provide additional assumptions and Figure 1 illustrates the geometry involved in the examination.

TABLE 1

**Example of a group of A-ESIM emissions
(with reference to relevant Appendix 4 data fields)**

Emission No.	C.7.a Designation of emission	$BW_{emission}$ MHz	C.8.c.3 Minimum power density dB(W/Hz)	C.8.a.2/C.8.b.2 Maximum power density dB(W/Hz)
1	6M00G7W--	6.0	-69.7	-66.0
2	6M00G7W--	6.0	-64.7	-61.0
3	6M00G7W--	6.0	-59.7	-56.0

TABLE 2

Additional example assumptions

ID	Parameter	Notation	Value	Unit
1	Frequency assignment	f	29.1	GHz
2	Reference bandwidth of pfd mask	BW_{Ref}	1.0 or 14.0, depending on the altitude under examination	MHz
3	A-ESIM antenna peak gain	G_{max}	37.5	dBi
4	A-ESIM antenna gain pattern	-	As per Rec. ITU-R S.580 (see C.10.d.5.a)	

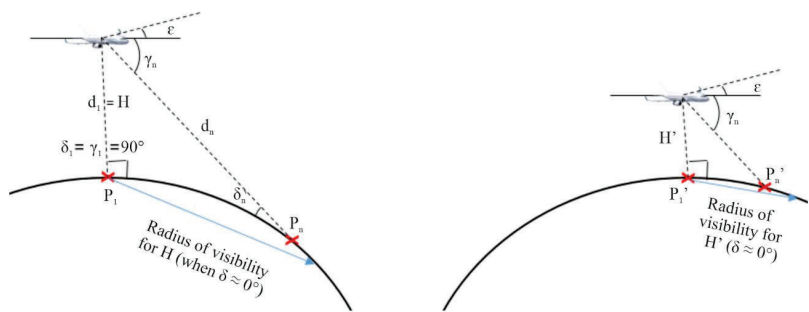
TABLE 3
Characteristics defined in the methodology

ID	Parameter	Notation	Value	Unit
1	A-ESIM minimum elevation angle towards non-GSO FSS system	ε	Appendix 4, data item A.36.a	degrees
2	Atmospheric attenuation	L_{atm}	Computed with Rec. ITU-R P.676 (see NOTE below)	dB
3	Angle of arrival of the incident wave on the Earth's surface	δ	Specified in the pre-established sets of pfd limits in Part 2 of Annex 1, variable from 0° to 90°	degrees
4	Minimum examination altitude	H_{min}	0.01	km
5	Maximum examination altitude	H_{max}	15.0	km
6	Examination altitude spacing ²	H_{step}	1.0	km
7	Fuselage attenuation	L_f	Use Table 4 if no ITU-R Recommendation provided in Appendix 4 (see data item A.36.b)	dB

NOTE: The atmospheric attenuation is computed using the most recent version of Recommendation ITU-R P.676, with the mean annual global reference atmosphere as defined in the most recent version of Recommendation ITU-R P.835.

FIGURE 1

Geometry for examination of compliance for two different A-ESIM altitudes



² The fourth altitude value (H_4) computed in accordance with this H_{step} is adjusted to 2.99 km to facilitate the examination of compliance with the two sets of pfd values indicated in Part 2 of Annex 1 to this Resolution.

TABLE 4

Fuselage attenuation model based on Report ITU-R M.2221-0

$L_{fuse}(\gamma) = 3.5 + 0.25 \cdot \gamma$	dB	for	$0^\circ \leq \gamma \leq 10^\circ$
$L_{fuse}(\gamma) = -2 + 0.79 \cdot \gamma$	dB	for	$10^\circ < \gamma \leq 34^\circ$
$L_{fuse}(\gamma) = 3.75 + 0.625 \cdot \gamma$	dB	for	$34^\circ < \gamma \leq 50^\circ$
$L_{fuse}(\gamma) = 35$	dB	for	$50^\circ < \gamma \leq 90^\circ$

NOTE: This fuselage attenuation model is based on measurements made at 14.2 GHz (see Figure 3.6-14 in Report ITU-R M.2221-0).

3.3 Calculation algorithm

This section includes a step-by-step description of how the examination methodology would be implemented.

START

- i) For each A-ESIM altitude, it is necessary to generate as many δ_n angles (angle of arrival of the incident wave) as required in order to test full compliance with the applicable set of pfd limits. The N angles δ_n must be between 0° and 90° and have a resolution compatible with the granularity of the pre-established pfd limits. Each of the N angles δ_n will correspond to as many N points on the ground.

- ii) For each altitude $H_j = H_{min}, H_{min} + H_{step}, \dots, H_{max}$:

- a) Set the altitude of the A-ESIM to H_j
b) Compute the angle below the horizon $\gamma_{j,n}$ as seen from the A-ESIM for each of the N angles δ_n generated in i) using the following equation:

$$\gamma_{j,n} = \arccos \left(\frac{R_e \cdot \cos(\delta_n)}{(R_e + H_j)} \right) \quad (1)$$

where R_e is the mean Earth radius.

- c) Compute the distance $D_{j,n}$, in km, for $n = 1, \dots, N$ between the A-ESIM and the tested point on the ground:

$$D_{j,n} = \sqrt{R_e^2 + (R_e + H_j)^2 - 2R_e(R_e + H_j)\cos(\gamma_n - \delta_n)} \quad (2)$$

- d) Compute the fuselage attenuation $L_{f,j,n}$ (dB) with $n = 1, \dots, N$ applicable to each of the angles $\gamma_{j,n}$ computed in b) above.
e) Compute the gaseous absorption $L_{atm,j,n}$ (dB) with $n = 1, \dots, N$ applicable to each of the distances $D_{j,n}$ computed in c) above, using the applicable sections of the most recent version of Recommendation ITU-R P.676.

- iii)

- a) For each altitude $H_j = H_{min}, H_{min} + H_{step}, \dots, H_{max}$, and each angle below the horizon $\gamma_{j,n}$, compute the maximum emission power in the reference bandwidth $P_{j,n}(\delta_n, \gamma_{j,n})$ for which the pfd limits are met using the following algorithm:

$$P_{j,n}(\delta_n, \gamma_{j,n}) = pfd(\delta_n) + 10 \log_{10} \left(4\pi (D_{j,n} \cdot 1000)^2 \right) + L_{f,j,n} + L_{atm,j,n} - Gtx(\gamma_{j,n} + \varepsilon)$$

With $G_{tx}(\gamma_{j,n} + \varepsilon)$ being the transmit antenna gain with the off-axis angle from the boresight, consisting of the summation of both angles $\gamma_{j,n}$ and minimum elevation angle ε as defined in Table 3.

- b) Compute the minimum P_j across all values calculated at the previous step:

$$P_j = \text{Min}\left(P_{j,n}\left(\delta_n, \gamma_{j,n}\right)\right)$$

The output of this step is the maximum power in the reference bandwidth that can be used by the A-ESIM to ensure it complies with the pfd limits in Part 2 of Annex 1, with respect to all angles δ_n at the altitude H_j , and the elevation indicated in Table 3. There will be one P_j for each of the H_j altitudes considered.

The output of step b) is summarized in Table 5 below:

TABLE 5
Computed P_j values

H_j (Altitude) (km)	P_j (Maximum power in the reference bandwidth that can be used at minimum elevation) dB(W/BW)
0.01	TBD
1.0	TBD
2.0	TBD
2.99	TBD
4.0	TBD
5.0	TBD
6.0	TBD
7.0	TBD
8.0	TBD
9.0	TBD
10.0	TBD
11.0	TBD
12.0	TBD
13.0	TBD
14.0	TBD
15.0	TBD

- c) For each altitude $H_j = H_{min}, H_{min} + H_{step}, \dots, H_{max}$, and each emission in each group of emissions under examination, compute the minimum and the maximum powers of the emission in the reference bandwidth:

$$P_{\min_emission,j} = \text{minimum power density}(\text{emission, dBW / Hz}) + 10 * \log_{10}(BW)$$

$$P_{\max_emission,j} = \text{maximum power density}(\text{emission, dBW / Hz}) + 10 * \log_{10}(BW)$$

BW in Hz is:

$$BW_{Ref} \text{ if } BW_{Ref} = 1 \text{ MHz}$$

$$BW_{Ref} \text{ if } BW_{Ref} = 14 \text{ MHz and } BW_{emission} \geq BW_{Ref}$$

$$BW_{emission} \text{ if } BW_{Ref} = 14 \text{ MHz and } BW_{emission} < BW_{Ref}$$

- d) For each emission in each group of emissions under examination check if there is at least one altitude H_j for which:

$$P_{\max_emission,j} > P_j > P_{\min_emission,j}$$

The results of this check are illustrated in Table 6 below:

TABLE 6

Example comparison between P_j and $(P_{\min_emission,j}, P_{\max_emission,j})$

Emission No.	C.7.a Designation of emission	$BW_{emission}$ MHz	C.8.c.3 Minimum power density dB(W/Hz)	C.8.a.2/C.8.b.2 Maximum power density dB(W/Hz)	Lowest altitude H_j (km) for which $P_{\max_emission,j} > P_j > P_{\min_emission,j}$
1	6M00G7W--	6.0	-69.7	-66.0	TBD
2	6M00G7W--	6.0	-64.7	-61.0	TBD
3	6M00G7W--	6.0	-59.7	-56.0	TBD

- e) Based on the test detailed in iii) d) above applied to all emissions in the group under examination, the results of the Bureau's examination for that group is favourable, after removing emissions that have failed the examination; otherwise, it is unfavourable (i.e. all emissions have failed).

- iv) The output of this methodology should, at a minimum, include:

- the resulting parameters as contained in Table 5;
- the examination results for each group;
- for those cases when some emissions successfully pass and some do not, the examination results for the resulting new group that includes only the emission(s) which successfully passed the examination.

END

ANNEX 3 TO RESOLUTION 123 (WRC-23)

**Provisions for non-geostationary-satellite fixed-satellite service systems³
transmitting to aeronautical and/or maritime earth stations in motion
operating in or over an ocean in the frequency bands
18.3-18.6 GHz and 18.8-19.1 GHz with respect to the Earth exploration-satellite
service (passive) operating in the frequency band 18.6-18.8 GHz
(in accordance with *resolves* 3.5 of this Resolution)**

Non-geostationary-satellite (non-GSO) space stations operating with an orbit apogee of more than 2 000 km and less than 20 000 km in the frequency bands 18.3-18.6 GHz and 18.8-19.1 GHz, when communicating with an aeronautical or maritime earth station in motion (A-ESIM and M-ESIM, respectively), shall not exceed a power flux-density (pfd) of $-118 \text{ dB(W/(m}^2 \cdot 200 \text{ MHz))}$ produced at the surface of the oceans across the 200 MHz of the frequency band 18.6-18.8 GHz.

Non-GSO space stations operating with an orbit apogee less than or equal to 2 000 km in the frequency bands 18.3-18.6 GHz and 18.8-19.1 GHz, when communicating with an A-ESIM or M-ESIM, shall not exceed a pfd of $-110 \text{ dB(W/(m}^2 \cdot 200 \text{ MHz))}$ produced at the surface of the oceans across the 200 MHz of the frequency band 18.6-18.8 GHz.

ANNEX 4 TO RESOLUTION 123 (WRC-23)

**Required capabilities of earth stations in motion communicating
with non-geostationary-satellite systems
(in accordance with *resolves* 6.1.1 of this Resolution)**

This Annex provides the minimum requirements for earth stations in motion (ESIMs) communicating with non-geostationary-satellite (non-GSO) systems subject to this Resolution, as shown in Table A4-1 below.

³ These provisions do not apply to non-GSO systems using orbits with an apogee less than 2 000 km that employ a frequency reuse factor of at least 3.

TABLE A4-1

Non-GSO ESIM minimum requirements

Requirement	Associated provision(s)
Ability to monitor and control pointing of main beam in direction of satellite with which ESIM communicates	<i>Resolves 7.1</i>
Geolocation capability	<i>Resolves 7.3</i> <i>Resolves 7.4</i>
Ability of ESIM to receive information and execute commands from network control and monitoring centre (NCCM)	<i>Resolves 7.2</i> <i>Resolves 7.3</i> <i>Resolves 7.4</i>
Ability to send information to NCCM	<i>Resolves 7.3</i>
Ability to monitor and control transmission power and frequency	<i>Resolves 7.3</i>
Ability to enable/disable ESIM transmission	<i>Resolves 7.3</i> <i>Resolves 7.4</i>