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**APT report on**

**OPERATIONal information OF a Non-GSO FSS Earth**

**Station TERMINAL ON VESSELs AND AIRCRAFT OPERATED UNDER FSS OPERATING in the frequency bands 10.7-12.75**

**GHz (space-to-Earth) and 14-14.5 GHz (Earth-to-space)**

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**APT REPORT ON**

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1. Introduction

Interest in large constellations of Low Earth Orbit (LEOs) satellites started in the 1990’s. Since 2014 such constellations have gradually been brought into use. Furthermore, LEO constellation systems will be used to bring broadband connectivity to end users on the move, including maritime and aviation.

This APT Report aims to provide new information about latest system and specific operational characteristics available in the ECC Report 271[[1]](#footnote-2) for newer NGSO FSS Earth Stations. It does so through examining a specificNGSO FSS Earth station, with selected parameters in the scope provided by the same report on vessels and aircraft operating in the frequency bands 10.7-12.75 GHz (space-to-Earth) and 14-14.5 GHz (Earth-to-space).

1. Scope

This APT Report addresses the characteristics and capability of a specificNGSO terminal, which is referred to as *specific**NGSO Earth Station Terminal* for applications on land (fixed or mobile), and on aircrafts or ships, using frequency bands allocated to Fixed Satellite Service (FSS) in Ku band. In this APT Report, Ku-band covers the frequency ranges 10.7-12.75 GHz and 14.0-14.5 GHz.

1. Relevant ITU Radio Regulations in the frequency bands

In accordance with the Radio Regulations (2024),

* In frequencies 14.0-14.5 GHz, there is a primary allocation for the FSS and a secondary allocation for Mobile Satellite Service (MSS).
* In frequencies 14-14.3 GHz, there is a primary allocation for RADIONAVIGATION.
* In frequencies 14.3-14.4 GHz, there are primary allocations for FIXED and MOBILE (Regions 1 and 3).
* In frequencies 14.4-14.5 GHz, there are primary allocations for FIXED and MOBILE (globally).

The footnotes that apply to frequency ranges 14-14.5 GHz are Nos. **5.28**, **5.59**, **5.30**, **5.31**, **5.504A**, **5.504B**, **5.504C**, **5.506A**, **5.508A** and **5.509A** of the Radio Regulations.

NGSO satellite systems operate under the primary allocation of the FSS (under various footnotes introduced by WRC-2000 and WRC-2003; i.e., Nos. **5.441,** **5.484A** and **5.487A**). Under such premise, the satellite terminals are part of such NGSO systems and are operating under the primary FSS allocation and all the regulatory status associated with the primary allocation. While the land terminals (either fixed, nomadic, or moving), operating within a country, operate on a co-primary basis vis-à-vis the other primary services, there is no specific ITU regulatory provision in the bands considered in this report (10.7-12.75 GHz and 14-14.5 GHz) for operation of NGSO terminals on board of airplanes or ships, operating to a satellite system in the primary FSS allocation.

Resolution **902 (Rev.WRC-23)** may apply to both GSO and NGSO FSS.

Firstly, irrespective of the type of NGSO satellite terminals (moving or not), the protection of geostationary satellites networks in the fixed-satellite service and the broadcasting satellite service from unacceptable interference caused by Ku-band NGSO satellite systems is ensured via the applicable provisions of the ITU Radio Regulations. On that basis, this report acknowledges the ITU provisions for coexistence between NGSO and GSO in Ku-band, through full compliance with **Article 22**, which relies on EPFD limits and the latest Recommendation ITU-R S.1503-4 (September 2023).

Secondly, at WRC-2003, the following conditions were introduced to protect microwave links use in the 14 GHz Fixed Service allocation:

* Resolution **902**, for Earth Stations on Vessels (ESV) operating under the FSS allocation; and,
* A new secondary allocation to the Aeronautical Mobile Satellite Service (AMSS) in the band 14.0-14.5 GHz, and with Recommendation ITU-R M.1643, which provides a PFD mask for Aircraft Earth Stations (AES) to protect the Fixed Service (FS).
1. Technical analysis of a specific NGSO Earth Station Terminal on ships

This section provides the results of calculations of the EIRP and EIRPsd toward the horizon and compares the results with the limits in Resolution 902. It is noted that Resolution **902 (Rev.WRC-23)** can be still applicable to NGSO Earth station terminals mentioned in this Report depending on the decision of an administration which considers the operation of Non-GSO Earth station terminal within its territory.

* 1. Maritime NGSO Earth Station Terminals

NGSO Earth Station Terminals installed on ships are operating under the primary FSS allocation in the Ku-band (14.0-14.5 GHz). As such they are considered as an integral part of these NGSO satellite systems recognized by the ITU as operating under the umbrella of the Fixed Satellite Service (FSS). This is the current case for NGSO equipment.

ITU-R SG4 process leading to WRC-2003, studied the matter, specifically related to Earth Station on Vessels (ESVs) of satellite networks using the FSS allocation in 14.0-14.5 GHz. The studies undertaken by the SG4 were mainly in relation to the protection of co-primary FS microwave links and requirements in Annex 2 of Resolution **902 (Rev.WRC-23)** related to the protection of victim GSO satellites and resulted in some technical limitation for ESVs given in Resolution **902 (Rev.WRC-23)**.

* 1. Interference potential of a specific NGSO Earth Station Terminal on ships

NGSO terminals are dynamically tracking the NGSO satellites, and the azimuth may vary between 0 and 360 degrees with no particular specific direction.

Annex 1 of this document provides one calculation of the EIRP and EIRPsd toward the horizon, related to NGSO Earth station terminals when the main lobe is at an elevation angle of 35 degrees. These calculations compare the limits in WRC Resolution **902** with a specific NGSO Earth station terminal.

 Resolution **902 (Rev.WRC-23)** EIRP limits:

* Maximum ESV e.i.r.p. toward the horizon 16.3 dBW
* Maximum ESV e.i.r.p. spectral density toward the horizon 12.5 dBW/MHz

From the calculations in Annex 1, Table 1 shows the comparison of the EIRP and EIRPsd towards the horizon.

**Table 1: Comparison of the EIRP and EIRPsd towards the horizon**

|  |  |  |
| --- | --- | --- |
|  | **specific NGSO terminal** | **Maximum ESV EIRP** |
| **EIRPhorizon [dBW]** | -7.6 | 16.3 |
| **EIRPsd,horizon [dBW/MHz]** | -20.6 | 12.5 |

This result demonstrates that a specific NGSO earth station terminal can comply with Resolution **902 (Rev.WRC-23)** EIRP and EIRPsd towards horizon. i.e.,

* For the EIRP toward horizon, in the calculation the margin is 23.9 dB.
* For the EIRPsd toward the horizon, in the calculation the margin is 33.1 dB.

Annex 2 of this document provides one calculation of the minimum distance when the main lobe is at an elevation angle of 35 degrees.

* 1. Consideration of the minimum distances beyond which ship based terminal can operate without the prior agreement for ship-based satellite terminals

The operational limitations of WRC Resolution **902 (Rev.WRC-23)** provides for a minimum distances beyond which ship based terminal can operate without prior agreement to protect the Fixed and Mobile Service (in Ku-band this is 125 km from the low-water mark of a country where FS links exists). Any transmissions from ship-based terminals within the minimum distance of 125km shall be subject to the prior agreement of the concerned administration. It is noted that such “concerned” country is one that has microwave links in operations under the Fixed and Mobile Service allocation in 14.0-14.5 GHz.

It is important to note that the minimum distance of 125km from the low-water mark was developed at WRC-03 and considered GSO systems for the studies.

1. Technical analysis of NGSO earth station terminals on aircrafts
	1. NGSO earth station terminals on aircrafts

Currently, the operation of earth station on aircraft is recognized as Aircraft Earth Stations (AES), which as per WRC-2003 are associated to satellite networks in the secondary MSS allocation at 14.0-14.5 GHz (see also definition of AES in provision No. **1.84** of the ITU RR).

The related ITU provisions and Recommendation ITU-R M.1643 were studied and proposed for AES that operates in the aeronautical mobile-satellite service (AMSS) secondary allocation. For example, Recommendation ITU-R M.1643 provides the PFD limit mask for AESs, required to protect the microwave-link receivers operating in the Fixed Service allocation in 14.0-14.5 GHz.

It was also recognized (through RR. No. **5.504A**) that AES can operate in the AMSS allocation using transponder of satellites whose assignments are filed under the FSS operating in the band 14‑14.5 GHz (Earth‑to-space), but without any priority over other GSO FSS systems. This means that the AES are not operating within a service in a primary allocation but are operating within mobile satellite service in a secondary allocation.

It is noted that Recommendation ITU-R M.1643 was developed in 2002-2003 specifically for AES terminals operating to satellite networks operating in the secondary MSS allocation. The NGSO terminals in this document operate under the co-primary FSS allocation.

* 1. Interference potential of a specific NGSO Earth Station Terminal on aircrafts into FS

As described Section 4, NGSO earth station terminals have to comply with EIRP/EIRPsd toward horizon in the same way as all other FSS. It is noted that NGSO earth station terminals are dynamically tracking the NGSO satellites, and the calculated geometry is nevertheless with a time percentage which is extremely low as well. .

Also, the CEPT studied the protection of FS links in a country, using ITU methodology and parameters (see section 6 below), from aeronautical equipment, and concluded that a new PFD mask, which is relaxed value from Recommendation ITU-R M.1643 as described in Section 6.

1. Example of technical conditions for the use of NGSO earth station in other regions

CEPT conducted studies between 2016 to 2021, which considered Fixed Service parameters taken from Recommendation ITU-R F.758-6 and ITU compatibility methodologies taken from Recommendation ITU-R SF.1650, and which developed and concluded a NGSO Earth station terminal PFD mask to protect FS microwave links. The PFD mask is as shown in Annex 2.

In relation to the NGSO earth station terminals in the 14.0-14.5 GHz frequency range, the ECC has developed the following instruments:

* **ECC Decision (18)05[[2]](#footnote-3)** – decision to allow spectrum-use, free circulation, and individual licence exemption NGSO terminals on airplane, ships and vehicles.
* **ECC Report 271[[3]](#footnote-4)** – technical compatibility report.
* **ECC Report 279[[4]](#footnote-5)** – regulatory framework as to why all NGSO equipment terminals are considered part of the FSS co-primary allocation.

And ETSI has developed the harmonized standard for the NGSO Earth stations **EN 303 980**, referred to into the above document.

Furthermore, ECC developed ECC Report 272, which demonstrates that a NGSO terminal of EIRP less than 54.5 dBW can be installed on the ground anywhere near and anywhere inside any airport; installed on any airplane, operate on an airplane from gate-to-gate (meaning at the gate, at the terminal, during taxiing, takeoff and landing) without causing any EMC issues to avionics, and airplanes.

1. Current Ku Band usage in APT

Considering that a recent APT Report on Vehicle Mounted Earth Stations (VMES) operating with GSO FSS networks in the Ku-band in APT countries (APT/AWG/REP-110, September 2021), frequency usage of each administration in the frequency bands 10.7-12.75 GHz and in the frequency bands 14 – 14.5 GHz has been surveyed and established, it is not proposed to conduct further survey at this time.

1. Operations of NGSO Earth Station Equipment in the 10.7-12.75 GHz FSS downlink allocation

It is recognized that the NGSO Earth Station terminals in the 10.7-12.75 GHz are in a receive mode operation, and as such they are prone to interference from the FS links (usually operating in the 10.7-11.7 GHz range), and not the other way around.

In relation to their regulatory status, this band may require some further consideration.

For the time being, this report proposes that the NGSO Earth station terminals should operate in this allocation on a non-protection basis from the FS, so that it can use the whole band between 10.7-12.75 GHz.

1. Summary and Conclusions

From the above sections it is shown that specific NGSO Earth Station Terminals in operation at the frequency range 14.0-14.5 GHz and under the co-primary FSS allocation:

1. The specific Earth station terminal for one single NGSO system used as an example for mobility applications in this report transmits at a lower power level than the levels referenced in Resolution **902 (Rev.WRC-23)**, so the results with lower transmit power level shows lower potential interference than that specified in Annex 2 of Resolution **902 (Rev.WRC-23)**.
2. Administrations may consider, where possible, the newer characteristics (i.e., minimizing transmitting power) that some NGSO Earth station equipment is able to achieve. This report provides an example of a specificNGSO Earth station with these newer characteristics.
3. Operations of NGSO Earth station terminals in the 10.7-12.75 GHz should be on a non-protection basis from other existing services allocated in the relevant frequency band.

ANNEX 1 Example of calculations of a specific NGSO Earth Station Terminal EIRP and EIRPsd toward the horizon

1. **Summary**

Section 2 of this Annex 1 determines the EIRP and EIRPsd toward the horizon of typical NGSO terminals. This is done to show that the NGSO earth station terminals have a very limited EIRP and EIRPsd toward the horizon.

1. **Comparison of ESV and a specific NGSO earth station terminal**

Typical parameters of ESV are given in Resolution **902** (WRC-2003) Annex 3, i.e.,

* Maximum ESV EIRP spectral density toward the horizon 12.5 dBW/MHz
* Maximum ESV EIRP toward the horizon 16.3 dBW

From the calculations we did below in Section 3 below, when comparing the NGSO EIRP and EIRPsd values with that of the Resolution **902 (Rev.WRC-23)** limits, NGSO terminals have a large margin, i.e.:

1. **EIRPsd,horizon limit of 12.5 dBW/MHz**

 EIRPsd,horizon,RES 902 = NGSO EIRPsd,horizon – 12.5

 = -20.6 – 12.5

 = -33.1 [dB]

1. **EIRPhorizon limit of 16.3 dBW**

 EIRPhorizon,RES 902 = NGSO EIRPhorizon – 16.3

 = -7.6 – 16.3

 = -23.9 [dB]

**Conclusion:** the specificNGSO earth station terminal on ships complies with EIRPsd / EIRP toward the horizon.

1. **Calculations**

**3.1 Terminal Parameters**

Table 1 shows the parameters assumed in the calculations.

**Table 1: Assumption parameters**

|  |  |
| --- | --- |
|  | **NGSO Terminal** (of an existing constellation) |
| **Carrier frequency**  | 14250 MHz |
| **Diameter (D)** | 60 cm |
| **Carrier bandwidth (BW)** | 20 MHz |
| **Peak EIRP** | 1. dBW[[5]](#footnote-6) / 35.8 dBW
 |

**3.2 Antenna parameters**

From the table above we get:

1. **Gpeak** = 10 Log (( D/)2)

Where:

 = efficiency of the antenna, usually for parabolic antennas this is 0.6.

= is the wavelength of the carrier, equal to c/f. with c being the speed of light

 and f is the carrier frequency.

= 3.1415…

Thus:

Gpeak = 36.8 [dBi]

1. **Beamwidth** = 70 /D

= 2.46 degrees

1. The **off-axis antenna gain G()** is calculated based on some given pattern, for example, ITU RR Appendix **8**, Annex 3, or, since the antenna has a small D/ is < 30, we needed to use an appropriate agreed ITU antenna pattern. For simplicity we chose Recommendation ITU-R S.1855 (although, ITU-R Recommendation S.1428 would be more appropriate for NGSO satellite terminals), shown below.



**3.3 EIRP toward the horizon**

The EIRP toward the horizon is calculated as:

 EIRPhorizon = EIRP – Gpeak + G()

Where:

EIRP is the Earth station peak EIRP (at boresight).

Gpeak is the antenna gain at the boresight.

G() is the antenna gain at an angle  from the boresight.

 is the elevation angle of the boresight with respect to the local horizontal plane.

The results of the calculations below are:

|  |  |
| --- | --- |
|  | **NGSO** |
| **EIRPhorizon[dBW]** | **-7.6** |

We now calculate these:

1. The **off-axis antenna gain G() at the horizon**

Hence the off-axis gain G() at the horizon is calculated in this case when the boresight is at the minimum elevation angle, i.e., min. Here then the off-axis gain is equal to G() = G(min).

NGSO case:NGSO systems cannot operate down at 5-degree elevation because the difference in spreading loss is quite large. Thus, they operate down to a higher minimum elevation. We have assumed here the minimum elevation of one of the constellations which operates down to about 35 degrees minimum.

Hence, we calculate the G(min) as:

|  |  |
| --- | --- |
|  | **NGSO** |
| **G(min=35)**  | **= 32 – 25 log(min=35 deg)**(noting from the graph below we are at a different slope) |
| **G(min)**  | **= -6.6 dBi** |

1. **EIRP toward the horizon** (EIRPhorizon):

EIRPhorizon = EIRP – Gpeak + G(min Elevation)

Where, G is the antenna gain pattern, and  is the off-axis angle between the antenna boresight and the horizon.

|  |  |
| --- | --- |
|  | **NGSO** |
| EIRPhorizon  | = EIRP – Gpeak + G(**min**) |
| EIRPhorizon | = 35.8 – 36.8 – 6.6= -7.6 [dBW] |

**3.4 EIRP spectral density toward the horizon**

This is equal to: EIRPsd,horizon = EIRPhorizon – 10 Log (BW)

Where, BW is the bandwidth of the signal.

When we calculate this with the values determine above we get:

|  |  |
| --- | --- |
|  | **NGSO** |
| EIRPsd,horizon  | = EIRPhorizon – 10 Log (BW) |
| EIRPsd,horizon  | = -7.6 – 10 Log (20) = -7.6 – 13.0= -20.6 [dBW/MHz] |

ANNEX 2 Example of calculation of the minimum distances for NGSO Earth Station Terminals installed on ships

Resolution **902 (Rev.WRC-23)** requires that a satellite terminal installed on a ship, and for operations toward to a GSO satellites requires a “minimum distance” of 125 km from the shores of a country that has terrestrial microwave systems in the band 14.0-14.5 GHz. This was determined from studies by ITU-R during the 2000-2003 period leading to the WRC-03. This was then confirmed by WRC-12.

However, in such studies none of the newer NGSO equipment were considered and as such the CEPT engaged in studies to determine the interference potential from the NGSO Earth station terminals to terrestrial microwave links operating it the range 14.0-14.5 GHz.

CEPT technical studies resulted in ECC Report 271 which shows some NGSO terminals on ships can operate closer to the shore of a country that has terrestrial FS links (receivers); i.e., closer than the 125 km distance recommended by the Resolution **902 (Rev.WRC-23).**

The ECC Report 271, goes even further to propose a PFD mask for NGSO Earth station terminals on ship (similarly to that of Earth stations installed on airplanes) instead of a minimum distance, so as to alleviate greatly the burden on both (i) the owners of Ships and (ii) the regulators in each country.

The ECC Report 271 carried out simulation studies using ITU-R FS link parameters and calculation methodologies, but this can also be seen from a very simple calculation.

The results given in the Annex 1, showed the difference in EIRP (or EIRPsd) toward the horizon, of a NGSO Earth station terminal, is 23.9 dB (or 33.1 dB) lower than the limit prescribed in Resolution **902 (Rev. WRC-23)** to protect a single FS station.

 Calculation of the reduction in minimum distance as a reduction from the D=125 km, can be done using the line-of-sight path loss formula (Lp = 20 Log (4 D f/c); which can provide a simple and conservative understanding of the matter), i.e.:

With respect to the EIRP toward the horizon: Dngso = 125 \* 10^(-23.9/20) = 8.0 km, or,

With respect to the EIRPsd toward the horizon: Dngso = 125 \* 10^(-33.1/20) = 2.8 km

Proper simulation results can be found in ECC Report 271, such report uses the same ITU-R technical references used to determine the distances of WRC Resolutions **902** (WRC-2003) i.e.,

* ITU-R Methodology of ESVs of Recommendation ITU-R SF.1650;
* FS parameters of Recommendation ITU-R F.758-6.

ANNEX 3 Technical conditions for NGSO Earth Station terminals

1. **Existing technical studies from CEPT**

CEPT has analyzed the interference potential of the NGSO satellite terminals, vis-à-vis protection of other services operating the same frequency band[[6]](#footnote-7); this resulted in ECC Report 271.

It then developed the regulatory framework made in ECC Report 279[[7]](#footnote-8), which provides the reasoning as to why NGSO Earth station terminals are an integral part of the FSS coprimary service.

It also studied all Earth stations for EMC with aircraft at airport and flights and concluded ECC Report 272, from which concluded that aircraft installed with NGSO Earth station terminals having an EIRP less than 54.5 dBW can operate anywhere at airport and gate-to-gate aircraft operations.

All of the above was taken and developed ECC Decision (18)05[[8]](#footnote-9), which provides the following technical means to protect several services operating in the 14.0-14.5 GHz range:

* **PFD mask for NGSO terminals installed on Aircraft to protect Fixed Service receivers:**
* –122 dB(W/(m² · MHz)) for θ ≤ 5°;
* –127 + θ dB(W/(m² · MHz)) for 5° < θ ≤40°;
* –87 dB(W/(m² · MHz)) for 40° < θ ≤90°

With θ being the elevation angle above the horizontal plane at a point in the Earth.

* **PFD mask for NGSO terminals installed on Ships to protect Fixed Service receivers:**
* –116 dB(W/(m² · MHz))

Applied at a height of 80 metres above mean sea level at the low-water mark of the territory of the administrations having FS links.

* **PFD mask for NGSO terminals installed on Vehicles (land-based service) to protect Radio Astronomy Service (RAS):**
* -116 dBW/m²/MHz

Applied at 30 m height above ground of the territory of the administrations having RAS receiver in 14.47-14.5 GHz.

* **Limitations to NGSO terminals installed on Aircraft to protect Radio Astronomy Service in the 14.47-14.5 GHz range:**
* ESIM installed on aircraft are required to cease emissions when in visibility of a RAS station performing observations in the 14.47-14.5 GHz secondary RAS allocation.
* **No limitations for NGSO terminals in the vicinity and/or inside an airport[[9]](#footnote-10)** (including on aircraft during take-off, landing, taxing and gate operations) as long at the peak EIRP of such terminals is below 54.5 dBW;

This matter is well exposed in the ECC Report 279[[10]](#footnote-11), and the technical results of the compatibility / sharing is given in ECC Report 271[[11]](#footnote-12).

1. **ETSI Equipment Standards**

Furthermore, the ETSI equipment standard developed by ETSI for Non-GSO constellations in the Ku-band FSS allocations is:

1. **ETSI Standard, EN 303 980 V 1.2.1[[12]](#footnote-13)**, “Satellite Earth Stations and Systems (SES); Fixed and in-motion Earth Stations communicating with non-geostationary satellite systems (NEST) in the 11 GHz to 14 GHz frequency bands; Harmonised Standard for access to radio spectrum”.
2. **System Reference Document**, **ETSI TR 103 399 V1.1.1[[13]](#footnote-14)**, “System Reference document (SRdoc); Fixed and in-motion Earth stations communicating with satellites in non-geostationary orbits in the 11 GHz to 14 GHz frequency band”.

The ETSI standard is for compliance of the equipment with the EU Radio Equipment Directive (DIRECTIVE 2014/53/EU).

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. in the ECC Report 271 <https://docdb.cept.org/download/3422> [↑](#footnote-ref-2)
2. ECC Decision (18)05, <https://docdb.cept.org/download/1462> [↑](#footnote-ref-3)
3. ECC Report 271, <https://docdb.cept.org/download/3422> [↑](#footnote-ref-4)
4. ECC Report 279, see, <https://docdb.cept.org/download/1330> [↑](#footnote-ref-5)
5. For license exempt NGSO terminals, CEPT has prescribed peak EIRP at 55.4 dBW (see, <https://docdb.cept.org/download/3536>). However, the typical NGSO terminal EIRP is far below the 55.4 dBW, and in effect between range of 34 to 43 dBW. [↑](#footnote-ref-6)
6. See ECC/Report 271, <https://docdb.cept.org/download/3422> [↑](#footnote-ref-7)
7. <https://docdb.cept.org/download/1330> [↑](#footnote-ref-8)
8. See ECC/DEC/(18)05, <https://docdb.cept.org/download/1462> [↑](#footnote-ref-9)
9. See, ECC Report 272, <https://docdb.cept.org/download/1315> . [↑](#footnote-ref-10)
10. See, <https://docdb.cept.org/download/1330> [↑](#footnote-ref-11)
11. See, <https://docdb.cept.org/download/3422> [↑](#footnote-ref-12)
12. <https://www.etsi.org/deliver/etsi_en/303900_303999/303980/01.02.00_20/en_303980v010200a.pdf> [↑](#footnote-ref-13)
13. <https://www.etsi.org/deliver/etsi_tr/103300_103399/103399/01.01.01_60/tr_103399v010101p.pdf> [↑](#footnote-ref-14)