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Task Group on Satellite Systems

WORKING DOCUMENT TOWARDS A DRAFT NEW APT REPORT ON NON-GSO EARTH STATION TERMINALS IN THE KU-BAND

1. Introduction

[Editor notes: briefly describe the purpose of such an APT report]

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 and are forecast to significantly increase the available internet bandwidth in remote and rural geographies not currently served by fibre or other terrestrial technologies.

Furthermore, LEO constellation systems will be used to bring broadband connectivity to end users on the move and will offer access solutions specifically tailored to the unique needs of the maritime and aviation services. Whether it is improving access to real time aircraft or ship performance data, or enhancing customer experiences for plane and cruise passengers, the capabilities of LEO satellites will enable access to fast, flexible, secure connectivity as a standardised service.

A harmonized approach to spectrum allocation to NGSO Earth Station Terminals used for mobility within the APT region and with other regions would enhance the prospects of unimpeded movement of such terminals in the region and internationally, therefore creating an opportunity for NGSO LEO systems to provide innovative high speed broadband access services to many businesses and consumers in the region.

This APT Report aimed at providing individual APT a regulatory foundation for facilitating the operation of such terminals in their countries.

2. Scope

[Editor notes: briefly describe the various use cases]

This APT Report addresses the characteristics and capability of LEO Constellation terminals, which we will refer to simply as NGSO Earth Station Terminals that would facilitate a wide range of applications either on land (fixed, nomadic, or mobile), from aircraft 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).

Information is provided in this document intended to demonstrate that the additional interference potential of the NGSO Earth station terminals used for mobility applications is mostly a localized (i.e., the coordination distances are very small) and as such that in practice this can be managed as a national licensing matter.

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3. ITU Radio Regulation

[Editor notes: list existing ITU Radio Regulation relevant to this topic]

In frequencies 14.0-14.5 GHz, there is a primary allocation for the FSS and a secondary allocation for Mobile Satellite Service (MSS).

NGSO satellite systems operate under the **primary allocation of the FSS** (under various footnotes introduced by WRC2000 and 2003; i.e., **No 5.441, 5.484A**, **5.487A**). Under such premise, the satellite terminals are part of such NGSO systems and are operating under the primary FSS allocation, thus all the regulatory status associated with the FSS 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 this allocation for operation of NGSO terminals, operating to a satellite system in the primary FSS allocation, installed on board airplanes, or ships, except that of operating under ITU provision No. **4.4**.

For our first point, 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, in particular Article 22.2, 22.5C to 22.5I and Resolution 85. On that basis, coexistence between NGSO and GSO in Ku-band is not further addressed in this Report.

Secondly, at WRC2003, the ITU introduced the following to protect microwave links use in the 14 GHz Fixed Service allocation:

- A new secondary allocation to the **Aeronautical Mobile Satellite Service** (AMSS) in the band 14.0-14.5 GHz, and with it **ITU-R Recommendation M. 1643**, which provides a PFD mask for Aircraft Earth Stations (AES) to protect the Fixed Service (FS); and,

- **Resolution 902**, for **Earth Stations on Vessels** (**ESV**) operating under the **FSS** allocation.

However, such regulatory instruments, being conceived to welcome the expansion of applications within GSO networks, don't account for the technical reality of NGSO constellations which arrived from 2014 onwards.

As such, this **Section 4** below analyses the ITU regulations and technical restrictions and highlights the shortcoming of these regulations, thus proposing a different solution to encompass NGSO terminals for aero and maritime use.

4. Analysis of inapplicability of Resolution 902 to NGSO Earth station terminals on ships

[Editor notes: Refer to Annex 1 for the calculations]

This section provides the results of calculations in Annex 1 and Annex 2, and shows that the NGSO Earth stations terminals have an extremely low interference potential, even in the worst geometry case the level of interference is many 100's/1000's times lower.

NGSO terminals are dynamically tracking the NGSO satellites and the worst case geometry is nevertheless with a time percentage which is extremely low as well. On the average elevation angle of a NGSO terminal is in the order of 50 to 75 degrees (depends on the latitude) from the horizontal plane, which is higher than the worst-case minimum elevation of 35 degrees (see Annex 1).

As such it can be concluded that NGSO Earth station terminals installed on ships do not cause any concern for the protection of FS microwave links operating in the range of frequencies 14.0-14.5 GHz.

4.1. 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 should be 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 GSO equipment.

ITU-R SG4 process leading to WRC-2003, studied the matter, specifically related to **Earth Station on Vessels** (**ESVs**) of GSO 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 resulted in some technical limitation for ESVs given in **ITU Resolution 902** (WRC-2003).

Resolution 902 provides for:

- **Technical parameters** for ESVs, such as antenna size, pointing accuracy, EIRP limits toward the horizon.

- **Operational limitations** for ESVs, such as a coordination distance (125 km) from countries that have FS links and limits to EIRP toward the horizon.

However, we consider in:

- **Section 4.2**: Why some limits given in Resolution 902 do not apply to NGSO Earth Station terminals installed on ships;

- **Section 4.2.1**: **Antenna Pointing Accuracy of NGSO terminals**

- **Section 4.2.2**: **Minimum antenna size**

- **Section 4.2.3**: **The coordination distance of 125 km for ship based satellite terminals**

- **Section 4.2.4: Compliance to Resolution 902 EIRP and EIRPsd limits toward the horizon.**

- **Section 4.3: Adopting a PFD mask for NGSO Earth Station Terminals installed on Ships**

4.2 Parameters of Resolution 902 that do not apply to NGSO Earth station terminals for sharing with FS

This subsection highlights which Resolution limitations do not apply to NGSO Earth stations terminals installed on ships in the framework of sharing Ku-band with FS networks.

4.2.1 Antenna Pointing Accuracy of NGSO terminals

ITU Resolution 902, states that the antenna pointing accuracy of the ESV shall be limited to **0.2 degrees.**

This limit was derived from considerations of GSO Earth stations pointing stability to protect adjacent GSO satellites and thus only applies to GSO ESV terminals. , and thus it is not relevant for the sharing between NGSO terminals and FS.

Discussion

Resolution 902 at WRC2003 only studied GSO terminals pointing at the satellites in the GSO arc, and such terminals require to protect a potential GSO satellite receiver at about 2 degrees away from the wanted satellite where the ESV terminal operates to. At such time it was agreed that a +/- 0.2 degrees is a generally agreed pointing accuracy for a satellite terminal pointing toward a GSO satellite.

This criteria being for the protection of GSO, it is not relevant in this section 4.2 which addresses the sharing between NGSO terminals and FS networks.

4.2.2 Minimum antenna size

ITU Resolution 902 limits the antenna size of ESVs to 1.2 meters in Ku-band and in proven cases of equal interference potential to FS links, such antenna size is allowed to be reduced to 0.6 meters.

The calculation in Annex 1 shows that there is no need to limit the size of the antenna for NGSO Earth Station terminals, because the interference potential is extremely small.

Discussion

Calculations made in **Annex 1** demonstrate that the worst-case interference potential of a NGSO antenna terminal (of 60 cm) toward a terrestrial receiver (like a microwave link) in Ku-band is extremely small, i.e.:

- With respect to the EIRP toward the horizon (dBW), for NGSO terminals, it is about **245 times smaller** than the limit prescribed in Res. 902 to protect a single FS station.

- With respect to the EIRP spectral density (dBW/MHz) toward the horizon, for NGSO terminals, it is about **2041 times smaller** than the limit prescribed in Res. 902 to protect a single FS station.

Equivalently, the above means that it takes the equivalent of **245 NGSO terminals** to have the same EIRP toward the horizon, and **2041 NGSO terminals** to have the same

EIRPsd toward the horizon, all placed at the same location and all pointing in the same direction all the time, to be equivalent to the maximum levels acceptable to protect a FS station. This of course is a conservative result, because the NGSO terminals are all constantly moving, at different locations, and pointing towards different directions.

As such the antenna size of the NGSO terminal does not need to be limited to 60 cm, it can be smaller.

4.2.3 The coordination distance of 125 km for ship based satellite terminals

The operational limitations of ITU **Resolution 902** (WRC2003) provides for a coordination distance to protect the **Fixed Service** (in Ku-band this is 125 km from the low-water mark of a country where FS links exists), that was proposed at WRC2003 as a threshold distance to trigger coordination for ESV approaching the country concerned[2].

APT Members should consider the application of a PFD mask as a technical and regulatory solution for NGSO Earth stations terminals installed on ships (national and foreign) and operating in the FSS allocation 14.0-14.5 GHz, for sharing with Fixed Service networks. This solution will drastically ease any frequency coordination exercises, which currently burden dramatically countries that have FS microwave links near a seashore and the ship operators that use the NGSO satellite terminals.

Discussion

When it comes to NGSO terminals on board ships, Annex 1 demonstrates that the interference potential (through the EIRP spectral density toward horizon) of such terminals is in the worst case at about **33.1 dB lower** than the limit prescribed in Res. 902 to protect a single FS station.

Furthermore, **Annex 2** takes this result and shows that the 125 km coordination distance reduces to a **few kilometers**, bringing the coordination distance from an international perspective to a national territorial (licensing) matter[3]. Thus, ITU Resolution 902 is not applicable any longer.

Also, the CEPT studied the problem for protection of FS links in a country, from maritime equipment, and concluded that a **PFD mask**, rather than a coordination distance, provides a more pragmatic approach that helps both the ship owners and the regulator, thus reducing the heavy burden which Resolution 902 creates.

The CEPT solution is introduced in **Section 4.3** (for NGSO terminals installed on ships) and **Section 5** (for installations on aircraft) below, and it is fully provided in **Annex 3**.

4.2.4 Compliance to Resolution 902 EIRP and EIRPsd limits toward the horizon

In **Annex 1** we provide the worst case calculation of the EIRP and EIRPsd toward the horizon, related to NGSO Earth station terminals. Here we compare these calculations to the limits in ITU Resolution 902.

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[2] Outside the 125 km the coordination between the ship and the country is not required; while if the ESV is inside such distance coordination is necessary only if the country has microwave links in the FS allocation.

[3] Countries territorial waters extend to a recognised distance of 12 nm (or 20 km) from their shores.

ITU Resolution 902 limits these parameters to:

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

From the calculations in **Annex 1**, we get:

		NGSO terminal	**Res 902 limits**
$EIRP_{horizon}$ [dBW]		-7.6	16.3
$EIRP_{sd,horizon}$ [dBW/MHz]		-20.6	12.5

We have from this that NGSO Earth station terminals will always meet the limits in Resolution 902 with a very large margin, i.e..:

- For the EIRP toward horizon, in the worst case the margin is 23.9 dB, equivalent to a NGSO terminal producing 245 times less interference than the limit prescribed in Res. 902 to protect a single FS station;

- For the EIRPsd toward the horizon, in the worst case the margin is 33.1 dB, equivalent to a NGSO terminal producing 2041 times less interference than the limit prescribed in Res. 902 to protect a single FS station.

As such we can conclude that NGSO do not require to comply with such Resolution 902 limits.

4.3 Adopting a PFD mask for NGSO Earth Station Terminals installed on Ships

This report has shown in this **Section 4** that **ITU Resolution 902** is not practically applicable to NGSO Earth station terminals installed on ships. We have provided technical reasons above.

For this reason, in the national frequency table of each country, when considering NGSO Earth station terminals installed on ship, ITU Resolution 902 should not be mentioned/referenced.

Instead, we recognized that a limitation of EIRP or PFD may be required to protect other co-primary services such as the FS in the 14-14.5 GHz frequency range. Hence, APT Members should consider the review and adoption of existing regulatory rules (such as a PFD mask on NGSO Earth station terminals) that have already been determined by other regional groups, such as those made by the European regional group.

This is because, such PFD mask will allow NGSO Earth station equipment installed on any ship to be mutually and bilaterally recognized by both regional groups, and any other region that adopts this mask. This bilateral solution will facilitate the operations of maritime communication services for consumers and passengers of countries in both regional groups and promote such solution with other world regions.

For example, CEPT/ECC Decision (18)05[4], developed by the CEPT, has certain rules that limits the **PFD** of such terminals. This PFD mask applies to both national ships, as well international ships that pass through the territorial waters of any APT country that has FS links in the specific sub-bands at 14 GHz range (we urge country not to adopt it indiscriminately across the whole frequency range, as it would unnecessarily burden both the operators and the regulators).

The CEPT PFD mask was determined by considering Fixed Service parameters taken from **ITU-R Recommendation F.758-6** and ITU compatibility methodologies taken from **ITU-R Recommendation SF.1650**, from which developed and concluded a NGSO Earth station terminal **PFD mask** to protect FS microwave links. This PFD mask is referenced in **Annex 3**[5].

We report it here (from ECC Decision (18)05):

> **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.

APT Members should consider adopting such PFD mask as a technical and regulatory solution for NGSO Earth stations terminals installed on ships (national and foreign) and operating in the FSS allocation 14.0-14.5 GHz.

Finally, acknowledging NGSO terminals not causing harmful interference to FS services, APT Members should consider to license exempt these NGSO terminals from having an individual license.

5. Analysis of inapplicability of ITU-R M.1643 to NGSO Earth station terminals on aircraft

5.1 Inapplicability of ITU-R Rec. M.1643 to NGSO Earth station terminals installed on aircraft

Currently, the ITU recognizes the operation of Earth station on airplanes as **Aircraft Earth Stations (AES)**, which as per WRC-2003 are associated to GSO 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 ITU-R Recommendation M.1643 were studied and proposed for **AES** that operate in the aeronautical mobile-satellite service (**AMSS**) secondary allocation. For example, **ITU-R Recommendation 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[6].

[4] See, https://docdb.cept.org/download/1462
[5] See also, ECC Decision (18)05, https://docdb.cept.org/download/1462
[6] Not many countries have deployed FS links in the 14.0-14.5 GHz range. Many countries will only have FS links in part of the allocation.

It was also recognized (through **No. 5.504A**) that AES can operate in the AMSS allocation using transponder of GSO 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.

We note that such ITU-R Recommendation 1643 was developed in 2002-2003 specifically for AES terminals operating to GSO networks operating in the secondary MSS allocation. As such, the compatibility assumption used for the AES, being that of a secondary MSS service vis-à-vis a primary FS service **are not applicable** to **NGSO Earth Stations Terminals** installed on aircraft for NGSO Ku-band systems operating under the co-primary **FSS** allocation.

5.2 Proposal for Adopting a PFD mask for NGSO Earth Station terminals installed on Aircraft

This paper proposes that for NGSO terminals operating under the co-primary **FSS** allocation a review on the compatibility of NGSO Earth Station Terminals installed on aircraft vis-à-vis other services (in particular vis-à-vis **FS** microwave links) is required.

Instead of duplicating work, APT Members should consider the adoption of existing regulatory rules that have already been determined by other regional groups, such as those made by the European regional group (see, ECC Report 271[7], and ECC Report 279[8]). This will allow NGSO Earth station equipment on European airlines and Asian airlines which have such terminals to be mutually and bilaterally recognized by both regional groups. This bilateral solution will facilitate the operations of aero services for consumers and passengers of countries in both regional groups and promote such solution with other world regions.

The proposed regulatory solution of this Report is the applicability of a **PFD mask** for the **NGSO Earth station terminals** installed on aircraft then different to the one given in ITU-R M.1643, but still technically appropriate for protecting FS microwave systems operating within the range of 14-14.5 GHz.

For example, CEPT conducted studies between 2016 to 2021, which considered Fixed Service parameters taken from **ITU-R Recommendation F.758-6** and ITU compatibility methodologies taken from **ITU-R Recommendation SF.1650**, and which developed and concluded a NGSO Earth station terminal **PFD mask** to protect FS microwave links. This PFD mask is referenced in **Annex 3**[9].

An excerpt from ECC Decision (18)05:

> **PFD mask for NGSO terminals installed on Aircraft to protect Fixed Service receivers:**
>
> - -122 dB(W/(m² · MHz)) for $\theta \leq 5°$;
> - $-127 + \theta$ dB(W/(m² · MHz)) for $5° < \theta \leq 40°$;
> - -87 dB(W/(m² · MHz)) for $40° < \theta \leq 90°$
>
> With θ being the elevation angle above the horizontal plane at a point in the Earth.

[7] See, https://docdb.cept.org/download/3422
[8] See, https://docdb.cept.org/download/1330
[9] See also ECC Decision (18)05, https://docdb.cept.org/download/1462

APT Members should consider adopting such PFD mask as a technical and regulatory solution for NGSO Earth stations terminals installed on airplanes (national and foreign) and operating in the FSS allocation 14.0-14.5 GHz.

Finally, acknowledging NGSO terminals not causing harmful interference to FS services, APT Members should consider to license exempt these NGSO terminals from having an individual license.

6. Current Ku Band usage in APT

[Editor notes: reference recent report and survey such as APT report 110 or other input about usage of Ku Band in APT]

In a recent APT Report 110[10], 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 a further survey.

7. Introduction of the CEPT regulatory solutions

In relation to the NGSO Earth station terminals in the 14.0-14.5 GHz frequency range, the ECC has developed the following instruments (see Annex 3):

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

And ETSI has developed the harmonised 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 airplace, operate on an airplane from gate-to-gate (meaning at the gate, at the terminal, during taxiing, take off and landing) without causing any EMC issues to avionics, and airplanes.

Most importantly, **Annex 3** here provides all the necessary tools to be considered by APT Members for **NGSO Earth station terminals** protecting other co-primary FS stations in the band 14.0-14.5 GHz range. In particular the PFD masks presented above in Section 4 and 5.

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

[10] APT Report on Vehicle Mounted Earth Stations (VMES) operating with GSO FSS networks in the Ku-band in APT countries, https://www.apt.int/sites/default/files/2021/09/APT-AWG-REP-110_-_APT_Report_on_Vehicle_Mounted_Earth_Stations_VMES_operating_with_GSO_FSS_networks_in_the_Ku-band_in_APT_countries.docx

We recognize that the NGSO 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 while not producing interference into the FS.

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

9. Summary and Conclusions

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

1. Pose no interference threat to any **Fixed Service** receiver operating in the range 14.0-14.5 GHz (thanks to the application of a PFD mask to the NGSO terminals); and,

2. Do not pose any interference threat to **GSO** satellite receivers (due to Article 22 e.p.f.d. limits).

As such, it is proposed that:

1. APT Members do not apply (1) ITU-R M.1643 and (2) ITU Resolution 902 to NGSO Earth Station Terminals (installed on airplanes or ships respectively), because such instruments were designed specifically for GSO terminals, and as such these will restrict or disrupt the operations of the NGSO Earth Station Terminals unnecessarily on a global scale.

   Furthermore, adopting the proposed solutions (see **Section 4** and **Section 5**) above, i.e., PFD masks studies by the CEPT, for NGSO satellite terminals on ships and airplanes, will **drastically ease** Administration from burdensome coordination (which takes time and resources), unnecessary technical restrictions which makes the equipment extremely costly and possibly unusable, and unnecessary administrative procedures (e.g., coordination between ship owners and regulators) on all parties. This, whilst protecting any incumbent terrestrial operator where these are present.

2. Operations of NGSO terminals in the 10.7-12.75 GHz should be on a non-protection basis from the FS, so as to operate across the whole range of frequencies.

3. As NGSO terminals do not cause harmful interference to other services, APT Members should consider to exempt these NGSO terminals from having an individual licensing.

ANNEX 1: Calculations of the 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 terminals have a very limited EIRP and EIRPsd toward the horizon, and thus a much lower interference potential than the limit prescribed in Res. 902 to protect a single FS station. This will justify that the NGSO terminals do not necessarily need to be bound by the ITU Resolution 902.

1. **Meeting Resolution 902 limits** on EIRP and EIRPsd toward the horizon.

   The limits in Resolution 902 for EIRP and EIRPsd toward the horizon are given in its Annex 3, i.e.:

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

   From the calculations we did below in **Section 2** below, when comparing the NGSO EIRP and EIRPsd values with that of the Resolution 902 limits the NGSO terminals meets both of them comfortably and in the worst case, with a large margin, i.e.:

   a. EIRPsd,horizon limit of 12.5 dBW/MHz

   Δ $EIRP_{sd,horizon,RES\ 902}$ = NGSO $EIRP_{sd,horizon}$ – 12.5

   = -20.6 – 12.5

   = -33.1 [dB]

   This means that if we place **2041 NGSO terminals**, placed at the same location (impossible) and pointing at any time at the minimum elevation and at the same satellite, will still meet the Resolution 902 limit.

   b. EIRPhorizon limit of 16.3 dBW

   Δ $EIRP_{horizon,RES\ 902}$ = NGSO $EIRP_{horizon}$ – 16.3

   = -7.6 – 16.3

   = -23.9 [dB]

   This means that if we place **245 NGSO terminals**, placed at the same location (impossible) and pointing at any time at the minimum elevation and at the same satellite, will still meet the Resolution 902 limit.

   Conclusion: Any NGSO Earth station terminals on ships, will always meet the Resolution 902 EIRPsd / EIRP toward the horizon.

2. Calculations

2.1 Terminal Paramaters

For the calculation we have assumed the following parameters.

		NGSO Terminal (of an existing constellation)
Carrier frequency		14250 MHz
Diameter (D)		60 cm
Carrier bandwidth (BW)		20 MHz
Peak EIRP		36 dBW[11]

2.2 Antenna parameters

From the table above we get:

1. **Gpeak** = 10 Log (η (π D/λ)^2)

   Where:

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

   λ = is the wavelength of the carrier, equal to c/f. with c being the speed of light and f is the carrier frequency.

   π = 3.1415…

   Thus:

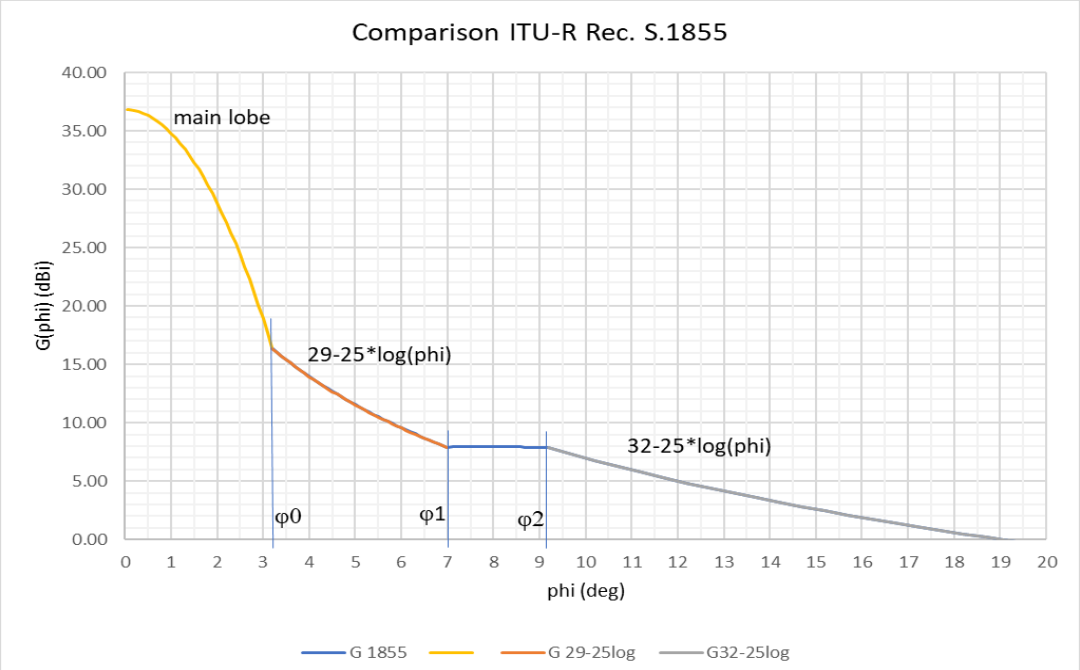
   Gpeak = 36.8 [dBi]

2. **Beamwidth** = 70 λ/D

   Beamwidth = 2.46 degrees

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

[11] 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.



2.3 EIRP toward the horizon

The EIRP toward the horizon is calculated as:

$$EIRP_{horizon} = EIRP - Gpeak + G(\varphi = \varepsilon)$$

Where:

- EIRP is the Earth station peak EIRP (at boresight);
- Gpeak is the antenna gain at the boresight;
- G(φ) is the antenna gain at an angle φ from the boresight.
- ε is the elevation angle of the boresight with respect to the local horizontal plane.

The results of the calculations below are:

		NGSO
$EIRP_{horizon}$[dBW]		**-7.6**

We now calculate these:

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

   Hence the off-axis gain G(φ) at the horizon is calculated at the worst case when the boresight is at the minimum elevation angle, i.e., $\varepsilon=\varepsilon_{min}$. Here then the off-axis gain is equal to $G(\varphi) = G(\varphi=\varepsilon_{min})$.

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 $G(\varepsilon_{min})$ as:

	NGSO
	$G(\varepsilon_{min}=35) = 32 - 25 \log(\varepsilon_{min}=35 \text{ deg})$ (noting from the graph below we are at a different slope)
	$G(\varepsilon_{min}) = -6.6$ dBi

2. **EIRP toward the horizon** ($EIRP_{horizon}$):

$$EIRP_{horizon} = EIRP - Gpeak + G(\text{min Elevation})$$

Where: G is the antenna gain pattern, and φ is the off-axis angle between the antenna boresight (we take the worst case, i.e., the minimum elevation angle) and the horizon.

	NGSO
$EIRP_{horizon} = EIRP - Gpeak + G(\boldsymbol{\varepsilon_{min}})$	
	$EIRP_{horizon} = 35.8 - 36.8 - 6.6$
	-7.6 [dBW]

2.4 EIRP spectral density toward the horizon

This is equal to: **$EIRP_{sd,horizon} = EIRP_{horizon} - 10 \text{ Log (BW)}$**

Where BW is the bandwidth of the signal.

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

	NGSO
$EIRP_{sd,horizon} = EIRP_{horizon} - 10 \text{ Log (BW)}$	
	$EIRP_{sd,horizon} = -7.6 - 10 \text{ Log (20)}$ $= -7.6 - 13.0$
	-20.6 [dBW/MHz]

ANNEX 2: Example calculation of the coordination distances for NGSO terminals installed on a vessel

ITU Resolution 902, requires that a satellite terminal installed on a ship, and for operations toward to a GSO satellites requires a "coordination 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 WRC2003. This was then confirmed by WRC2012.

However, in such studies none of the new NGSO constellations 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 that the NGSO terminals on ships can operate closer to the shore of a country that has terrestrial FS links (receivers); i.e., much closer than the 125 km distance recommended by the Resolution 902, and to the point that the coordination distance is within the territorial waters of the country (i.e., 20 km). Hence, the issue becoming a national licensing one, rather than an international coordination issue of ships out at sea versus the country in concern.

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 coordination distance, so as to alleviate greatly the burden on both (i) the owners of Ships and (ii) the regulators in each country. Hence, a PFD mask for maritime terminals is welcomed.

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

Taking the results given in the **Annex 1**, we determined that 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 Res. 902 to protect a single FS station.

Hence, in a simplistic manner, if we were to calculate the reduction in coordination distance as a **reduction** from the D=125 km, this can be done using the line-of-sight path loss formula (Lp = 20 Log (4π 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

This is a rough calculation which indicates that the coordination distance for a NGSO terminals on ships is many times smaller than the 125 km distance.

Proper simulation results can be found in ECC Report 271, where you can see that such report uses the same ITU-R technical references used to determine the distances of ITU Resolutions 902, 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

[Editor notes: Develop/reference technical studies on the coexistence of NGSO Earth Station Terminals with other co-primary services in Ku-band]

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[12]; this resulted in ECC Report 271.

It then developed the regulatory framework made in ECC Report 279[13], 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[14], which provides the following technical means to protect several services operating in the 14.0-14.5 GHz range:

i. **PFD mask for NGSO terminals installed on Aircraft to protect Fixed Service receivers:**
   - -122 dB(W/(m² · MHz)) for $\theta \leq 5°$;
   - $-127 + \theta$ dB(W/(m² · MHz)) for $5° < \theta \leq 40°$;
   - -87 dB(W/(m² · MHz)) for $40° < \theta \leq 90°$

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

ii. **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.

iii. **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.

iv. **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

[12] See ECC/Report 271, https://docdb.cept.org/download/3422
[13] https://docdb.cept.org/download/1330
[14] See ECC/DEC/(18)05, https://docdb.cept.org/download/1462

allocation.

v. **No limitations for NGSO terminals in the vicinity and/or inside an airport**[15] (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[16], and the technical results of the compatibility / sharing is given in ECC Report 271[17].

2. ETSI Equipment Standards

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

i. **ETSI Standard, EN 303 980 V 1.2.1**[18], "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".

ii. **System Reference Document**, **ETSI TR 103 399 V1.1.1**[19], "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[1](**DIRECTIVE 2014/53/EU**).

[15] See, ECC Report 272, https://docdb.cept.org/download/1315 .
[16] See, https://docdb.cept.org/download/1330
[17] See, https://docdb.cept.org/download/3422
[18] https://www.etsi.org/deliver/etsi_en/303900_303999/303980/01.02.00_20/en_303980v010200a.pdf
[19] https://www.etsi.org/deliver/etsi_tr/103300_103399/103399/01.01.01_60/tr_103399v010101p.pdf