



**Satellite Earth Stations and Systems (SES);
Considerations on off-axis EIRP density mask applicability for
Ka band GSO ESOMPs in relation to potential revision
to ETSI EN 303 978 (V2.1.2)**

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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Executive summary

The off-axis EIRP density mask included in clause 4.2.3 of ETSI EN 303 978 [i.4], which refers to COPOL and crosspol components (and the consequential test clause 6.4 of ETSI EN 303 978 [i.4]) has not been reconsidered since its creation in 2013. It now appears that consideration of total transmitted off axis EIRP density rather than its polarized components would bring ETSI EN 303 978 [i.4] more in line with the masks used in ITU-R Resolution 156 [i.6] on Earth Stations In Motion (ESIM) and Recommendation ITU-R S.524-9 [i.1]. These masks are used globally, including in Europe for inter-satellite coordination and for the protection of the GSO arc.

Introduction

It is proposed to revise the off axis EIRP density mask which has been inserted in ETSI EN 303 978 [i.4] in 2013 and in the subsequent versions up to V2.1.2. The present document is intended to show that considering the total transmitted off axis EIRP rather than its polarized components is consistent with other International masks and equally suitable for the protection of satellites on the GSO arc.

ETSI EN 303 978 [i.4] was published ten years ago in 2013. Experience acquired since then on ESOMPs has shown that protection of the GSO arc from their off-axis transmissions using a mask for the total transmitted off axis EIRP density is more consistent with current practices than use of the present masks which consider the polarized components of the off-axis transmission.

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1 Scope

The present document aims at studying the implications of reviewing the applicability of the mask for off-axis EIRP density in ETSI EN 303 978 (V2.1.2) [i.9].

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

- [i.1] Recommendation ITU-R S.524 (May 2000): "Maximum permissible levels of off-axis e.i.r.p. density from earth stations in geostationary-satellite orbit networks operating in the fixed-satellite service transmitting in the 6 GHz, 13 GHz, 14 GHz and 30 GHz frequency bands".
- [i.2] ETSI EN 301 459 (October 2000): "Satellite Earth Stations and Systems (SES); Harmonized EN for Satellite Interactive Terminals (SIT) and Satellite User Terminals (SUT) transmitting towards satellites in geostationary orbit in the 29,5 to 30,0 GHz frequency bands covering essential requirements under article 3.2 of the R&TTE Directive".
- [i.3] Recommendation ITU-R S.1594 (September 2022): "Maximum emission levels and associated requirements of high density fixed-satellite service earth stations transmitting towards geostationary fixed-satellite service space stations in the 30 GHz range".
- [i.4] ETSI EN 303 978 (V1.1.2) (2013): "Satellite Earth Stations and Systems (SES); Harmonised Standard for Earth Stations on Mobile Platforms (ESOMP) transmitting towards satellites in geostationary orbit, operating in the 27,5 GHz to 30,0 GHz frequency bands covering the essential requirements of article 3.2 of the Directive 2014/53/EU".
- [i.5] Report ITU-R S.2357 (2015-06): "Technical and operational guidelines for earth stations on mobile platforms communicating with geostationary space stations in the fixed-satellite service in the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz".
- [i.6] ITU-R Final Acts (WRC-15) (2015) Resolution 156: "Use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service".
- [i.7] FCC 47 CFR 25.138 (2014): "Licensing requirements for GSO FSS Earth Stations in the 18.3-18.8 GHz (space-to-Earth), 19.7-20.2 GHz (space-to-Earth), 28.35-28.6 GHz (Earth-to-space), and 29.25-30.0 GHz (Earth-to-space) bands".
- [i.8] ITU-R Final Acts (WRC-19) Resolution 169: "Use of the frequency bands 17.7-19.7 GHz and 27.5-29.5 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service".

- [i.9] ETSI EN 303 978 (V2.1.2) (2016): "Satellite Earth Stations and Systems (SES); Harmonised Standard for Earth Stations on Mobile Platforms (ESOMP) transmitting towards satellites in geostationary orbit, operating in the 27,5 GHz to 30,0 GHz frequency bands covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

3 Definition of terms, symbols, and abbreviations

3.1 Terms

Void.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

$U_{TOT}(\theta, \phi)$ radiation intensity of an antenna defined as the power per unit solid angle (distance independent)

NOTE: The subscript denotes the polarization basis (TOT = total polarization, L = left handed circular, etc.).

(θ, ϕ) spherical coordinate system

P_{Acc} power accepted by the antenna

η_0 free space impedance; namely 377 ohms for standard atmosphere

E_L radiated electric far field

NOTE: The subscript denotes the polarization basis (TOT = total polarization, L = left handed circular, θ is the spherical theta-aligned polarization, x is the x-aligned or horizontal linear polarization, etc.).

G_{TOT} gain of the antenna

NOTE: The subscript denotes the polarization basis.

r radial distance away from an antenna

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AZ	Azimuth
COPOL	CO-POLarization gain pattern
CP	Circular Polarization
EIRP	Effective Isotropically Radiated Power
EIRP-SD	Effective Isotropically Radiated Power Spectral Density
EL	Elevation
ES	Earth Station
ESIM	Earth Stations In Motion
ESOMP	Earth Station Onboard Mobile Platform
FCC	US Federal Communications Commission
GSO	Geostationary Orbit
LHCP	Left Hand Circular Polarization
RHCP	Right Hand Circular Polarization
RX	Receive
TOT	Total polarization
TOTPOL	Total Polarization gain pattern
TX	Transmit
WRC	World Radiocommunications Conference
XPOL	Cross-Polarization gain pattern

4 Applicability of off-axis EIRP density within the band in ETSI EN 303 978

4.0 General

The specifications for off-axis EIRP density within the band for different standardization texts referenced in clause 2.2 above are compared in Table 1 below.

Table 1: Comparison of Ka band ES off-axis EIRP density in published standardization texts

Source	Date	Applicability	Co-polarization	Cross polarization	No reference to polarization
Recommendation ITU-R S.524 [i.1]	May 2000	within $\pm 3^\circ$ of the GSO			19 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$; -2 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$; 22 - 25 log Φ dBW/40 kHz for $9,2^\circ < \Phi \leq 48^\circ$; -10 dBW/40 kHz for $48^\circ < \Phi \leq 180^\circ$
ETSI EN 301 459 [i.2]	End 2000	within $\pm 3^\circ$ of the GSO	19 - 25 log Φ dBW/40 kHz for $1,8^\circ \leq \Phi \leq 7,0^\circ$; -2 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$; 22 - 25 log Φ dBW/40 kHz for $9,2^\circ < \Phi \leq 48^\circ$; -10 dBW/40 kHz for $48^\circ < \Phi \leq 180^\circ$	9 - 25 log Φ dBW/40 kHz for $1,8^\circ \leq \Phi \leq 7,0^\circ$; -12 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$	
Recommendation ITU-R S.1594 [i.3]	September 2002	within $\pm 3^\circ$ of the GSO	19 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$; -2 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$; 22 - 25 log Φ dBW/40 kHz for $9,2^\circ < \Phi \leq 48^\circ$; -10 dBW/40 kHz for $48^\circ < \Phi \leq 180^\circ$	9 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$; -12 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$	
ETSI EN 303 978 [i.4]	2013	within $\pm 3^\circ$ of the GSO	19 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$; -2 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$; 22 - 25 log Φ dBW/40 kHz for $9,2^\circ < \Phi \leq 48^\circ$; -10 dBW/40 kHz for $48^\circ < \Phi \leq 180^\circ$	9 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$; -12 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$	
FCC 47 CFR 25.138 [i.7]	2014	within $\pm 3^\circ$ of the GSO	18,5 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7^\circ$; -2,63 dBW/40 kHz for $7^\circ \leq \Phi \leq 9,23^\circ$; 21,5 - 25 log Φ dBW/40 kHz for $9,23^\circ \leq \Phi \leq 48^\circ$; -10,5 dBW/40 kHz for $48^\circ < \Phi \leq 180^\circ$	8,5 - 25 log Φ dBW/40 kHz for $2,0^\circ < \Phi \leq 7,0^\circ$; -12,63 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,23^\circ$	
Report ITU-R S.2357 [i.5] & ITU-R Resolution 156 (WRC-15) [i.6]	2015	within $\pm 3^\circ$ of the GSO			19 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$; -2 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$; 22 - 25 log Φ dBW/40 kHz for $9,2^\circ < \Phi \leq 48^\circ$; -10 dBW/40 kHz for $48^\circ < \Phi \leq 180^\circ$;

The latest regulatory texts (Report ITU-R S.2357 [i.5], ITU-R Resolution 156 (WRC-15) [i.6] and ITU-R Resolution 169 (WRC-19)) [i.8] do not mention explicitly a reference to polarization for the mask.

In order to protect other satellites on the geostationary orbit, it makes more sense to take into account the total off-axis transmitted power rather than taking into account a co-pol and a cross-pol components which may become meaningless a few degrees away from the main axis of the transmit antenna. In fact, the majority of ITU inter-satellite coordination agreements do not consider co-pol and cross-pol components separately and set limits on emissions towards each other's networks based on power density without regard to polarization. The rationale for use of a total EIRP density limit toward other GSO satellite networks is reasonable because GSO satellites typically operate on both polarizations. That is, the target GSO satellite can operate with either RHCP, LHCP, or both polarizations in a given geographic area. Operators of nearby GSO satellites can expect full power emissions from either polarization from the satellite and from earth stations accessing the target satellite, reduced only by the off-axis gain reduction in the direction of the given nearby satellite.

On-axis cross-polar emission limits are needed mainly for the purposes of frequency reuse on the target satellite - not for adjacent or nearby satellites which as noted above could see co-polar emissions on both polarizations from earth stations of the target GSO Network.

It is thus proposed to:

- 1) suppress the reference to polarization in clause 4.2.3 of ETSI EN 303 978 [i.9], replacing the EIRP density limitation on polarized components by total transmitted power density;
- 2) maintain the present mask which applied for the co-polarized component and becomes a mask for total transmitted off-axis EIRP density (which would be in line with ITU-R Resolution 156 (WRC-15) [i.6].

Consequently, changes in clause 4.2.3 of ETSI EN 303 978 [i.9] would read as follows:

"4.2.3.2

~~Co-polarized Specification~~

The following specifications apply to the ESOMP transmitting at EIRP values up to $EIRP_{max}$.

The ~~maximum total~~ EIRP in any 40 kHz band within the nominated bandwidth ~~of the co-polarized component~~ in any direction ϕ degrees from the antenna main beam axis shall not exceed the following limits for more than 0,01 % of the time:

19 - 25 log ϕ - K dBW for $2,0^\circ \leq \phi \leq 7,0^\circ$;

-2 - K dBW for $7,0^\circ < \phi \leq 9,2^\circ$;

22 - 25 log ϕ - K dBW for $9,2^\circ < \phi \leq 48^\circ$;

-10 - K dBW for $48 < \phi \leq 180^\circ$;

where:

- ϕ is the angle, in degrees, between the main beam axis and the direction considered; and
- K is as defined in clause 4.2.2.2.1."

4.2.3.4

Cross-polarization Specification

The following mask is included in ETSI EN 303 978 (V2.1.2) [i.9]:

9 - 25 log Φ dBW/40 kHz for $2,0^\circ \leq \Phi \leq 7,0^\circ$

-12 dBW/40 kHz for $7,0^\circ < \Phi \leq 9,2^\circ$)

It would become Void in any revision of ETSI EN 303 978 for the reasons developed in the present document.

Suggested changes to clause 6.4:

6.4 Off-axis EIRP emission density within the band

Currently, the fourth paragraph of this clause reads:

"The EIRP density is determined from the measurements of the antenna copolar and crosspolar gain patterns, and of the power density at the antenna flange."

Suggested new text developing the total off-axis EIRP density method is as follows:

"The total off-axis EIRP density is determined from the measurements of the antenna copolar and crosspolar gain patterns, and of the power density at the antenna flange. For each off-axis angle considered, the copolar and crosspolar gains are combined together to develop a total gain in that direction."

New clause 6.4.1.4 should be added which describes how the copolar and crosspolar gains are numerically combined for the azimuth and elevation gain pattern cuts to develop a total off-axis gain pattern for azimuth and elevation.

Basically, for each angle X between $\pm 180^\circ$, compute:

$$10 \times \log_{10}(10^{(\text{copolar gain (dBi) at angle X/10})} + 10^{(\text{crosspolar gain (dBi) at angle X/10})})$$

and record this new value as the total off-axis gain (dB) to be combined with the antenna input power density to determine the total off-axis EIRP density.

4.1 Rationale for revision of off-axis EIRP density applicability

The rationale is to better protect neighbouring satellites on the geostationary orbit from off-axis transmission from an ESOMP with a mask consistent with modern regulatory framework for ESOMPs and with current inter-satellite coordination practices.

4.2 Total Gain Definition

The total EIRP density which has been referenced earlier is the product of the transmitted power density by the "total gain" of the ESOMP. This "total gain" is defined in this clause.

Radiation intensity or "U" can be expressed conventionally by either total or individual polarization (e.g. "L" or LHCP):

$$U_{TOT}(\theta, \phi) = \frac{1}{2} \frac{|\vec{E}|^2}{\eta_0} r^2$$

$$\text{Or Single POL, e. g.: } U_L(\theta, \phi) = \frac{1}{2} \frac{|\vec{E}_L|^2}{\eta_0} r^2$$

This is directly proportional to the gain by:

$$G_{TOT}(\theta, \phi) = \frac{4\pi}{P_{Acc}} U_{TOT}(\theta, \phi)$$

$$\text{Or Single POL, e. g.: } G_L(\theta, \phi) = \frac{4\pi}{P_{Acc}} U_L(\theta, \phi)$$

Where the total electric field can be expressed as:

$$\vec{E} = E_L \hat{L} + E_R \hat{R} = E_x \hat{x} + E_y \hat{y} = E_\theta \hat{\theta} + E_\phi \hat{\phi}$$

$$\text{where } E_{POL} = \vec{E} \cdot \hat{P} \hat{L}^*$$

And the squared, complex L2-norm of E can be expressed by:

$$|\vec{E}|^2 = |E_L|^2 + |E_R|^2 = |E_x|^2 + |E_y|^2 = |E_\theta|^2 + |E_\phi|^2$$