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OPEN SERVICE

QUARTERLY PERFORMANCE REPORT

OCTOBER – DECEMBER 2023

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1 INTRODUCTION

This document is the Galileo Open Service (OS) Public Performance Report for the period of **October**, **November** and **December 2023**. Since the declaration of Initial Services (IS) in December 2016, a new edition is published after each quarter, to provide the public with information about the Galileo Open Service measured performance statistics.

The document reports on the following performance parameters, with respect to their Minimum Performance Levels (MPLs) declared in the [OS-SDD]:

- ◊ Galileo Open Service Ranging Performance
- ◊ Galileo UTC and GGTO Dissemination and Determination Performance
- ◊ Galileo Positioning Performance
- ◊ Timely Publication of Notice Advisory to Galileo Users (NAGUs) [1]

In addition, information is provided about measured values and metrics that are not subject to MPL targets, for example for the recently introduced reporting on the Galileo OSNMA "Public Observation" phase. The document comprises the following sections:

Section 1: introduces this report, including the status of the Galileo constellation over the quarterly reporting period.

Section 2: provides an executive summary describing main statistics about the achieved OS performance. Details are reported in the following chapters.

Section 3: the Open Service Ranging Performance comprises 2 subsections: "Per-slot Availability of HEALTHY Signal in Space" and "Galileo Signal in Space Ranging Accuracy".

Section 4: the "UTC and GGTO Dissemination and Determination Performance" is presented in two subsections: the "Availability of the Galileo Time Correlation Parameters and of UTC Determination" and the "Accuracy of Galileo Time Correlation Parameters". Performance is evaluated for the Universal Time Coordinated (UTC) Time & Frequency provision Service and the GST-GPS Time Offset (GGTO) Determination.

Section 5: the "Galileo Positioning Performance" is illustrated in three subsections: "Availability of the Galileo Position Dilution of Precision", "Availability of the Galileo Positioning Service" and "Galileo measured Positioning Performance".

Section 6: the "Timely Publication of Notice Advisory to Galileo Users (NAGUs)" is analysed.

Section 7: preliminary performance information about the new Galileo OSNMA Service is given, even if Service is not yet declared by the EU, according to the ongoing "Public Observation Phase" announced by the Galileo Service Notice #09 [SvNOTE #09]. In particular, "Availability of Authentication Tags" and "Statistics on Success of Tag Authentication" are reported.

Section 8: all the cited reference documents are listed.

Section 9: terms, acronyms and abbreviations used in the document are defined.

[1] NAGUs are issued publicly by the European GNSS Service Centre (GSC)

Table 1 provides the status of the Galileo constellation for which the performance data has been measured over the reporting period.

Table 1: Galileo reported constellation information

Satellite		orbital slot	status
ID	PRN		
GSAT0101	E11	B05	usable
GSAT0102	E12	B06	usable
GSAT0103	E19	C04	usable
GSAT0201	E18	non-nominal	not usable since 2021-02-18. This was notified with NAGU 2021008, and the reason is clarified by Galileo Service Notice #05 (SNGU 2021001, [SvNOTE #5])
GSAT0202	E14	non-nominal	not usable since 2021-02-18, as it is the case of GSAT0201
GSAT0203	E26	B08	usable
GSAT0205	E24	A08	usable
GSAT0206	E30	A05	usable
GSAT0207	E07	C06	usable (*)
GSAT0208	E08	C07	usable (*)
GSAT0209	E09	C02	usable
GSAT0211	E02	A06	usable
GSAT0212	E03	C08	usable (*)
GSAT0213	E04	C03	usable, subject in December to a planned maintenance, as per NAGUs 2023056, 2023057, having short duration (55 minutes)
GSAT0214	E05	C01	usable (*) – Subject in November to a planned orbit manoeuvre as per NAGUs 2023054, 2023055, having long duration (9.55 days)
GSAT0215	E21	A03	usable (*) (**)
GSAT0216	E25	A07	usable (*) (**)
GSAT0217	E27	A04	usable (**)
GSAT0218	E31	A01	usable (*) (**)
GSAT0219	E36	B04	usable
GSAT0220	E13	B01	usable (*)
GSAT0221	E15	B02	usable
GSAT0222	E33	B07	usable (*)
GSAT0223	E34	B03	usable
GSAT0224	E10	B15	usable, however to be considered as auxiliary vehicle

(*) = subject in October to a short maintenance pre-announced by NAGU 2023050, lasting less than 40 min

(**) = subject in November to a short maintenance pre-announced by NAGU 2023050, lasting less than 40 min

For the most up-to-date information about the Galileo Constellation, please refer to the information published by the European GNSS Service Centre (GSC) on its website:

Table 2: Galileo Service Centre main information web pages for Galileo status

Constellation Status Information https://www.gsc-europa.eu/system-service-status/constellation-information
Reference Constellation Orbital and Technical Parameters https://www.gsc-europa.eu/system-service-status/orbital-and-technical-parameters
Incident Reporting (Galileo Incidents Report Form) http://www.gsc-europa.eu/helpdesk → "Report a Galileo Incident"
Interactive support to users (Galileo Help Desk) http://www.gsc-europa.eu/helpdesk → "Raise your questions"

The Galileo Helpdesk at GSC allows close interaction with users, both to support the exploitation of Galileo services and to collect relevant information on signal performance as observed by the users. The GSC is also responsible for providing the Notice Advisory to Galileo Users (NAGU) messages, as detailed in Section 6.

Note, that since December 2023, the reported metrics are based upon the [OS-SDD] edition v1.3, which is in force since November 2023.

Regarding **GSAT0224** (**E10**), it should be noted that this space vehicle is considered as an "auxiliary" satellite, and it is not located in a nominal orbit slot. Hence the constellation availability targets need to be achieved even without taking it into account, and the satellite contribution is neglected when computing MPLs such as "Availability of healthy SIS" and "Availability of PDOP $\leq$ 6". However, it is also a requirement that it shall not degrade the overall system performance, therefore, its ranging accuracy is monitored and reported and is included in the computation of the associated constellation average.

2 EXECUTIVE SUMMARY

During the quarterly reporting period under consideration, the measured Galileo Open Service performance figures exceed the Minimum Performance Level (MPL) targets specified in the [OS-SDD]. Table 3 and Table 4 summarise the compliance with MPLs as dashboards, using the colour coding defined in Table 5.

Table 3: OS MPL fulfilment status dashboard (1/2)

signal in space ranging					
accuracy, any satellite [2] (95%), in m					
satellite			**2023**		
ID	**PRN**	**target value**	**October**	**November**	**December**
GSAT0101	E11	≤ 7	■■■■■	■■■■■	■■■■■
GSAT0102	E12		■■■■■	■■■■■	■■■■■
GSAT0103	E19		■■■■■	■■■■■	■■■■■
GSAT0203	E26		■■■■■	■■■■■	■■■■■
GSAT0205	E24		■■■■■	■■■■■	■■■■■
GSAT0206	E30		■■■■■	■■■■■	■■■■■
GSAT0207	E07		■■■■■	■■■■■	■■■■■
GSAT0208	E08		■■■■■	■■■■■	■■■■■
GSAT0209	E09		■■■■■	■■■■■	■■■■■
GSAT0211	E02		■■■■■	■■■■■	■■■■■
GSAT0212	E03		■■■■■	■■■■■	■■■■■
GSAT0213	E04		■■■■■	■■■■■	■■■■■
GSAT0214	E05		■■■■■	■■■■■	■■■■■
GSAT0215	E21		■■■■■	■■■■■	■■■■■
GSAT0216	E25		■■■■■	■■■■■	■■■■■
GSAT0217	E27		■■■■■	■■■■■	■■■■■
GSAT0218	E31		■■■■■	■■■■■	■■■■■
GSAT0219	E36		■■■■■	■■■■■	■■■■■
GSAT0220	E13		■■■■■	■■■■■	■■■■■
GSAT0221	E15		■■■■■	■■■■■	■■■■■
GSAT0222	E33		■■■■■	■■■■■	■■■■■
GSAT0223	E34		■■■■■	■■■■■	■■■■■
GSAT0224	E10		■■■■■	■■■■■	■■■■■
accuracy, over all satellites (95%), in m					
		≤ 2	■■■■■	■■■■■	■■■■■
availability per slot, in %					
		≥ 92	■■■■■	■■■■■	■■■■■

■■■■■ E1/E5a | E1/E5b | E1 | E5a | E5b

[2] Note, that GSAT0210 was declared not any longer contributing service provision until further notice, since 05/09/2023 @ 00:00 (ref.: NAGU 2023048).

Table 4: OS MPL fulfilment status dashboard (2/2)

OS MPL	target value	2023 October	2023 November	2023 December
positioning and dilution of precision (DOP)				
availability				
PDOP ≤ 6 at AUL, F/NAV, in %	≥ 90	■	■	■
PDOP ≤ 6 at AUL, I/NAV, in %	≥ 90	■	■	■
PDOP ≤ 6 at WUL, F/NAV, in %	≥ 87	■	■	■
PDOP ≤ 6 at WUL, I/NAV, in %	≥ 87	■	■	■
positioning @ AUL, DF, in %	≥ 90	■	■	■
positioning @ AUL, SF, in %	≥ 90	■	■	■
positioning @ WUL, DF, in %	≥ 87	■	■	■
positioning @ WUL, SF, in %	≥ 87	■	■	■
timing				
accuracy				
UTC time dissemination (95%), in ns	≤ 30	■	■	■
UTC frequency dissemination (95%), unitless	≤ 3E–13	■	■	■
UTC Time Determination Accuracy, in ns [3]	≤ 30			■
GGTO determination (95%), in ns	≤ 20	■	■	■
availability				
UTC dissemination, in %	≥ 95	■	■	■
UTC determination accuracy better than 31 ns, in %	≥ 95	■	■	■
GGTO determination, in %	≥ 80	■	■	
	≥ 95			■
user interface				
NAGU timeliness				
planned, in days	≥ 2	■	■	■
unplanned, in days	≤ 1.25	■	■	
service recovery, in days [3]	≤ 0.625			■

Table 5: legend of OS MPLs verification dashboard

legend colour	interpretation
none	MPL measurement is not available
■	target value for MPL is fulfilled
■	target value for MPL is not fulfilled (less than 10% away from the target value)
■	target value for MPL is not fulfilled (more than 10% away from the target value)

[3] Introduced by OS-SDD v1.3

Table 6: Additional MPLs for Ranging and Positioning [4]

MPLs			target value	2023 Oct.	2023 Nov.	2023 Dec.
Ranging Rate Accuracy, in mm/s						
Single Frequency			≤ 5			■■■
Dual Frequency			≤ 5			■■
Positioning Accuracy, in m						
Global Average		Single Frequency	≤ 5 (HPE) ≤ 8 (VPE)			■
		Dual Frequency	≤ 5 (HPE) ≤ 8 (VPE)			■
Worst User Location		Single Frequency	≤ 10 (HPE) ≤ 16 (VPE)			■
		Dual Frequency	≤ 10 (HPE) ≤ 16 (VPE)			■
■■■	(Single Frequency): E1 | E5a | E5b		■■	(Dual Frequency): E1-E5a | E1-E5b		

Table 7: MPLs for Galileo support of Aviation Users [4]

MPLs		target value	2023 Oct.	2023 Nov.	2023 Dec.
User Range Accuracy (URA), in m					
σ_{URA}, Single Frequency		≤ 7.5			■■
σ_{URA}, Dual Frequency (E1-E5a)		≤ 6			■
Probability of SIS fault ($0 \leq P_{sat} \leq 1$)					
P_{sat}		≤ 3E-5			■
Probability of Constellation fault ($0 \leq P_{const} \leq 1$)					
P_{const}		≤ 1E-4			■
Ranging Accuracy at 99.9% confidence level, in m					
Global Average	Single Frequency	≤ 10			■■
	Dual Frequency	≤ 10			■
Worst User Location	Single Frequency	≤ 20			■■
	Dual Frequency	≤ 20			■
■■	(Single Frequency): E1 | E5a	■	(Dual Frequency): E1-E5a		

[4] All introduced by OS-SDD v1.3

2.1 SUMMARY NOTES ABOUT OPEN SERVICE

New issue 1.3 of the [OS-SDD] was published in November 2023 and entered in force for the reporting of Galileo Open Service as of December 2023. For the commodity of the reader, the changes introduced re-called briefly in what follows.

1) On already existing MPLs:

- Availability of GGTO Determination has a target now set at 95% (was previously 80%)

2) New MPLs have been introduced, most of them aiming to support Galileo Aviation Users:

- UTC Time Determination Accuracy: ≤ **30 ns** [5].
- URA parameter for single-frequency SIS E1, E5a and dual-frequency combination E1-E5a: σ_{URA} (SF) ≤ **7.5 m**, σ_{URA} (DF) ≤ **6 m** [6].
- Probability of SIS fault (P_{sat}): P_{sat} ≤ **3E-5** [7] that users are not warned, if SISE > 4.17 × Galileo σ_{URA} .
- Probability of Constellation fault (P_{const}): P_{const} ≤ **3E-5** [8] that users are not warned, if SISE > 4.17 × Galileo σ_{URA} , for 2 or more space vehicles.
- Ranging Accuracy at 99.9% confidence level (single-frequency E1, E5a, and dual-frequency E1-E5a): as global average (Average User Location, AUL): ≤ **10 m** [9] and for Worst User Location (WUL): ≤ **20 m** [9].
- Ranging Rate Accuracy: ≤ **5 mm/s** (SF, DF) [10].
- Positioning Accuracy as Global Average (Average User Location, AUL): HPE ≤ **5 m**, VPE ≤ **8 m** (SF, DF) [11] and for Worst User Location (WUL): HPE ≤ **10 m**, VPE ≤ **16 m** (SF, DF) [12].
- NAGU timeliness in the case of Service Recovery: ≤ **15 hours** after the event [13].

5 Ref.: [OS-SDD] §3.3.6 (Table 15)
6 Ref.: [OS-SDD] §3.6.11 (Table 26)
7 Ref.: [OS-SDD] §3.6.12 (Table 28)
8 Ref.: [OS-SDD] §3.6.13 (Table 29)
9 Ref.: [OS-SDD] §3.3.2 (Table 11)
10 Ref.: [OS-SDD] §3.3.3 (Table 12)
11 Ref.: [OS-SDD] §3.3.7 (Table 16)
12 Ref.: [OS-SDD] §3.3.7 (Table 17)
13 Ref.: [OS-SDD] §3.7.1 (Table 30)

The "per-slot" **availability of a healthy signal** is above the MPL threshold of 92%, with averaged monthly values at least equal to **95.96**% for every single-frequency – SF – (E1-B, E5a, E5b) and dual-frequency (DF) combination (E1/E5a, E1/E5b) during the quarter (ref.: Figure 1).

The monthly figures are normalised annually, according to the MPL definition, by a moving average applied over the most recent twelve months and excluding any auxiliary space vehicles, like it is the case of GSAT0224 (E10) and, starting from September, neglecting GSAT0210 (E01), removed from the active constellation until further notice.

The **signal in space ranging accuracy** shows a 95th percentile monthly accuracy between **0.14 m** and **0.38 m** (ref.: Figure 7, Figure 8) for individual space vehicles ("any satellite"), dual-frequency signal combinations [14], while in the range from **0.25 m** and **1.30 m** on single-frequency observables [15] (ref.: Figure 9, Figure 10). Measurements are compliant with the [OS-SDD] MPL, where the threshold is specified as **7 m**, so that performance target appears achieved with significant margin by all satellites of the Galileo constellation. Worst satellite performance is also shown, for dual-frequency (ref.: Figure 5) and single-frequency (ref.: Figure 6).

The evaluation of worst-satellite ranging accuracy, Global Average at 99.9% confidence level, exposes values between **0.23 m** to **1.44 m** for dual-frequency signal combinations, **0.44 m** and **1.69 m** on single-frequency observables. Since December 2023, such ranging accuracy at high confidence level is subject to MPL targets: as Global Average: $\leq$ 10 m (SF[16], DF[17]) and for Worst User Location: $\leq$ 20 m (SF[16], DF[17]). In the case of Worst User Location, values appear between **0.41 m** to **1.42 m** for dual-frequency, and in the range from **0.55 m** and **1.57 m** for single-frequency, over the whole quarter.

More details are provided in the dedicated section 3.2.

The average **ranging accuracy at constellation level** (over "all satellites", ref.: Figure 11) provides values "per signal" that are better than or equal to **0.15 m** for dual-frequency signal combinations and **0.46 m** for single-frequency signals. The results achieved for DF are at least one order of magnitude better than the specified MPL threshold of **2 m**.

Concerning the **UTC time related service**, both **availability of the dissemination** and **availability of determination with a target accuracy** ($\leq$ 31 ns) are characterised (ref.: Figure 12 and Figure 13). In both cases, metrics had a monthly value of 100**%** during the entire quarterly reporting period, while the [OS-SDD] MPL target is **95%** for both.

The **availability of GGTO determination** metric was also **100%** during the whole quarter (ref.: Figure 14): valid GGTO coefficients were always disseminated. The measured values are comfortably above the [OS-SDD] MPL target of **80%**, raised to **95%** in December.

Good values are also achieved for the **UTC time dissemination service accuracy** (ref.: Figure 15), which was $\leq$ **4.3 ns** during the quarter. The **UTC frequency dissemination service accuracy** had offset $\leq \mathbf{8.0 \times 10^{-14}}$ (ref.: Figure 16) and the **GGTO determination accuracy** was better than or equal to **4.1 ns** in the reporting quarter (ref.: Figure 17). We remind that, for those MPLs, targets are respectively **30 ns**, $\mathbf{3 \times 10^{-13}}$ and **20 ns**, thus they are all met.

The [OS-SDD] includes commitments related to a full **3D positioning service** that are consistent with the achieved deployment status of the Galileo constellation.

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[14] Ranging signal combinations E1/E5a, E1/E5b.

[15] Ranging signals E1, E5a, E5b.

[16] Ranging signals E1, E5a, as per OS-SDD v1.3

[17] Ranging signal combination E1/E5a, as per OS-SDD v1.3

Regarding the **availability of PDOP ≤ 6**, the [OS-SDD] foresees a MPL target for the Average User Location (AUL) equal to **90%**, and **87%** for the case of Worst User Location (WUL). At AUL (ref.: Figure 18), the availability was at least **99.51%**, while at WUL (ref.: Figure 19), figure was better than or equal to **98.70%**.

Previous values have been computed without accounting for any auxiliary satellite. The additional contribution provided by the auxiliary satellite GSAT0224 (E10) is also given for information (ref.: Figure 20).

Under the conditions that HPE ≤ 7.5 m and VPE ≤ 15 m (95% confidence level), the **availability of positioning** figures for any single-frequency SIS or dual-frequency combination at AUL (ref.: Figure 21) and at WUL (ref.: Figure 22) are as follows, being computed without accounting for any auxiliary satellite:

- in October: **99.75%** (DF) and **99.53%** (SF) at WUL; **99.97%** (DF) and **99.91%** (SF) at AUL
- in November: **99.71%** (DF) and **99.35%** (SF) at WUL; **99.95%** (DF) and **99.85%** (SF) at AUL
- in December: **99.83%** (DF) and **99.46%** (SF) at WUL; **99.97%** (DF) and **99.90%** (SF) at AUL

The target MPL values specified by the [OS-SDD] are **87%** at WUL and **90%** at AUL, respectively; these targets are plainly met with large margin.

The contribution provided by the auxiliary satellite GSAT0224 (E10) is given as well, again for information (ref.: Figure 23).

The availability figures are complemented with measured "Galileo-only" 3D positioning performance, attainable when PDOP ≤ 6. These metrics are not currently subject to an MPL target, but are reported because of their relevance, being obtained by processing data from a network of reference receivers (ref.: from Figure 24 up to Figure 29).

For dual-frequency combinations (E1/E5a and E1/E5b), the 95th percentile confidence level of **Horizontal and Vertical 3D Positioning Errors** (HPE and VPE, correspondingly) did not exceed **1.90 m** and **3.35 m** during the whole quarter. The corresponding root mean square (RMS) values, which are also not subject to an MPL assessment, are within respectively **1.28 m** and **2.29 m**.

The new [OS-SDD] in force, applicable since December 2023, foresees the evaluation of 3D Positioning Accuracy accounting (only) from contributions from Galileo System, neglecting RF propagation effects and user equipment error contributions. This is to be evaluated for Average User Location (AUL) and for Worst User Location (WUL). Achieved figures are as follows; please consider that in the case of October and November they are provided for info, being not subject to MPL:

- in October:
  - at AUL: HPE≤ **0.47 m**, VPE≤ **0.82 m** (DF); HPE≤ **0.79 m**, VPE≤ **1.42 m** (SF)
  - at WUL: HPE≤ **0.61 m**, VPE≤ **1.01 m** (DF); HPE≤ **1.00 m**, VPE≤ **1.66 m** (SF)
- in November:
  - at AUL: HPE≤ **0.49 m**, VPE≤ **0.87 m** (DF); HPE≤ **0.94 m**, VPE≤ **1.74 m** (SF)
  - at WUL: HPE≤ **0.63 m**, VPE≤ **1.10 m** (DF); HPE≤ **1.20 m**, VPE≤ **2.09 m** (SF)
- in December:
  - at AUL: HPE≤ **0.50 m**, VPE≤ **0.87 m** (DF); HPE≤ **0.92 m**, VPE≤ **1.69 m** (SF)

    (MPL Targets: **5** m for HPE, **8** m for VPE are comfortably met)
  - at WUL: HPE≤ **0.64 m**, VPE≤ **1.15 m** (DF); HPE≤ **1.18 m**, VPE≤ **2.03 m** (SF)

    (MPL Targets: **10** m for HPE, **16** m for VPE are comfortably met)

Concerning P_{sat} , values for December are: **2.7E-6** for DF and **3.2E-6** for SF, one order of magnitude below the MPL target 3E-5. About P_{const} in December we get: **7.1E-5** for both DF SF, again one order of magnitude below the MPL target 1E-4.

UTC Time Determination Accuracy in December was better that 7.1 ns, thus well below the MPL target of 30 ns applicable since that month; furthermore, we got:

- σ_{URA} (E1) $\leq$ **0.86 m**, σ_{URA} (E5a) $\leq$ **1.90 m**, thus below the MPL threshold of 7.5 m
- σ_{URA} (E1-E5a) $\leq$ **0.96 m**, while MPL threshold is of 6 m.

Regarding the **publication of NAGUs**, **4 NAGUs** pertaining with OS have been issued in the reporting period, in all cases respecting the requirements for their timeliness. According to the [OS-SDD], the minimum time for publishing a NAGU before the start of a scheduled event is **48 hours** (two days), and **30 hours** (1.25 days) after the occurrence of an unscheduled one. Most recent [OS-SDD] in force, applicable since December 2023, foresees **15 hours** (0.625 days) of maximum delay in the notification of unplanned NAGUs related to service recovery.

The Additional details about NAGU timeliness are presented in chapter 6.

3 OPEN SERVICE RANGING PERFORMANCE

In this section of the report, the following performance figures for the Galileo Open Service are provided:

- Per-slot Availability of HEALTHY Signal in Space: annually normalised MPL (ref.: Figure 1), as well as monthly average (ref.: Figure 2) and monthly values for individual space vehicles (ref.: Figure 3) which are provided for info, having no MPL target assigned;
- Galileo Signal in Space Ranging Accuracy: MPL at 95% confidence level for "any satellite" (ref.: Figure 7, Figure 8, Figure 9, Figure 10), and metric at 99.9% confidence level, the latter delivered for info, being not subject to a target (ref.: Figure 5, Figure 6, where it is compared with the MPL at 95%). Furthermore, MPL at 95% confidence level over "all satellites" (ref: Figure 11), as constellation average per single-frequency signal and dual-frequency combination.

3.1 PER-SLOT AVAILABILITY OF HEALTHY SIGNAL IN SPACE

The "availability of healthy signal in space" is defined, for each Galileo operational satellite in a nominal slot, as the percentage of time that the specific satellite broadcasts Galileo Open Service Signals in Space (SIS) that are considered "healthy". The SIS status is derived according to [OS-SDD] rules, regarding the configuration of specific L-band SIS status flags and the validity period of Navigation messages.

Figure 1 provides the SIS "per slot" availability of Galileo healthy signals in space, averaged over the entire constellation during the reporting period and normalised annually.[18] The [OS-SDD] MPL specifies **92%** [19] as the target value for this constellation metric. The achieved performance is between **95.90%** (single-frequency E5a and dual frequency E1-E5a in October) and **96.89%** (single-frequency SIS E1-B, E5b and dual-frequency combination E1-E5b in December).

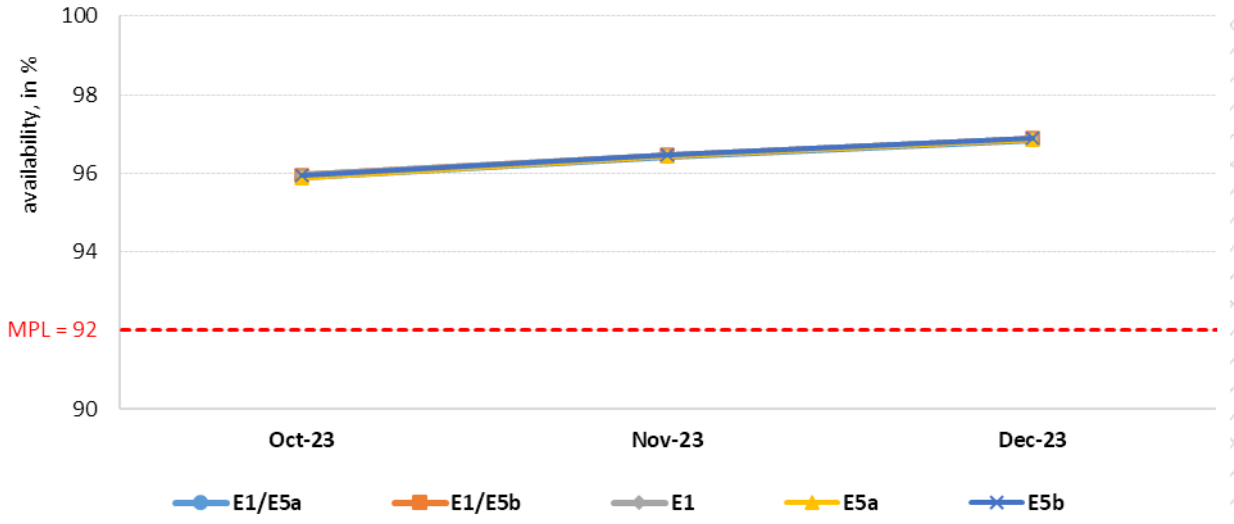

Figure 1: "per slot" availability of healthy signal in space for the reporting period (annually normalised)

[18] The [OS-SDD] foresees an "annual normalisation", which is implemented with a moving average over twelve months. Monthly figures consider only those space vehicles that are declared active members of the constellation during the whole month.

[19] Ref.: [OS-SDD] §3.4.1 (Table 18)

Figure 2 provides the SIS "per slot" availability of Galileo healthy signals in space, averaged over the entire constellation during each month, but not normalised; as such, this performance measure is not subject to an MPL target and is provided for info:

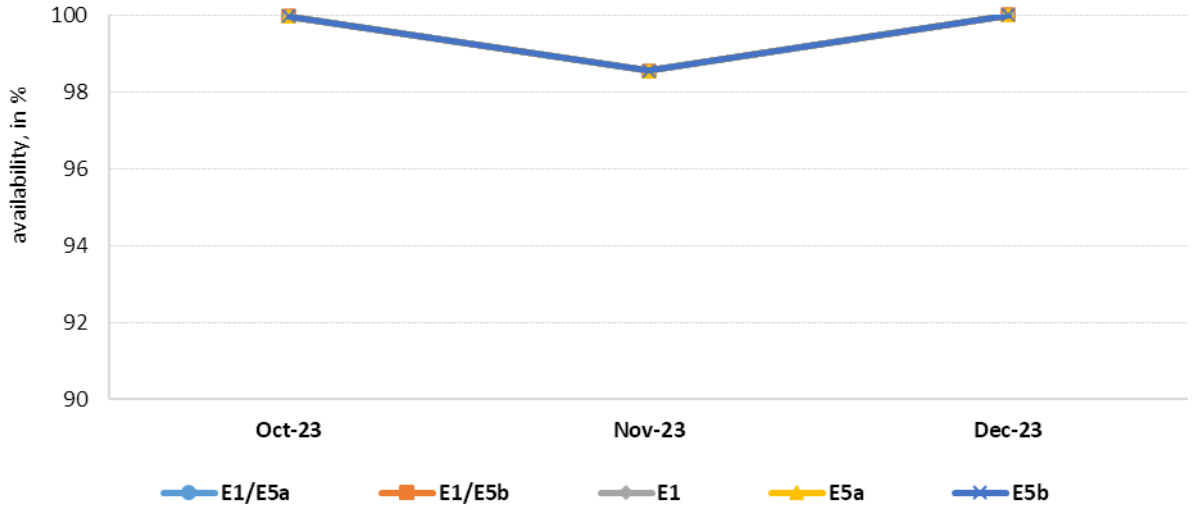

Figure 2: "per slot" availability of healthy signal in space for the reporting period, not normalised (monthly values)

The availability of Galileo healthy SIS, evaluated individually per frequency combination, satellite and month (without any averaging/normalisation), again not subject to an MPL target, is shown in Figure 3.

During the quarter, such availability was quite high, even if (by referring only to satellites occupying nominal orbit slots), such availability never achieved 100% for all space vehicles. However, please note that:

- only planned events affected healthy SIS status, over the whole quarter
- in October, maximum duration of individual (planned) outages did not trespass 40 minutes
- in November, exception made for GSAT0214 (E05), which was subject to an orbit correction operation causing service unavailability over XX days, for the rest of the constellation (planned) outages did not last more than 50 minutes
- in December, availability of healthy SIS achieved 100% for all space vehicles, exception made for GSAT0213 (E04), subject to (planned) on-board maintenance over 55 minutes.

General NAGU 2022050 issued in September warned users about the forthcoming update of the on board S/W of multiple Galileo space vehicles, according to the published Galileo Service Note [SvNOTE #11].

We can comment Figure 3, providing explanation for most relevant cases (healthy SIS availability lower than 90%):

October — The following space vehicles were subject to short on-board maintenance operations: GSAT0212 (**E03**), GSAT0214 (**E05**), GSAT0207 (**E07**), GSAT0208 (**E08**), GSAT0220 (**E13**), GSAT0215 (**E21**), GSAT0216 (**E25**), GSAT0218 (**E31**), GSAT0222 (**E33**)

November — The following space vehicles were subject to short on-board maintenance operations: GSAT0221 (**E15**), GSAT0215 (**E21**), GSAT0216 (**E25**), GSAT0217 (**E27**), GSAT0218 (**E31**)

GSAT0214 (**E05**) underwent an orbit correction having long duration (9.55 days), as per NAGUs 2023054, 2023055

December — GSAT0213 (**E04**) was subject to a short on-board maintenance, as per NAGUs 2023056, 2023057, having short duration (55 minutes).

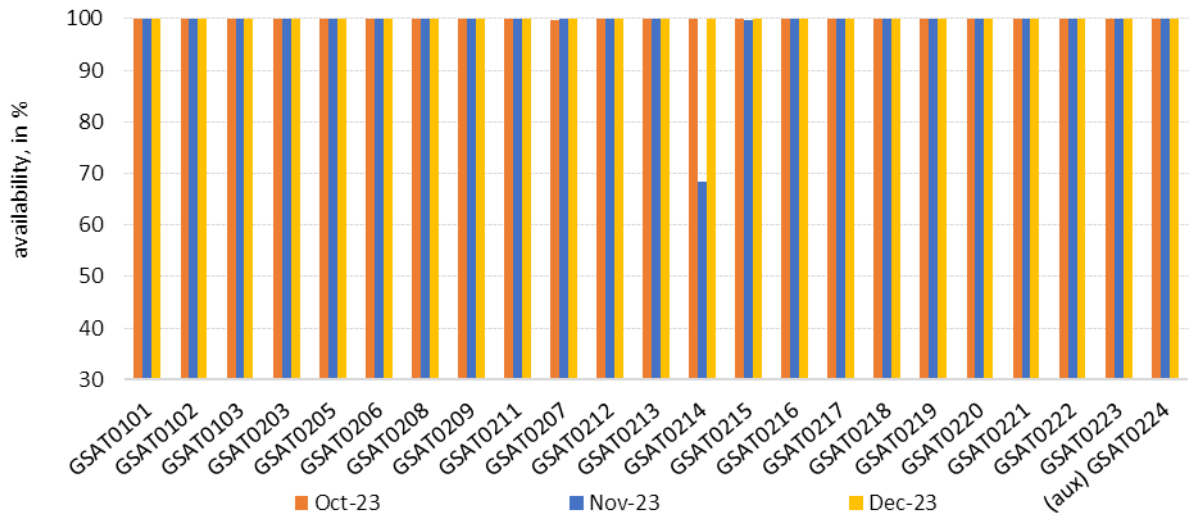

Figure 3: “per satellite” worst-case signal in space availability of healthy signal in space for the reporting period

Figure 4 provides the monthly percentage of availability of "N" space vehicles simultaneously transmitting a healthy SIS, with age of ephemeris less than or equal to four hours. Auxiliary satellites are included, in the case that they are declared available for service provision.

Please note that, in all cases, the unavailability of healthy SIS depended only on planned operations, as previously explained, and complemented by NAGUs in section 6. As far as GSAT0210 (E01) was already excluded from the active constellation providing Navigation Services, a healthy SIS could be granted only up to 23 space vehicles, including the auxiliary ones declared usable.

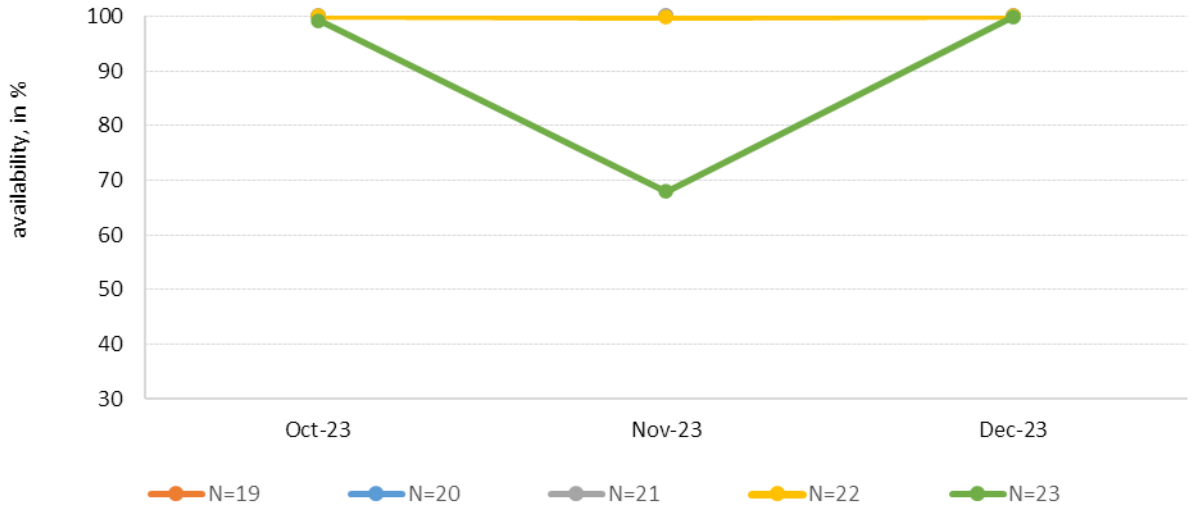

Figure 4: monthly percentage of availability of "N" space vehicles transmitting a healthy signal in space

3.2 GALILEO SIGNAL IN SPACE RANGING ACCURACY

The Galileo Signal In Space Error (SISE) vector provides the instantaneous difference between the Galileo satellite position/clock offset as obtained from the broadcast Navigation message, and the "true" satellite position/clock offset.

The true orbit path and clock performance are precisely reconstructed using sophisticated tools. When projecting SISE to the user location, the obtained scalar value is also named ranging accuracy and represents the ranging error affecting a user receiver.

The following figures show the 95th percentile of the monthly global average of the instantaneous ranging accuracy, achieved for each Galileo operational satellite and single-/dual-frequency combinations. Projection of SISE is implemented at the nodes of a virtual grid, representing all user locations within the navigation service coverage area.

Any signals carrying navigation message information with age of time of ephemeris beyond the validity period of four hours are filtered out, as per [OS-SDD] and explained in section 5.3.

Figure 7, Figure 8, Figure 9, Figure 10 show the monthly 95% confidence level metric for Galileo signal in space ranging accuracy (for average user location, AUL), to be compared against the MPL target levels. Computation is applied "for any space vehicle", over all satellites [20] and frequency combinations [21], achieving the following results:

October (for individual space vehicles) worst case values were of **0.35** m for dual-frequency and **1.13** m for single-frequency. The best-case values over the month are **0.14** m and **0.28** m, respectively.

November worst case values were of **0.34** m for dual-frequency and **1.30** m for single-frequency. The best-case values over the month are **0.14** m and **0.32** m, respectively.

December worst case values were of **0.38** m for dual-frequency and **1.00** m for single-frequency. The best-case values over the month are **0.14** m and **0.25** m, respectively.

In order to achieve a better view of Galileo ranging performance, Figure 6 provides the worst-case ranging accuracy values at AUL for both 95% confidence level (target level: **7** m [22]) and 99.9% confidence level (target level: **10** m [23]), the latter being subject to target since December 2023 (as per [OS-SDD] MPL), while given for information only in the previous months.

Note that the [OS-SDD] in force also presents MPL targets for ranging accuracy at worst user location (WUL), applicable since December 2023, when worst case values at WUL were of **1.55** m for dual-frequency and **1.60** m for single-frequency. The best-case values at WUL over the month are **0.34** m and **0.55** m, respectively. Compliance with MPL target level of **20** m [23] is ensured.

Please note, that ranging accuracy MPL at high confidence level of 99.9% is applicable single-frequency E1, E5a, and Dual-Frequency E1-E5a.

During the quarter, in particular referring to November, a slight degradation of ranging accuracy for single-frequency is observed, affecting multiple space vehicles. This was due to the solar activity, determining a worsening in the quality of Broadcast Group Delays (BGDs).

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[20] Satellites in nominal slots plus auxiliary satellites.

[21] Graphics provide worst-case among all SIS (for single-frequency) or between E1-E5a / E1-E5b for dual-frequency combinations.

[22] Ref.: [OS-SDD] §3.3.1 (Table 9)

[23] Ref.: [OS-SDD] §3.3.2 (Table 11)

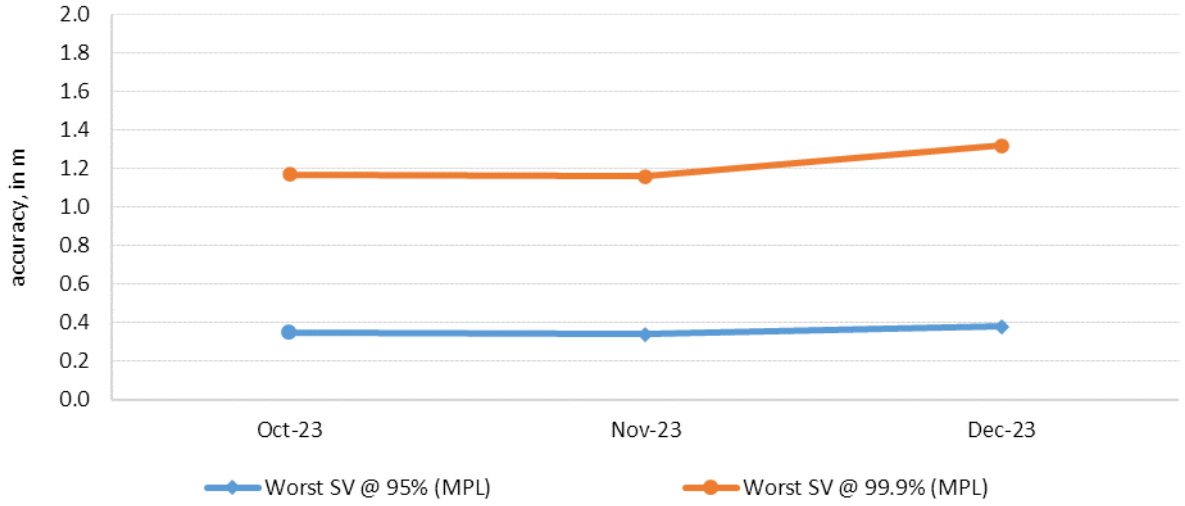


Figure 5: worst-case, monthly Galileo signal in space ranging accuracy (at 95th and 99.9th confidence level percentiles) for any satellite and any signal in space (dual frequency)

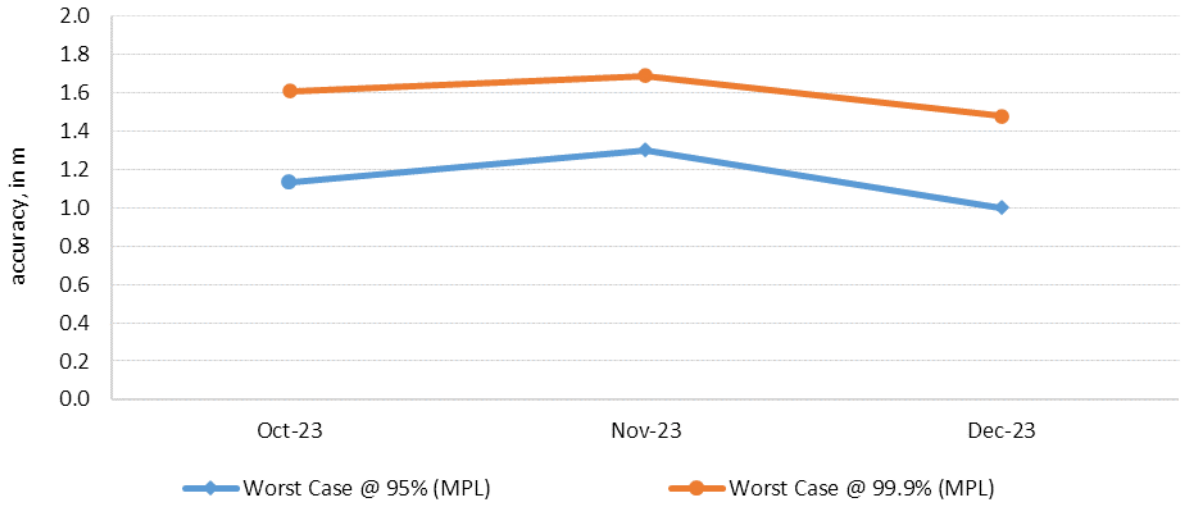


Figure 6: worst-case, monthly Galileo signal in space ranging accuracy (at 95th and 99.9th confidence level percentiles) for any satellite and any signal in space (single frequency)

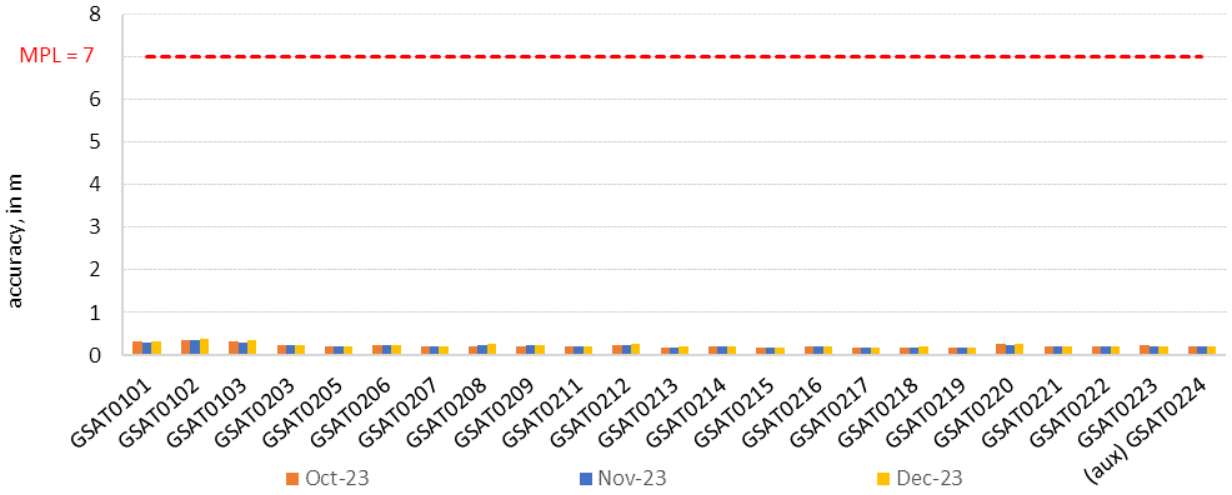


Figure 7: monthly Galileo signal in space ranging accuracy (95th percentile) for any satellite, measured during reporting period for dual frequency against MPL (minimum performance level)

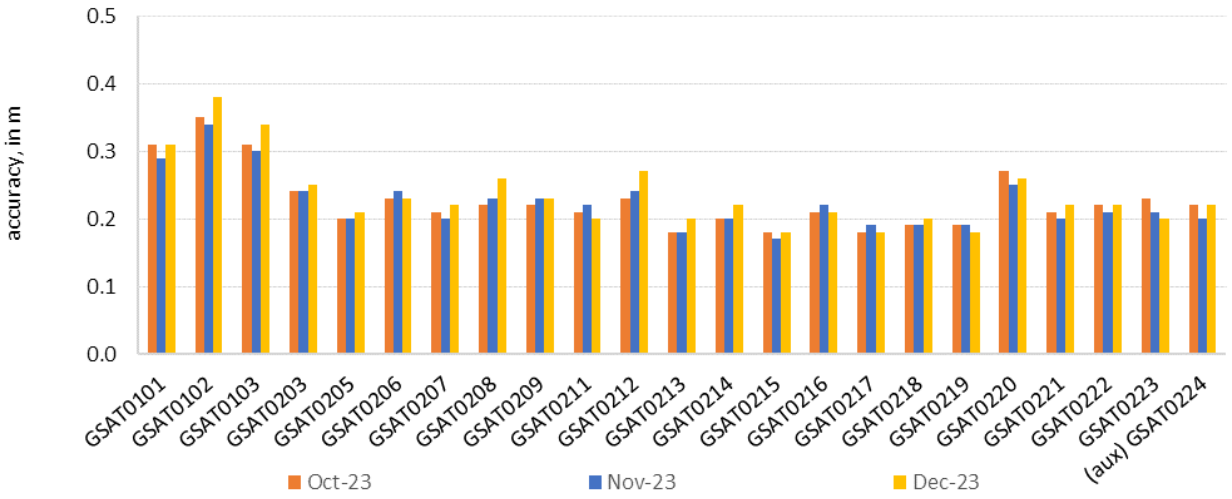


Figure 8: monthly Galileo signal in space ranging accuracy (95th percentile) for any satellite, measured during reporting period for dual frequency – zoom in

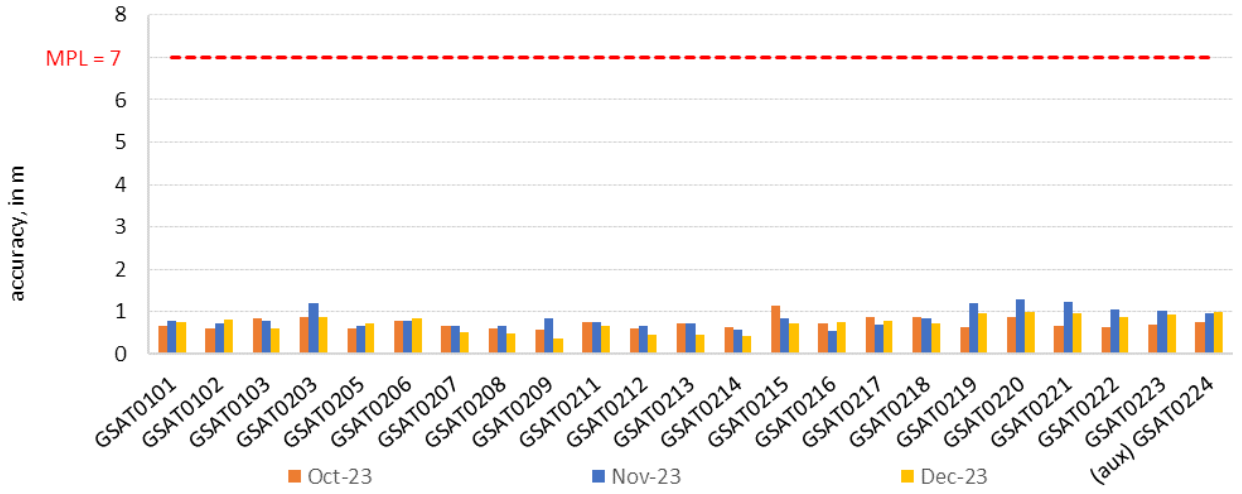


Figure 9: monthly Galileo signal in space ranging accuracy (95th percentile) for any satellite, measured during reporting period for single frequency against MPL (minimum performance level)

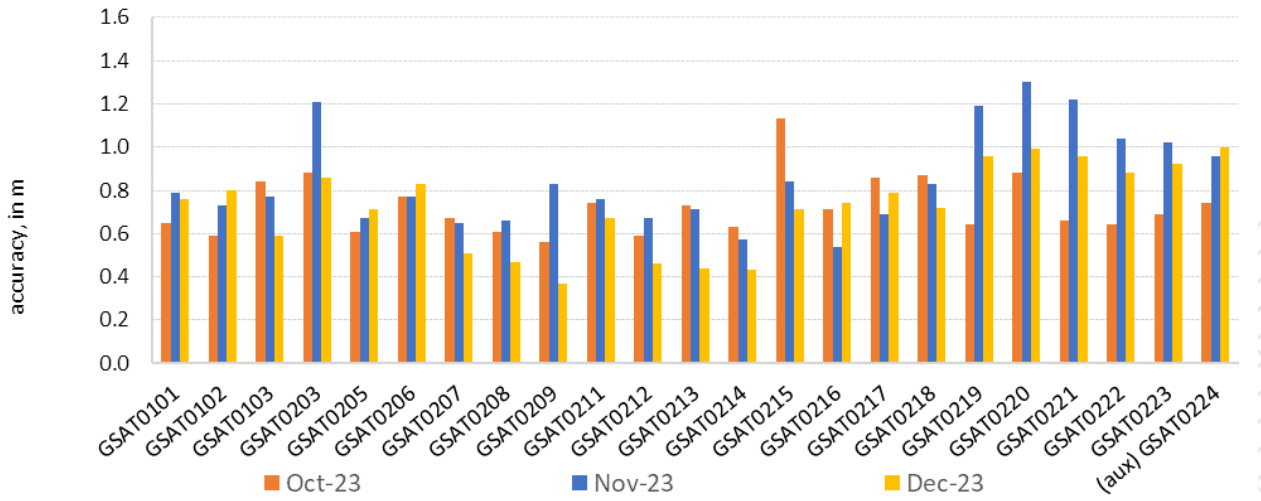


Figure 10: monthly Galileo signal in space ranging accuracy (95th percentile) for any satellite, measured during reporting period single frequency – zoom in

Compliance with the MPL in [OS-SDD], referring to 95% confidence level, is achieved in all cases, with a specified maximum threshold of **7 m** [24] for the monthly performance of each individual satellite.

[24] Ref.: [OS-SDD] §3.3.1 (Table 9)

Figure 11 depicts the average “over all satellites”; according to the MPL definition, separately per each single-frequency and dual frequency combination, this consists of 95% confidence level for the time series constituted by the instantaneous RMS of pertinent ranging accuracy values, operated among all space vehicles. Again, the [OS-SDD] MPL target of **2** m [25] is met by the constellation average value.

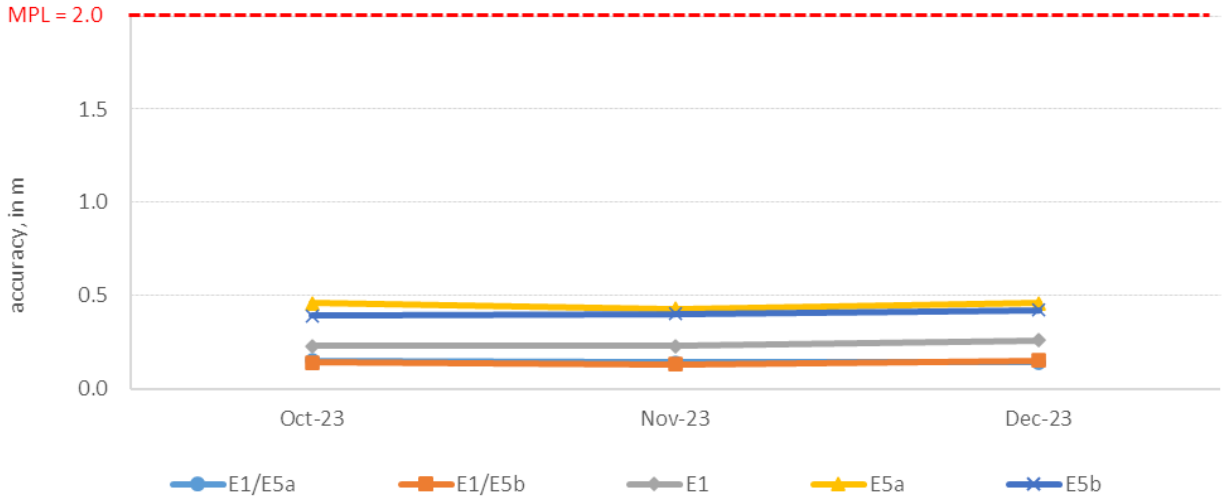


Figure 11: monthly Galileo signal in space ranging accuracy (95th percentile) over all satellites (constellation average), measured during the reporting period

[25] Ref.: [OS-SDD] §3.3.1 (Table 10)

4 UTC AND GGTO DISSEMINATION AND DETERMINATION PERFORMANCE

In this section of the report the following performance figures are provided:

- Availability of the Galileo Time Correlation Parameters and of UTC Determination;
- Accuracy of Galileo Time Correlation Parameters.

4.1 AVAILABILITY OF THE GALILEO TIME CORRELATION PARAMETERS AND OF UTC DETERMINATION

The **availability** of the Galileo Universal Time Coordinated (**UTC**) **time dissemination service** is defined as the percentage of time that the system provides at least one healthy ranging/timing signal in space above a minimum elevation angle of 5 degrees. Figure 12 provides the WUL availability of such service, computed for a virtual grid of user positions over the service coverage area.

As shown (ref.: Figure 12), the monthly (short-term) availability of the Galileo **UTC dissemination service** achieved **100**% of the time during all three months of the reporting period. The MPL target of **95**% [26] prescribed by the [OS-SDD] is therefore fulfilled with the maximum margin.

Regarding the commitment concerning the **availability of UTC time determination service** with the assigned accuracy threshold of 31 ns, results for the observation period (ref.: Figure 13) depict an availability of **100**% during the entire quarter, against a MPL target of **95**% [27], which is then also fully met.

The availability of Galileo to GPS Time Offset (GGTO) determination is the percentage of time that the system provides at least one non-dummy GGTO[28] set of coefficients within the navigation message, acquiring SIS from a space vehicle seen above a minimum elevation angle of five degrees.

The **availability of the GGTO determination** for WUL (ref.: Figure 14) is computed for a virtual grid of user positions over the service coverage area. The MPL of **80%** specified by [OS-SDD] for the monthly performance in September and October, then **95%** [29] from December, is fully achieved.

The GGTO Determination capability was never reduced during the quarter, having an availability of **100**%.

[26] Ref.: [OS-SDD] §3.4.2 (Table 19)
[27] Ref.: [OS-SDD] §3.4.5 (Table 23)
[28] "Dummy" GGTO is defined in [OS-SDD] and in Galileo SIS ICD in terms of "all 1's" appearing in the GGTO parameters binary slot(s) carried by the navigation message.
[29] Ref.: [OS-SDD] §3.5.1.2 (Table 25)

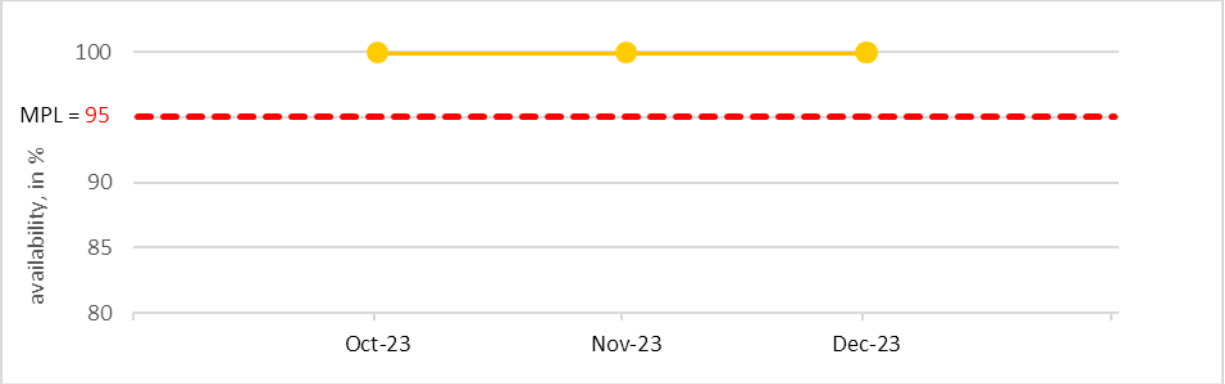


Figure 12: monthly availability of the UTC dissemination service during the reporting period

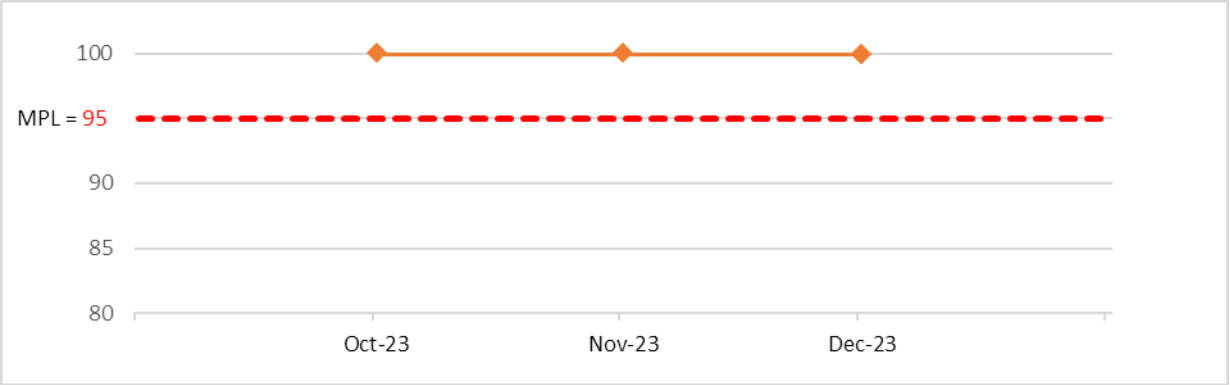


Figure 13: monthly availability of the UTC determination ≤ 31 ns during the reporting period

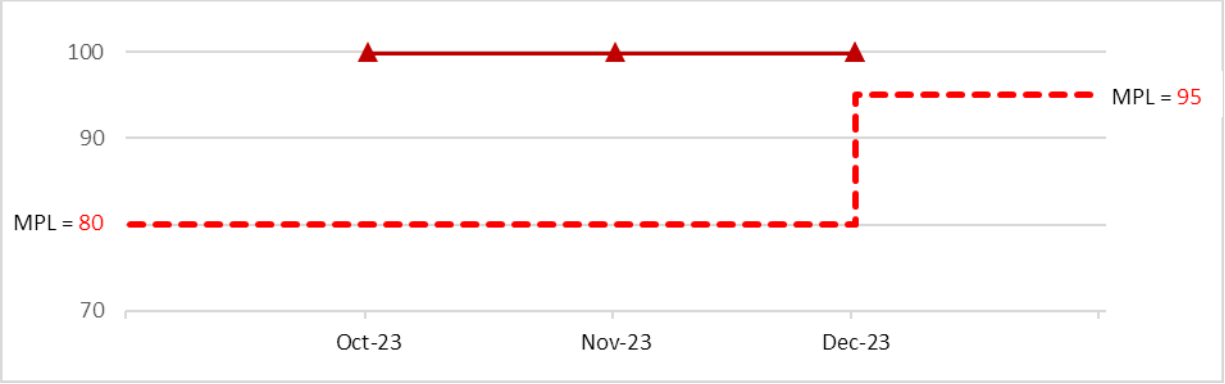


Figure 14: monthly availability of the GGTO determination, during the reporting period

4.2 ACCURACY OF GALILEO TIME CORRELATION PARAMETERS

The Galileo SIS **UTC time dissemination accuracy** (ref.: Figure 15) and the Galileo SIS **UTC Frequency Dissemination Accuracy** (ref.: Figure 16) are computed as the daily average error of the normalised time and frequency offset relative to UTC, for a user equipped with a standard timing/calibration laboratory receiver [30].

We remind that measured MPL values are not any longer annually averaged.

Figure 15 shows the 95th percentile of the daily average of the UTC dissemination accuracy, observed over each period of one month.

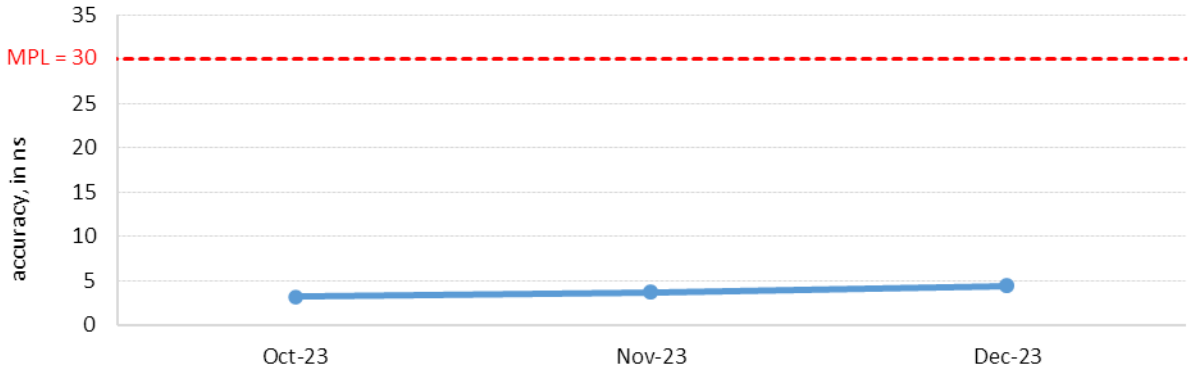


Figure 15: monthly UTC time dissemination accuracy (95th percentile) during the reporting period

As seen in Figure 15, the UTC dissemination accuracy achieves a very good performance level, being ≤ **4.32** ns. All figures are well below the [OS-SDD] MPL specification of **30** ns [31] .

Figure 16 shows the 95th percentile of the UTC frequency dissemination accuracy, also in this case computed accumulating measurement data over a single month.

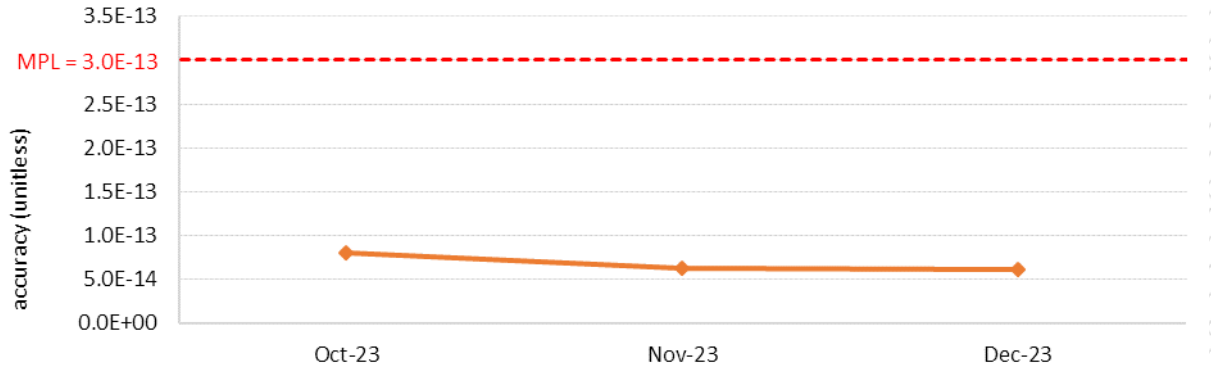


Figure 16: monthly UTC frequency dissemination accuracy (95th percentile) during the reporting period

[30] Note that the final UTC determination accuracy experienced by the user will also be affected by ranging errors, on top of the committed UTC dissemination accuracy.

[31] Ref.: [OS-SDD] §3.3.3 (Table 13)

Regarding the UTC frequency dissemination accuracy, Figure 16 shows that the measured 95th percentile value is ≤ **8.0E–14**, which is significantly better than the [OS-SDD] MPL normalised annual ceiling of **3.0E–13** [32].

The **GGTO determination accuracy** is computed as the daily average of the difference between the GST-GPS time offset computed using the Galileo navigation message and the true GST-GPS time offset. Figure 17 shows the 95th percentile of the daily average of the GGTO determination accuracy, also again not any longer normalised annually [33]. The measured values were quite good, being ≤ **4.1** ns. Figures are much lower than the [OS-SDD] MPL threshold of **20** ns [33].

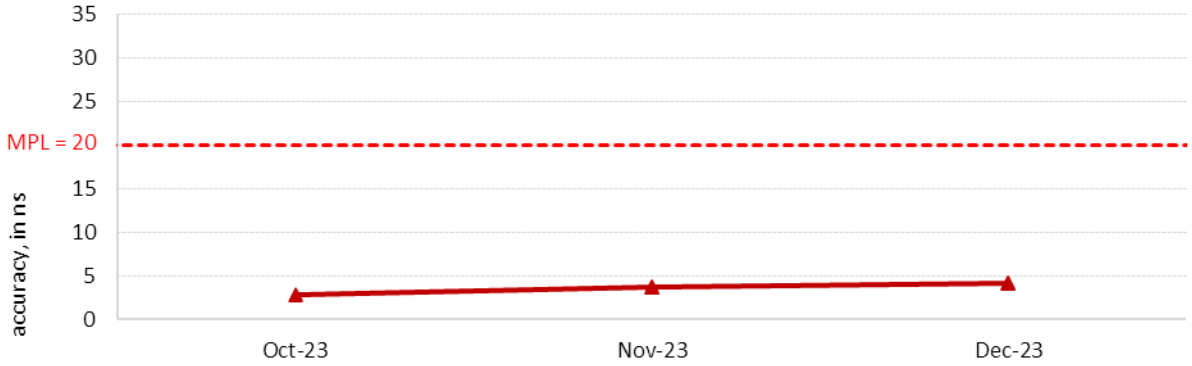


Figure 17: monthly GGTO determination accuracy (95th percentile) during the reporting period

The latest version of [OS-SDD] in force since December 2023 introduced an additional MPL, consisting of UTC determination accuracy, which includes both the UTC dissemination error and the incorrectness in the determination of GST induced by the uncompensated ranging errors accountable to Galileo System.

This MPL has a threshold of **30 ns** [34], while performance in December equalled **7.1 ns**, significantly better than the assigned target, given the good values of both the components mentioned before.

[32] Ref.: [OS-SDD] §3.3.5 (Table 14)
[33] Ref.: [OS-SDD] §3.5.1.2 (Table 19)
[34] Ref.: [OS-SDD] §3.3.6 (Table 15)

5 GALILEO POSITIONING PERFORMANCE

In this section of the report, the following performance figures are provided:

- Availability of the Galileo Position Dilution of Precision;
- Availability of the Galileo Positioning Service;
- Galileo measured Positioning Performance.

These MPL parameters are reported considering only satellites in nominal slots; however, the improvement due to the usability of auxiliary space vehicles is also presented.

5.1 AVAILABILITY OF THE GALILEO POSITION DILUTION OF PRECISION

The applicable [OS-SDD] defines MPLs on the **availability of a (3D) PDOP** (Position Dilution of Precision) less than or equal to **six**. The target for AUL is **90**% [35], while the target for WUL is set to **87**% [35].

Results are presented in Figure 18 and Figure 19, distinguishing between the cases of SIS carrying I/NAV or F/NAV messages.

With values all greater than or equal to **96.71**%, the target is met for the AUL, and exceeded with significant margin for the WUL as well.

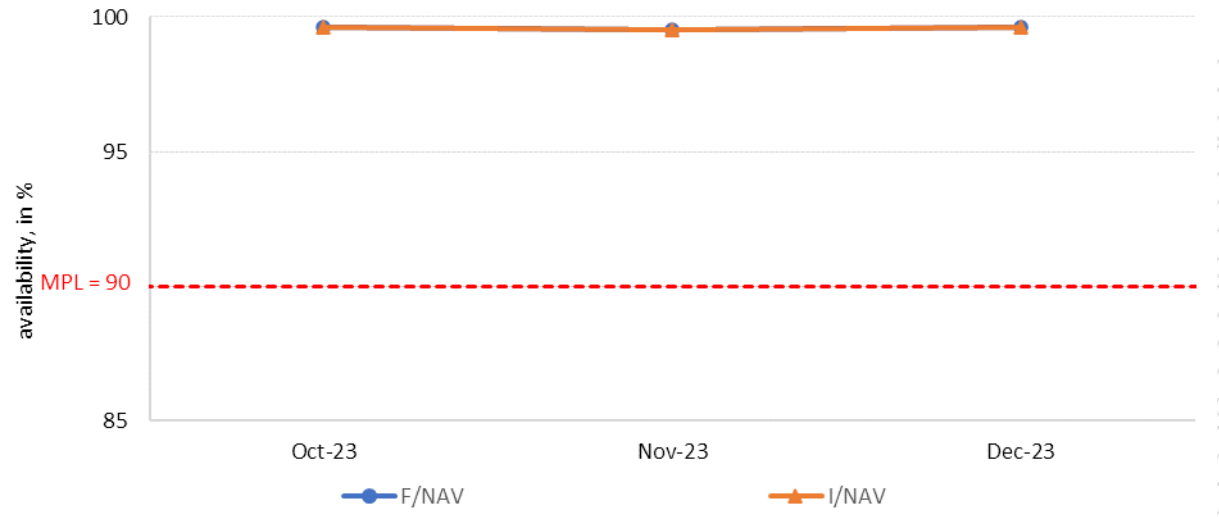


Figure 18: monthly availability of PDOP ≤ 6 at Average User Location (AUL) with F/NAV and I/NAV during the reporting period

[35] Ref.: [OS-SDD] §3.4.3 (Table 20)

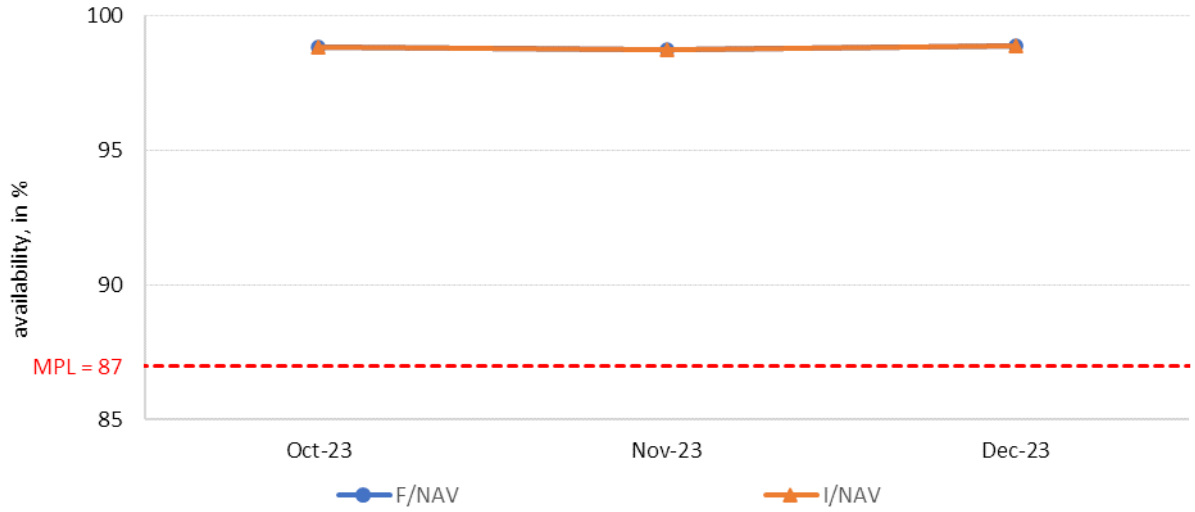


Figure 19: monthly availability of PDOP ≤ 6 at Worst User Location (WUL) with F/NAV and I/NAV during the reporting period

The usability of the auxiliary satellite GSAT0224 (E10) determines an increase in the availability percentages for PDOP ≤ 6, especially at the Worst User Location (WUL). The following Figure 20 depicts the achieved increments during the reporting quarter.

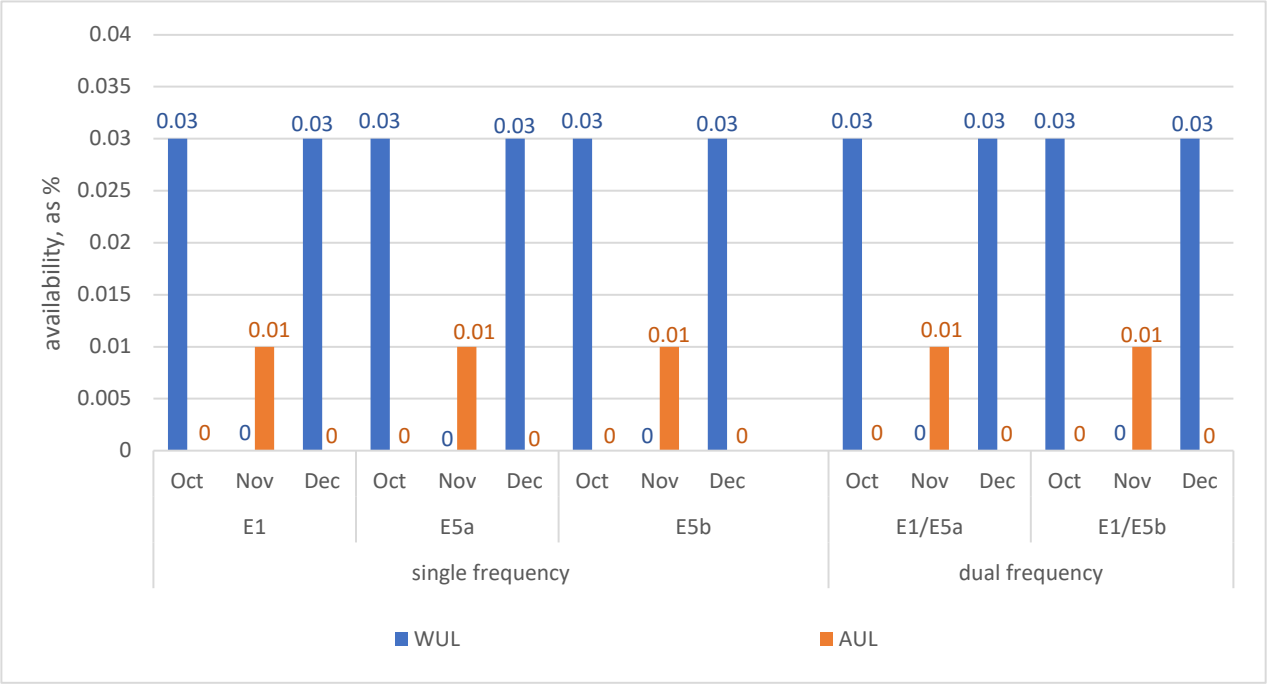


Figure 20: monthly availability of PDOP ≤ 6 – increment due to auxiliary satellite(s)

5.2 AVAILABILITY OF THE GALILEO POSITIONING SERVICE

The [OS-SDD] defines the **availability of positioning**, under the condition that location error due to system contribution is required to be not worse than **7.5** m for the horizontal positioning error (HPE), and not worse than **15** m for the vertical positioning error, evaluated at 95%.

Different targets are assigned: increased to **87**% [36] at WUL, and to **90**% [37] for the AUL.

The achieved results are shown separately for the case of worst single-frequency SIS (E1, E5a, E5b) and of worst dual-frequency combination (E1-E5a, E1-E5b) in the following Figure 21 and Figure 22. The target values are met with large margins, given that figures all greater than or equal to **99.22**%.

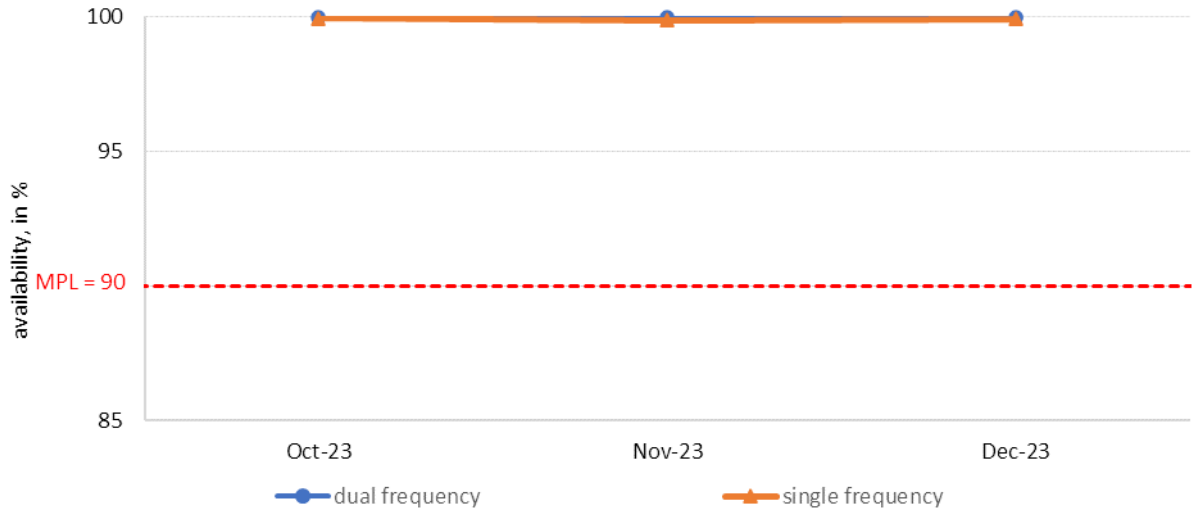


Figure 21: availability of positioning at Average User Location (AUL) for single and dual frequency during the reporting period

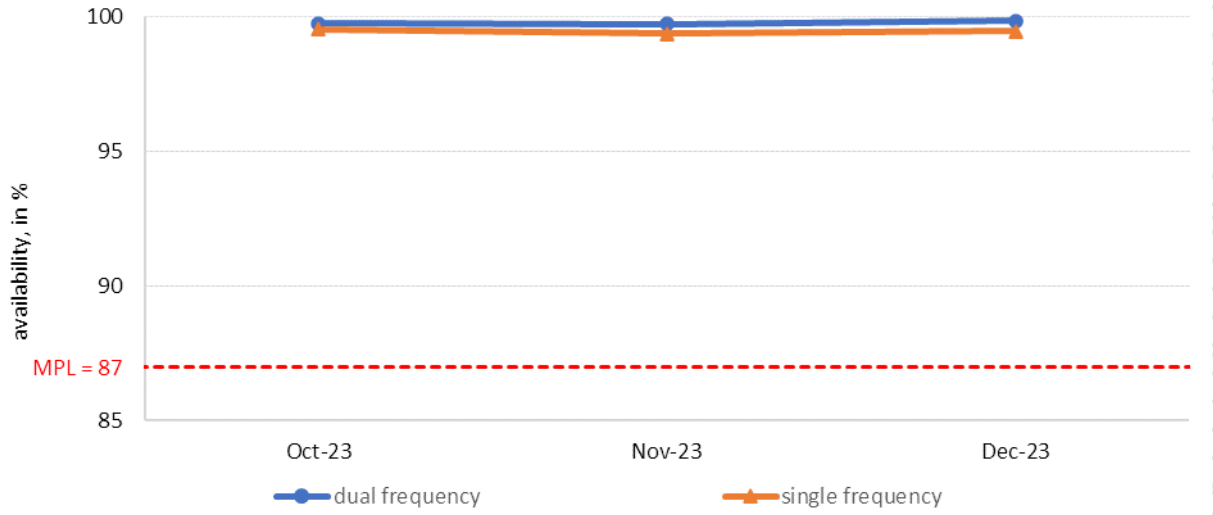


Figure 22: availability of positioning at Worst User Location (WUL) for single and dual frequency during the reporting period

[36] Ref.: [OS-SDD] §3.4.4 (Table 22)
[37] Ref.: [OS-SDD] §3.4.4 (Table 21)

As seen in the case of PDOP, the availability of the auxiliary satellite GSAT0224 (E10) determines a slight increase in the availability percentages for positioning with target thresholds on HPE and VPE, as shown in the following Figure 23.

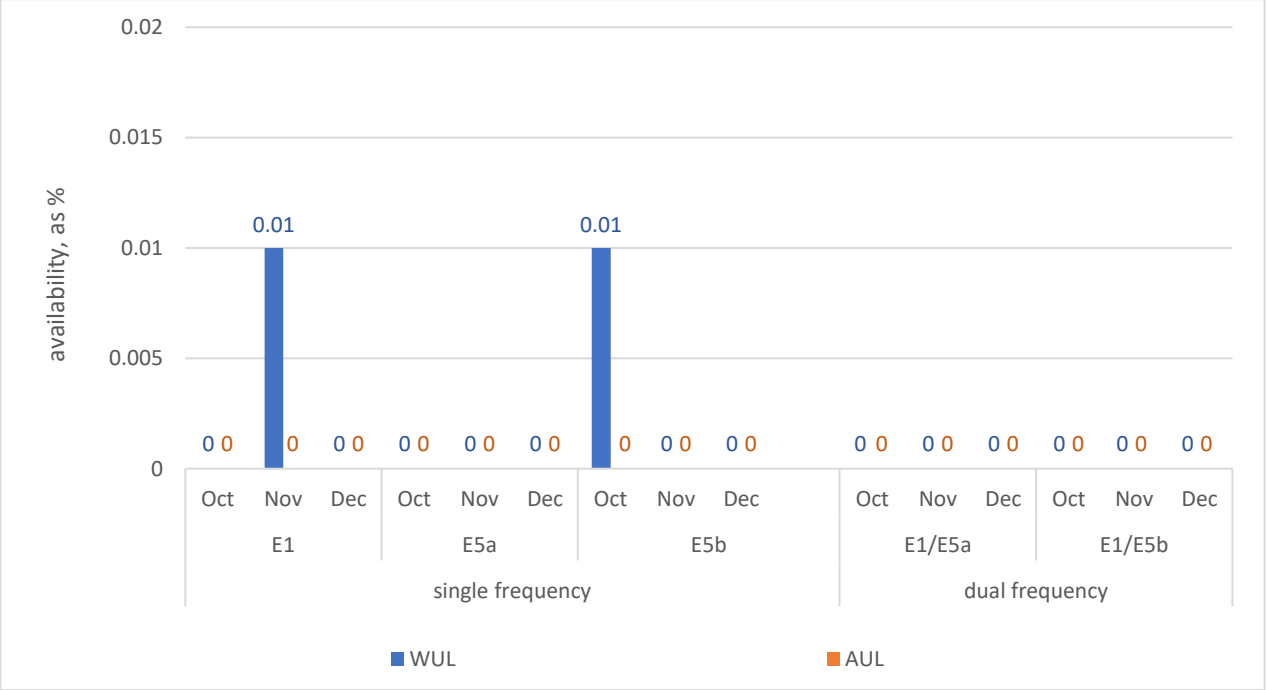


Figure 23: availability of positioning – increment due to auxiliary satellite(s)

5.3 GALILEO MEASURED POSITIONING PERFORMANCE

Although the Galileo Full Operational Capability (FOC) constellation is not yet completely deployed, since August 2019 the 3D positioning service achievable with the Galileo system is subject to a commitment regarding the availability for given positioning accuracy targets, as reported in the previous section 5.2.

In addition, this section provides navigation sensor error estimates for a full (3D) solution of navigation equations, i.e.: the horizontal and vertical positioning accuracy performance based on real measurements, collected over a number of test receivers, solving for user coordinates with a constraint of PDOP ≤ 6 and following [OS-SDD] recommendations regarding SIS health status and "age of ephemeris" [38].

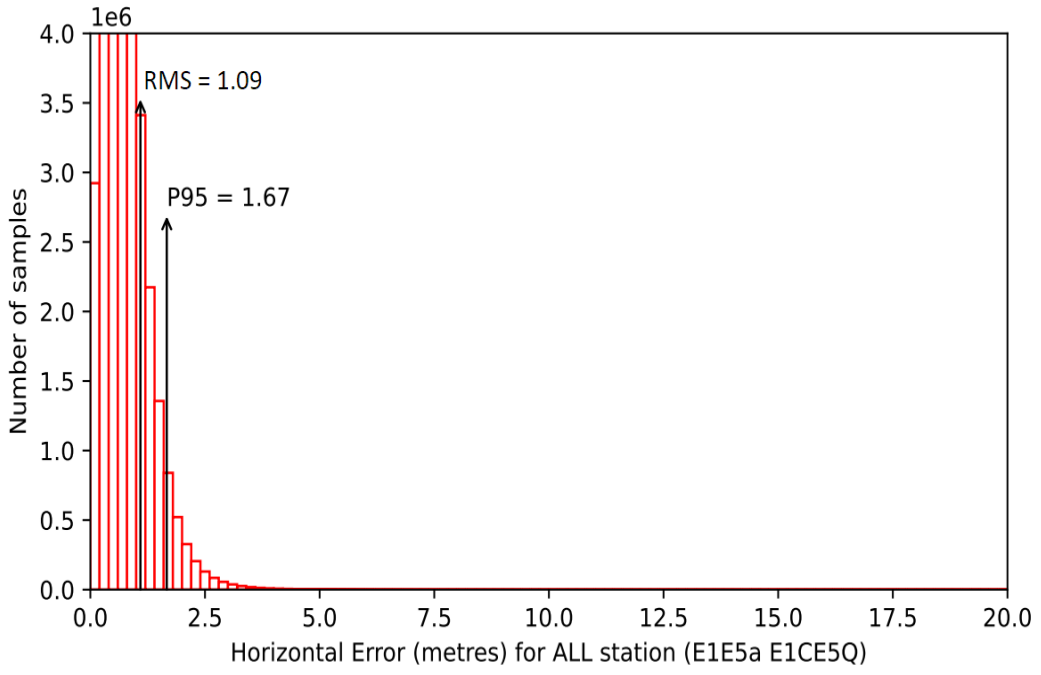
As specified in the [OS-SDD], navigation message coefficients with an "age of ephemeris" beyond four hours are no longer considered valid, so that ranging observables from the corresponding satellite and signal should not be used for positioning and/or time measurement purposes.

Samples affected by local issues, thus not attributable to Galileo SIS, are no longer included in the reported results, based on the adoption of an automatic outlier detection filtering.

In the following figures, the horizontal axis is limited on each plot to a maximum error of 20 metres. Each figure also reports the number of samples exceeding a horizontal or vertical error larger than 20 metres.

Positioning performance is reported considering all satellites declared available for the provision of service, thus demonstrating that auxiliary satellite(s) are not degrading it.

[38] The Time of Ephemeris (toE in the [OS-SDD]), also called ephemeris reference time (t_{0E} in the [SIS-ICD], section 5.1.1.), is disseminated in the navigation message, as part of the precision ephemeris set. The terms "age of ephemeris" mentioned by the [OS-SDD] and "time from ephemeris reference epoch" appearing in the [SIS-ICD] are equivalent.

October 2023	
HPE **3D Positioning** **E1-E5a (DF)** **F/NAV**	
Note: 15969 samples > 20 m, around 0.04% of total	

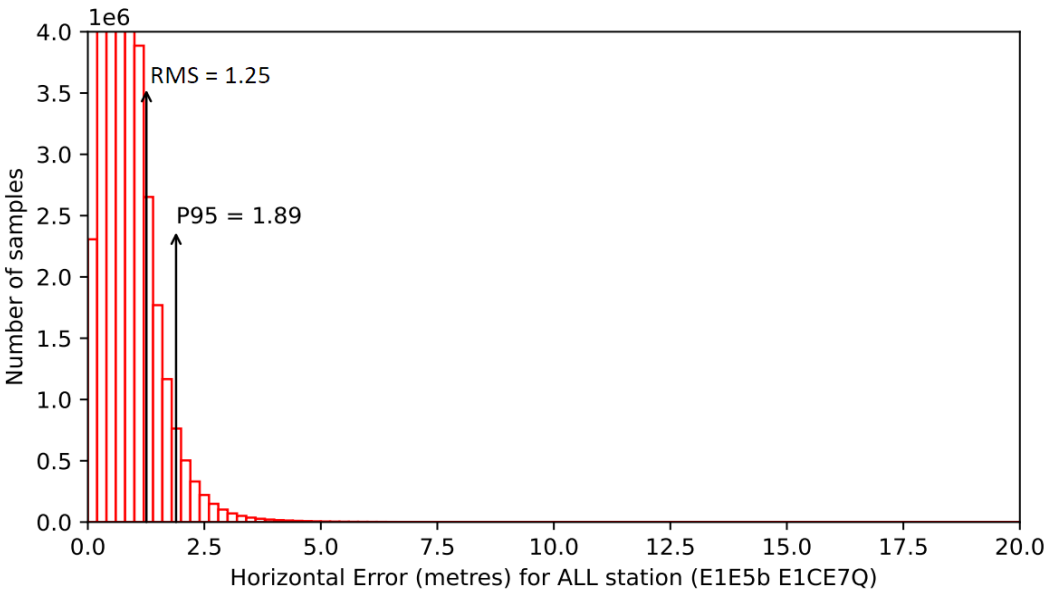
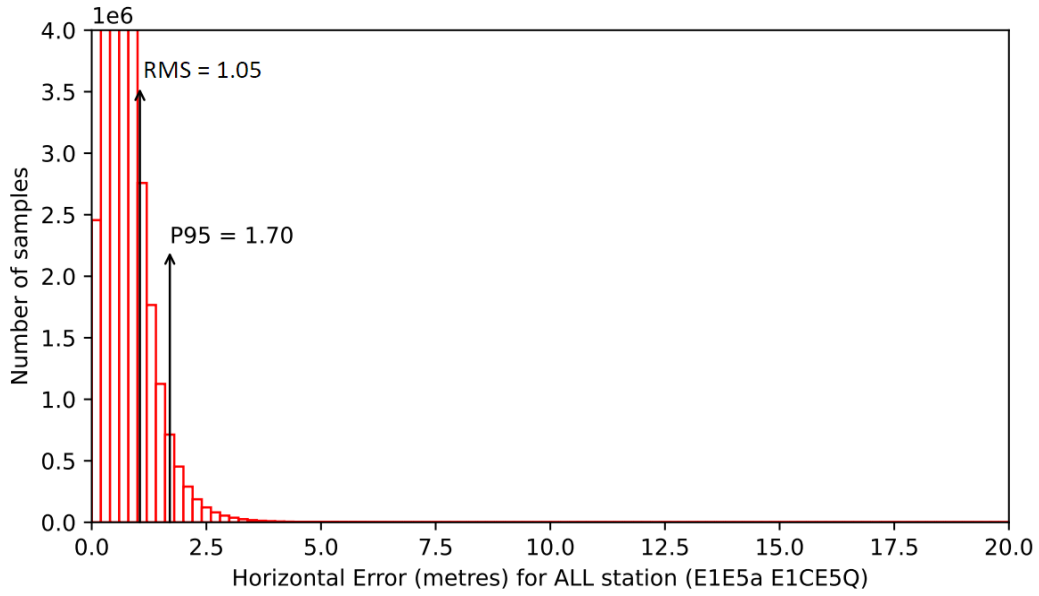
October 2023	
HPE **3D Positioning** **E1-E5b (DF)** **I/NAV**	
Note: 18608 samples > 20 m, around 0.05% of total	

Figure 24: Horizontal Positioning Error (HPE) for "Galileo-only" DF users in October 2023

November 2023	
HPE **3D Position-ing** **E1-E5a (DF)** **F/NAV**	
Note: 8115 samples > 20 m, around 0.02% of total	

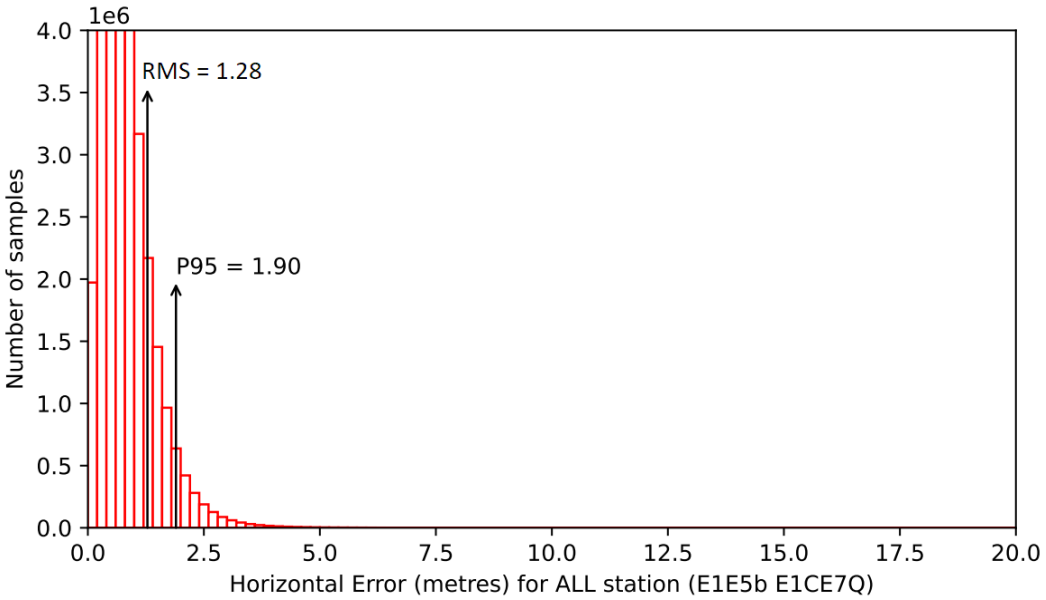
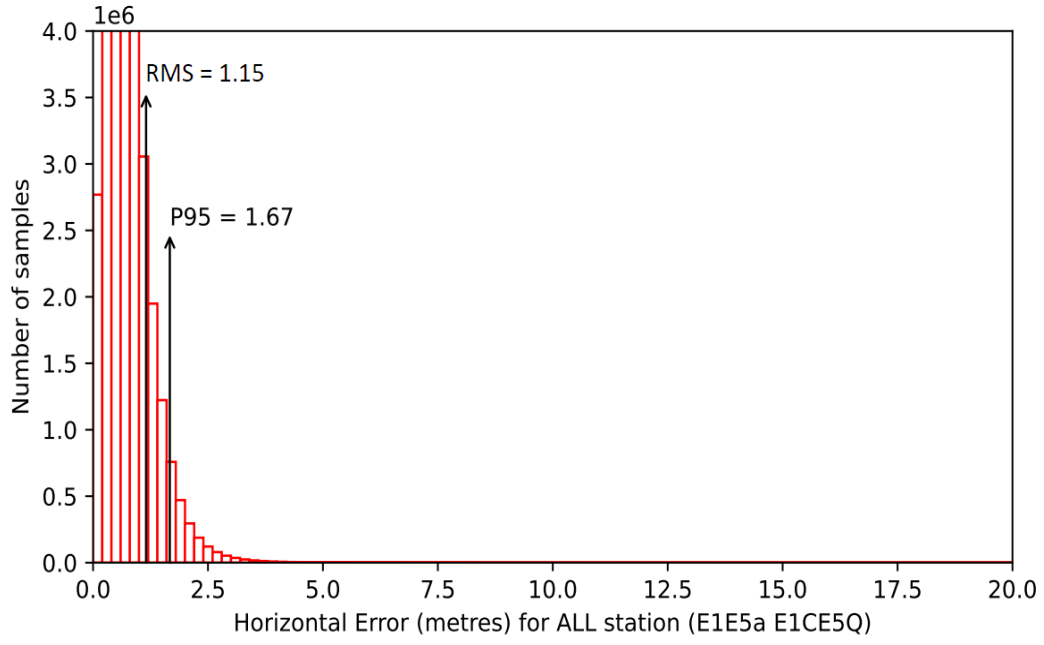
November 2023	
HPE **3D Positioning** **E1-E5b (DF)** **I/NAV**	
Note: 14263 samples > 20 m, around 0.04% of total	

Figure 25: Horizontal Positioning Error (HPE) for "Galileo-only" DF users in November 2023

December 2023	
HPE 3D Positioning E1-E5a (DF) F/NAV	
Note: 19337 samples > 20 m, around 0.05% of total	

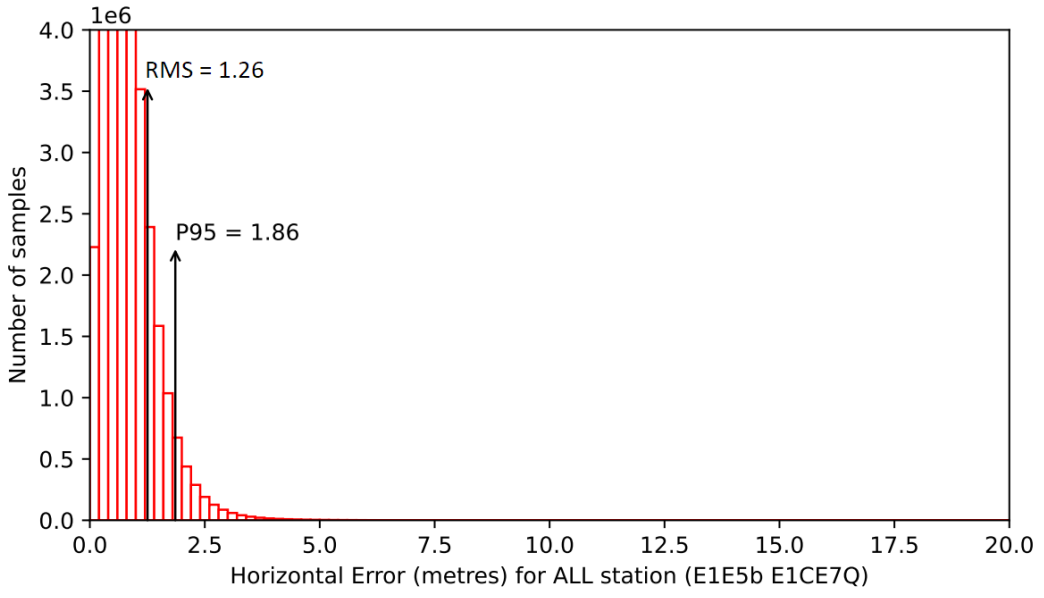
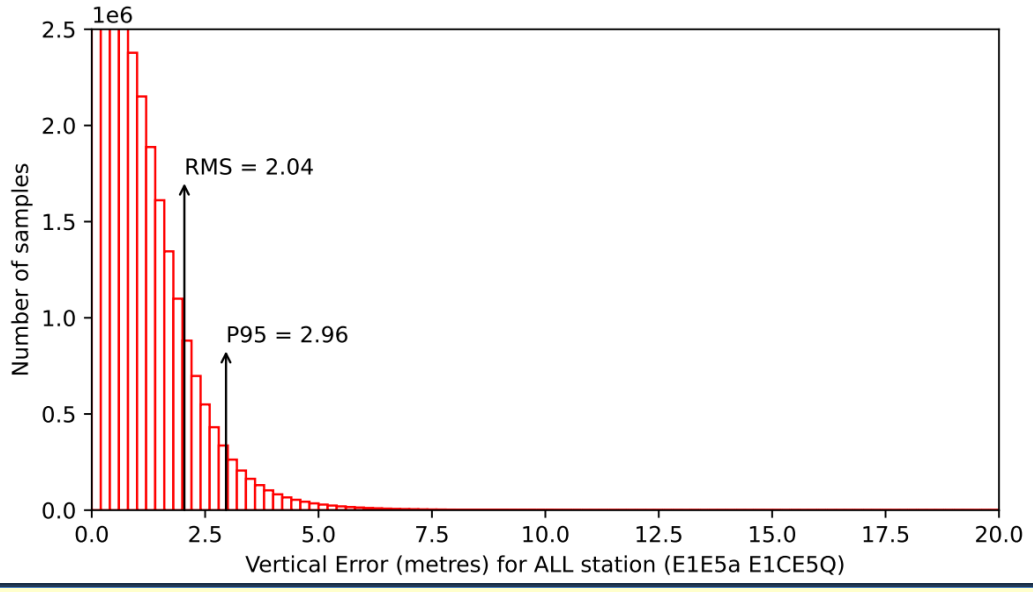
December 2023	
HPE 3D Positioning E1-E5b (DF) I/NAV	
Note: 18402 samples > 20 m, around 0.05% of total	

Figure 26: Horizontal Positioning Error (HPE) for "Galileo-only" DF users in December 2023

October 2023	
VPE 3D Positioning E1-E5a (DF) F/NAV	
Note: 19415 samples > 20 m, around 0.05% of total	

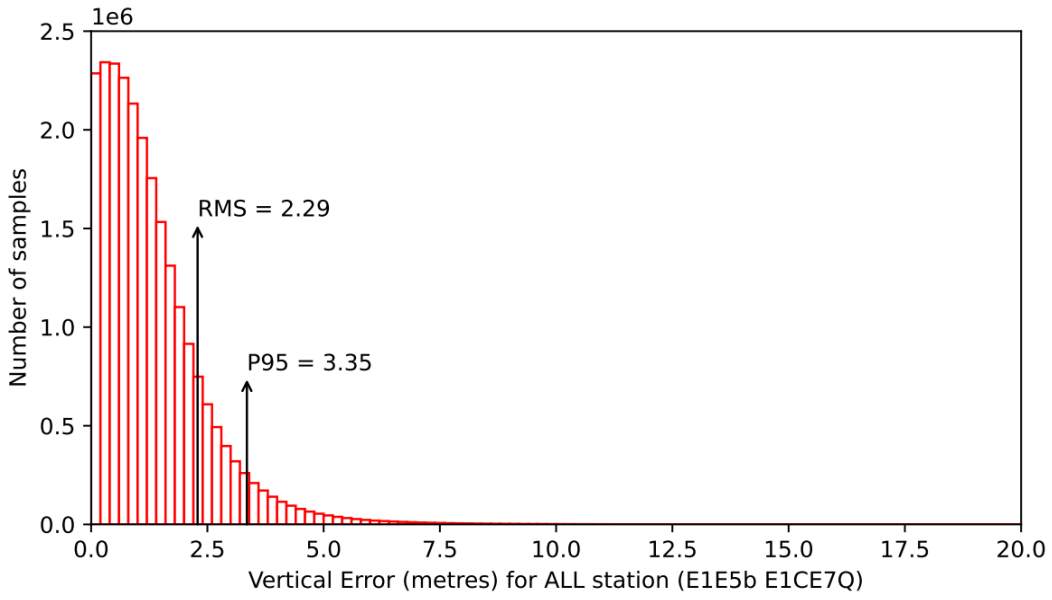
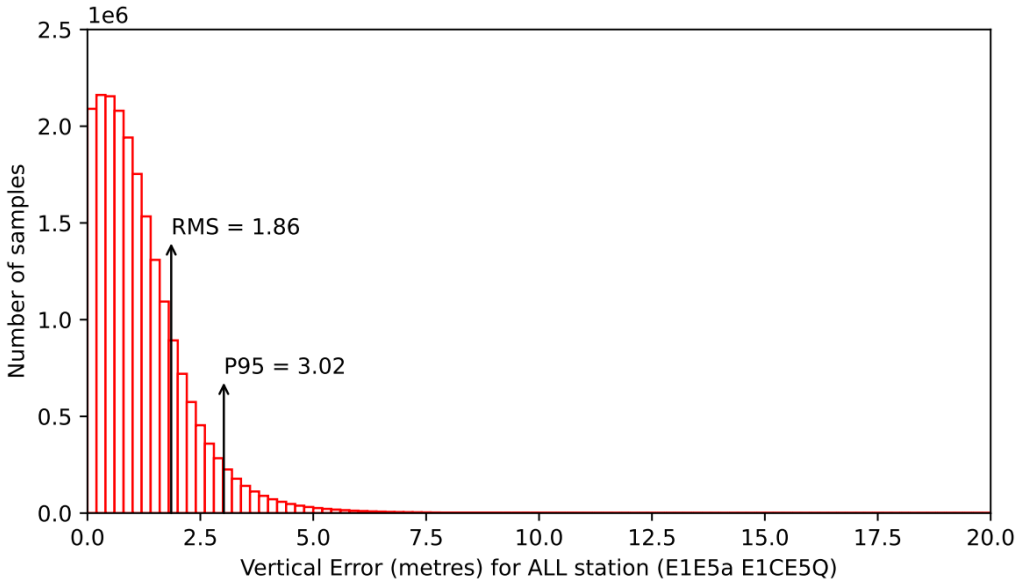
October 2023	
VPE 3D Positioning E1-E5b (DF) I/NAV	
Note: 21654 samples > 20 m, around 0.05% of total	

Figure 27: Vertical Positioning Error (VPE) for "Galileo-only" DF users in October 2023

November 2023	
VPE 3D Positioning E1-E5a (DF) F/NAV	
Note: 14304 samples > 20 m, around 0.04% of total	

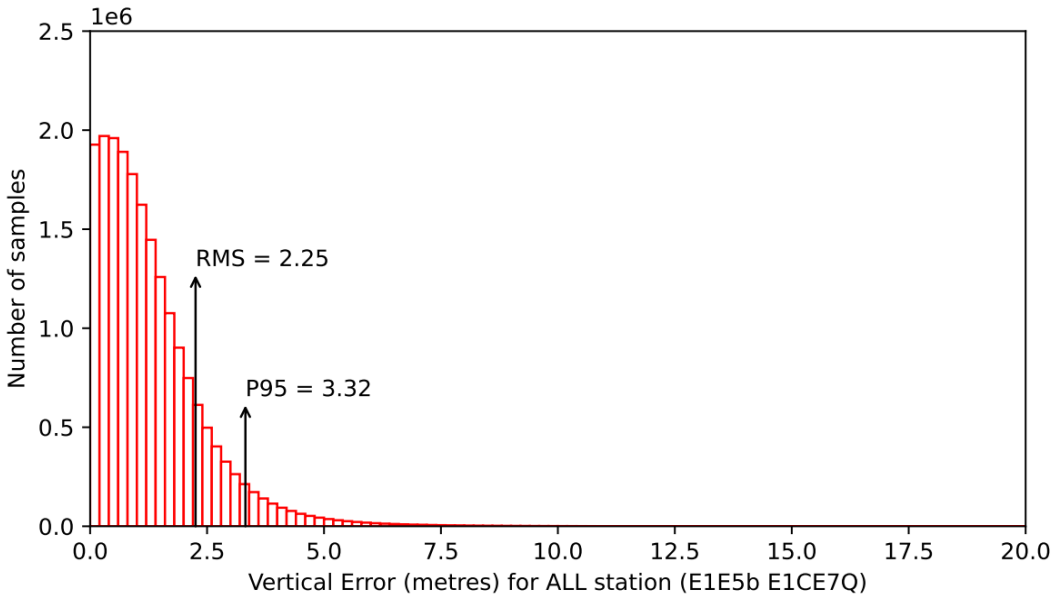
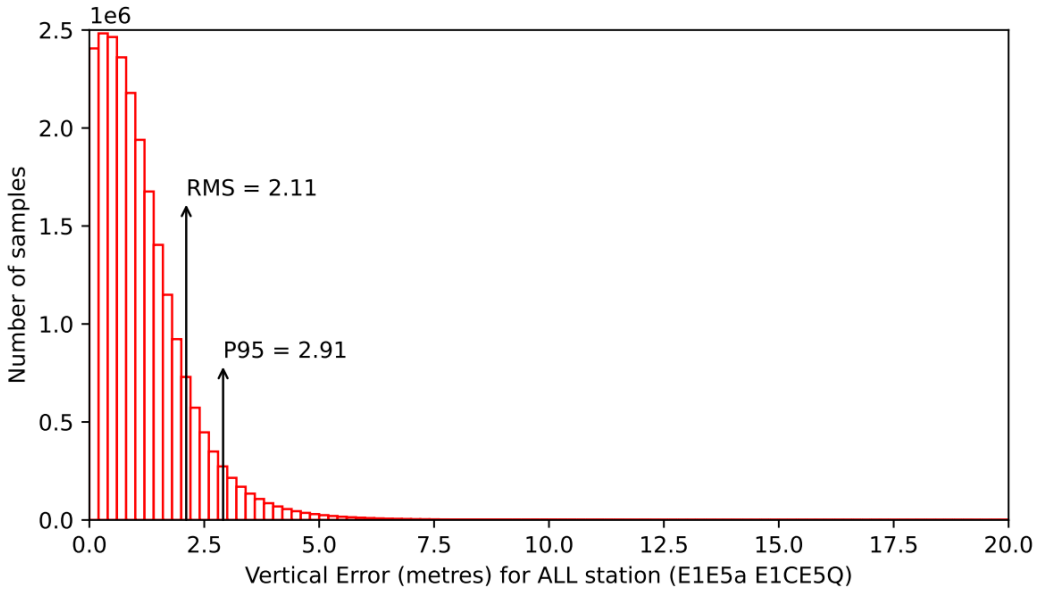
November 2023	
VPE 3D Positioning E1-E5b (DF) I/NAV	
Note: 20267 samples > 20 m, around 0.06% of total	

Figure 28: Vertical Positioning Error (VPE) for "Galileo-only" DF users in November 2023

December 2023	
VPE 3D Positioning E1-E5a (DF) F/NAV	
Note: 28950 samples > 20 m, around 0.08% of total	

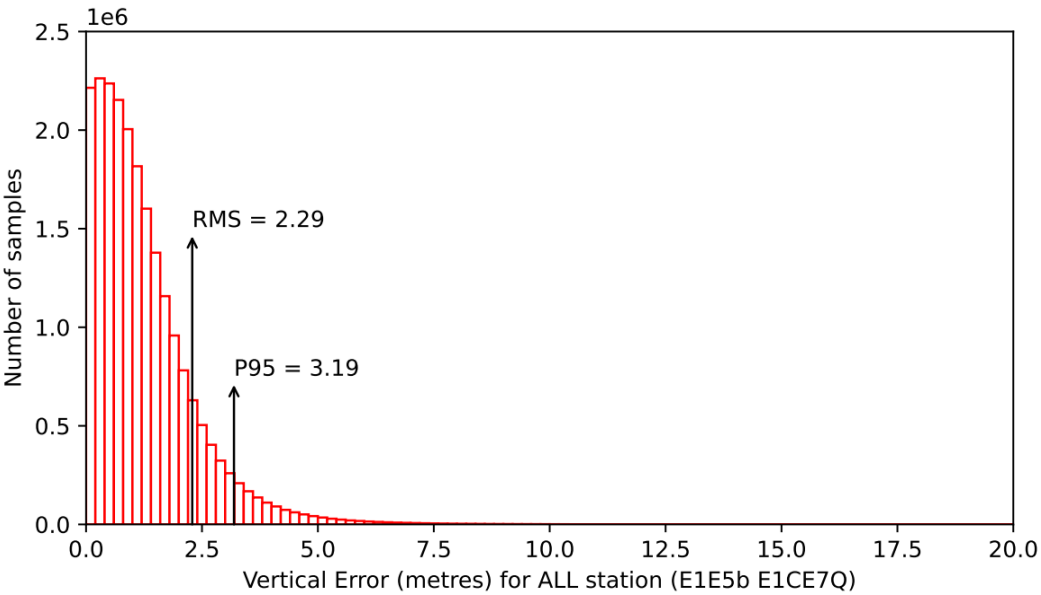
December 2023	
VPE 3D Positioning E1-E5b (DF) I/NAV	
Note: 27359 samples > 20 m, around 0.07% of total	

Figure 29: Vertical Positioning Error (VPE) for "Galileo-only" DF users in December 2023

6 TIMELY PUBLICATION OF NOTICE ADVISORY TO GALILEO USERS (NAGUS)

The European GNSS Service Centre (GSC) is responsible for timely publication of Notice Advisory to Galileo Users (NAGU) messages on its web pages:

Table 8: Galileo Service Centre web pages for Notice Advisory to Galileo Users (NAGUs)

active NAGUs
https://www.gsc-europa.eu/system-status/user-notifications
archived NAGUs
https://www.gsc-europa.eu/system-status/user-notifications-archived

According to the [OS-SDD] in force, NAGUs related to planned events need to be published at least **48** hours [39] before the start of the event. For unplanned events, the [OS-SDD]specifies a delay of up to **30** hours [39] from the detection of the unplanned event until a corresponding NAGU is issued, which is reduced to **15** [39] hours in the case of a NAGU announcing navigation service available again from a space vehicle.

The summary of NAGUs that have been published during the reporting period is as per the following Table 9; NAGU publication timeliness requirements were met with large margins, as per figures reported in it.

During the quarter, **4** NAGUs have been published referring specifically to Open Service. In particular:

- in **October,** the only NAGU issued was related to High Accuracy service (HAS).
- in **November, 2 (two)** NAGUs were published, both regarding a planned orbit correction manoeuvre operated on GSAT0214 (E05).
- in **December, 2 (two)** NAGUs have been published, both regarding a planned on-board maintenance operated on GSAT0213 (E04).

Table 9 provides a summary of published NAGUs during the quarter that are specifically referring to Open Service.

[39] Ref.: [OS-SDD] §3.7.1 (Table 30)

Table 9: NAGUs published during the last quarter of 2023, referring to Open Service

month	NAGU type	reason for publishing	notice advisory ID	NAGU categ.*	timeliness
October					
	No NAGU published related to OS. (NAGU 2023053 pertains with HAS)		-	**-**	-
November					
	PLN_MAN	Warning about forthcoming unavailability of GSAT0214 (E05) for planned orbit manoeuvre, as of 07/11/2023 @ 05:00 UTC.	2023054	**P**	Published **3.75** days before the event.
	USABLE	Announcing the service recovery for GSAT0214 (E05), as of 16/11/2023 @ 18:05 UTC.	2023055	**U**	Published **0.059** days (**01h:25m**) after the event.
December					
	PLN_OUTAGE	Warning about forthcoming unavailability of GSAT0213 (E04) for on-board maintenance, as of 11/12/2023 @ 13:25 UTC.	2023056	**U**	Published **4.05** days before the event.
	USABLE	Announcing the service recovery for GSAT0213 (E04), as of 11/12/2023 @ 14:31 UTC.	2023057	**P**	Published **0.062** days (**01h:29m**) after the event.

* NAGU categorisation for timeliness evaluation: **P** = planned, **U** = unplanned

7 GALILEO OSNMA PERFORMANCE

In November 2021, as per [SvNOTE #09], EUSPA officially initiated the OSNMA "Public Observation Test Phase", which involves the dissemination of a Test SIS and the active involvement of key stakeholders and interested parties. This allows receiver manufacturers, application developers and members of research institutions to access for the first time a real OSNMA data stream from the Galileo space segment.

EUSPA started a regular measurement of OSNMA key performance metrics applicable at this stage. Even if the parameters characterising the quality of delivered OSNMA Service are not currently subject to any MPL target, they are of interest and are reported starting with this quarterly report.

The main performance parameters currently detailed in the following are:

- OSNMA availability (ref.: Figure 30, Figure 31, Figure 32, Figure 33), measured as the percentage of time that the user is receiving OSNMA tags to perform a new authentication event, and this for the different navigation data types that are authenticated. Availability is measured for a Tag length of 40 [40] bits. Please refer to the applicable Interface Control Document [OSNMA SIS-ICD] and the guidelines for the OSNMA implementation at user receiver [OSNMA Rx GL],
- percentage of OSNMA tag verification success (ref.: statistics in Table 10). This characterisation is provided to allow developers to cross-check their observed authentication performance. Any root cause leading to MAC (Message Authentication Code) verification failures will be corrected for the service provision phase.

7.1 AVAILABILITY OF AUTHENTICATION TAGS

The following Navigation message authentication types are considered:

- **ADKD0** → for the Galileo I/NAV Orbit and Clock correction data of word types 1–5. Availability figure is measured as the percentage of time that at least **1×40-bit ADKD0 MAC** can be achieved 1) from all space vehicles in view, within a period of **600 s** (Figure I 1) and 2) from at least four satellites in view, now within 1 subframe (**30 s**)
- **ADKD4** → for the Galileo GST-UTC and GST-GPS conversion parameters. Availability figure is measured as the percentage of time that at least **1×ADKD4 MAC** can be accumulated from at least one satellite in view, within a period of **60 s**.
- **ADKD12** → for the Galileo I/NAV data of word types 1–5, targeting receivers with low synchronization requirements. Availability figure is measured as the percentage of time that at least **1×40-bit ADKD12 MAC** can be accumulated from at least four satellites in view, within a period of **240** s.

Results obtained during the Quarter are shown in the following figures.

[40] Previously 80 bits

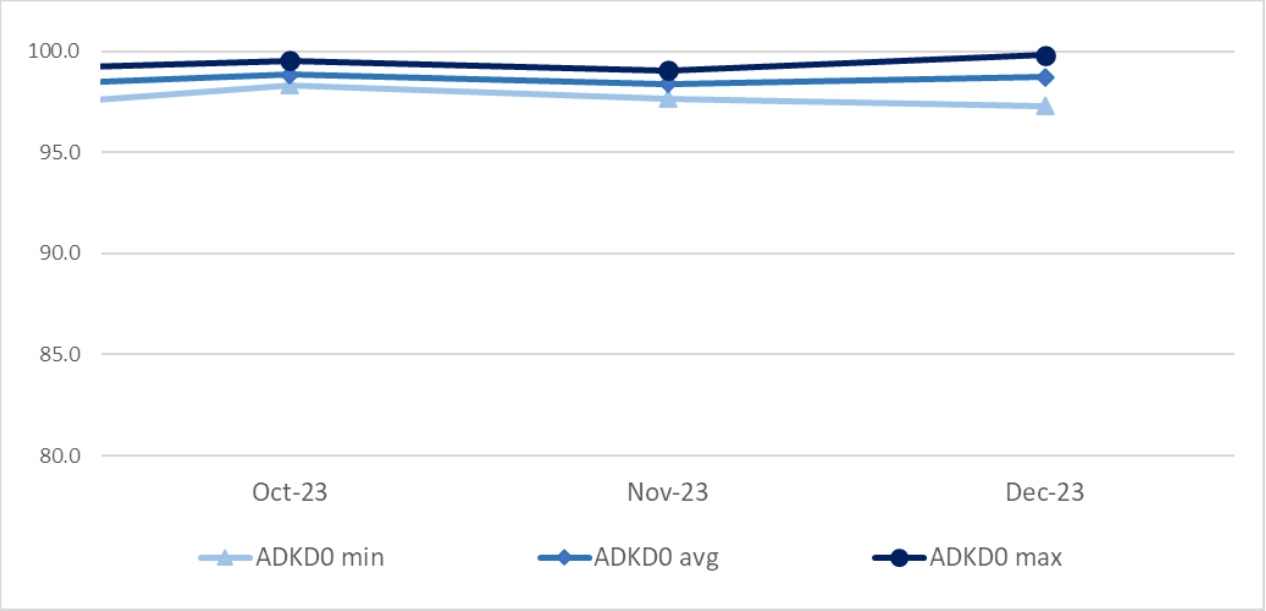


Figure 30: availability of tags for Galileo I/NAV orbit and clock data (ADKD0) – 1×40 bit ADKD0 MAC for all space vehicles in view, within 600 s

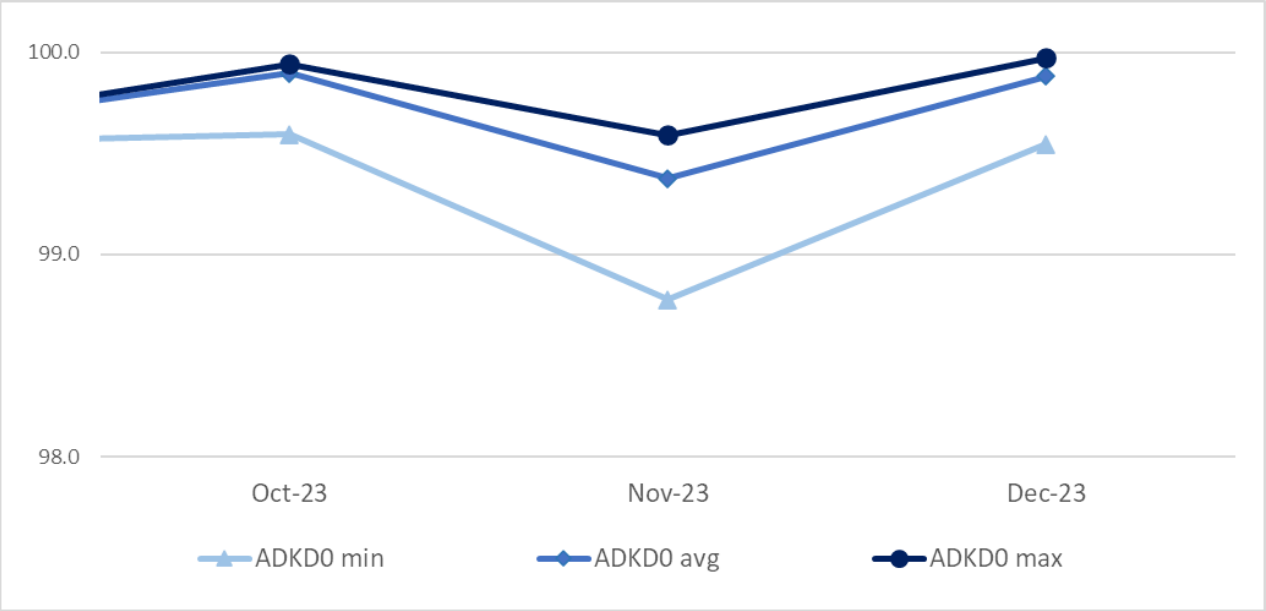


Figure 31: availability of tags for Galileo I/NAV orbit and clock data (ADKD0) – 1×40 bit ADKD0 MAC for at least four space vehicles, within 30 s

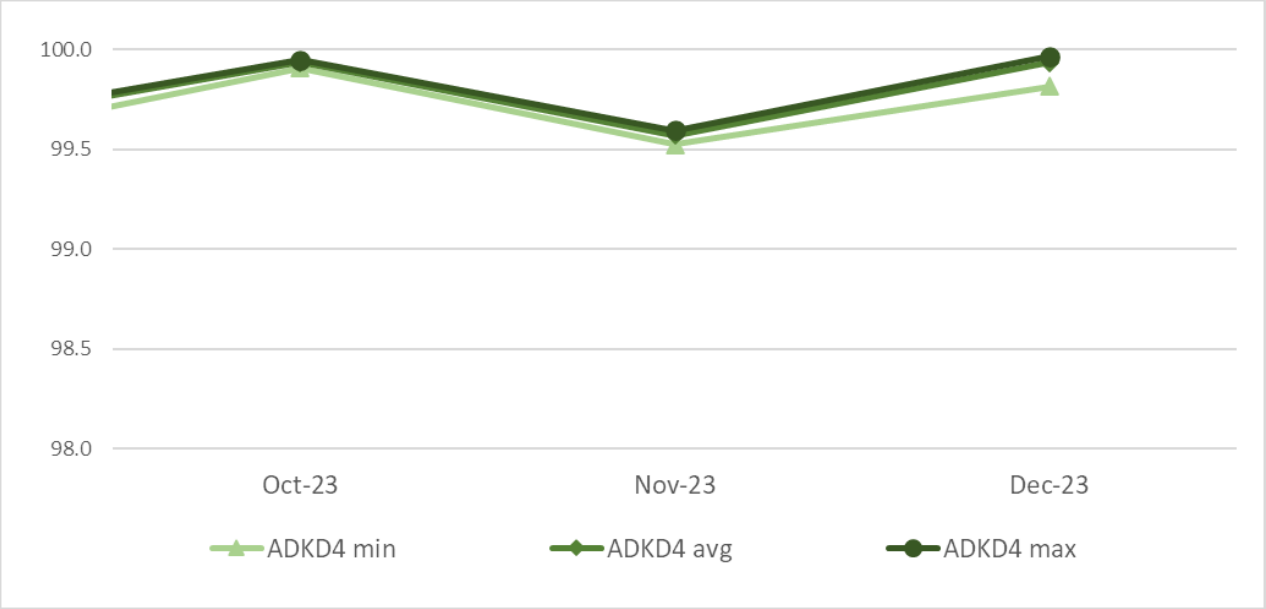


Figure 32: availability of tags for the GST-UTC and GGTO parameters (ADKD4) - 1×ADKD4 MAC from at least one satellite, within 60 s

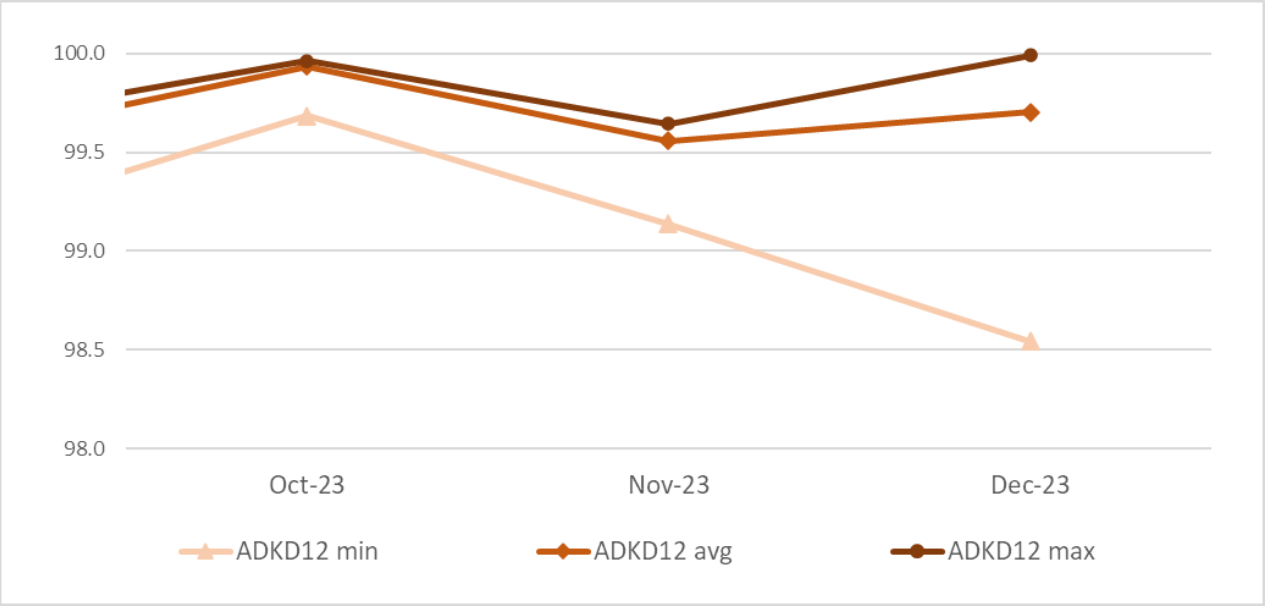


Figure 33: availability of tags for Galileo I/NAV orbit and clock data (ADKD12) - 1×40 bit ADKD12 MAC from at least four satellites in view, within 240 s

7.2 STATISTICS ON SUCCESS OF TAG AUTHENTICATION

The following table shows the percentage of OSNMA tag verification success depending on user receiver operation (single-frequency, dual-frequency) and on the kind of authentication performed (ADKD type):

Table 10: Statistics for successful OSNMA tags for single- and dual-frequency

	2023		
	October	**November**	**December**
single frequency, in %			
ADKD0	99.99941	99.99971	100.0000
ADKD4	100.00000	100.00000	100.0000
ADKD12	99.99890	100.00000	100.0000
dual frequency, in %			
ADKD0	99.99991	99.99981	99.9999998
ADKD4	100.00000	100.00000	100.0000000
ADKD12	99.99978	99.99977	99.9999995

Percentages in Table 10 do not account for space vehicles GSAT0201 (E18) and GSAT0202 (E14), which are on elliptical orbits and declared not usable.

8 REFERENCES

This section identifies the documents explicitly referenced in this Galileo Open Service Public Performance Report. It also provides references to additional documents considered of interest for users.

[SIS-ICD] European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document (OS-SIS-ICD), Issue 2.0, European Union, January 2021.

[IONO] Ionospheric Correction Algorithm for Galileo Single Frequency Users, Issue 1.2, European Union, September 2016.

[OS-SDD] European GNSS (Galileo) Open Service Definition Document: OS-SDD v1.2 applicable in October and November 2023 (European Union, November 2021), OS-SDD v1.3 adopted for reporting since December 2023 (European Union, November 2023).

[SvNOTE #5] Galileo Service Notice #05 - Unavailability of the Galileo Auxiliary satellites GSAT0201 and GSAT0202

[SvNOTE #09] Galileo Service Notice #09 - Officially announcing the beginning of Galileo OSNMA "Public Observation Phase", which implies the dissemination of a Test SIS and the active involvement of key stakeholders and parties interested in this new Service, devoted to the authentication of the engineering information carried by the Navigation signal.

[SvNOTE #11] Galileo Service Note #11 - Following the successful Testing activities for the enhanced I/NAV message on GSAT0223 (E34) and GSAT0224 (E10), Galileo users are notified that, until July 2023, the on-board S/W of all FOC satellites need to be upgraded, enabling the improvement.

[OSNMA SIS-ICD] On November 18th 2020 @ 15:28 UTC, Galileo satellites started the transmission of authentication information for testing purposes. The OSNMA Signal In space Interface Control Document (OSNMA SIS-ICD) Issue 1.0, released in December 2022 and applicable to the Service phase, is available.

[OSNMA Rx GL] Receiver Guidelines have been published to support the implementation of Galileo OSNMA at user receiver level.

Previous documents are available to users through the web portal of the European GNSS Service Centre (http://www.gsc-europa.eu/).

Individual sections of the Open Service – Service Definition Document [OS-SDD] have been referenced throughout this report when referring to MPL target values and calculation methods.

For an exhaustive description of the Open Service Minimum Performance Levels (MPLs), the reader is addressed to the [OS-SDD] in force.

9 LIST OF ACRONYMS

Acronym	Definition
AUL	Average User Location
BGD	Bias Group Delay (parameter delivered in the Navigation messages)
DF	(Galileo OS) dual-frequency combination (E1/E5a, E1/E5b)
DOP	Dilution of Precision
ECEF	Earth Centred, Earth Fixed frame coordinates
EUSPA	European Union Agency for the Space Programme
F/NAV	Navigation message provided by the E5a signal [SIS-ICD]
FOC	Full Operational Capability
GGTO	GST-GPS Time Offset
GMS	Galileo Mission Segment
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
G/S	Ground Segment
GSC	European GNSS Service Centre
GST	Galileo System Time
HAS	High Accuracy Service
HDOP	Horizontal Dilution of Precision
HPE	Horizontal Positioning Error
ICD	Interface Control Document
IDD	Internet Data Distribution (HAS)
I/NAV	Navigation message provided by the E1-B and E5b signals [SIS-ICD]
IS	(Galileo) Initial Services
MPL	Minimum Performance Level
MAC	Message Authentication Code
NAGU	Notice Advisory to Galileo Users
NAPA	No Accuracy Prediction Available
OLTN	OSNMA Live Test Notification
OS	(Galileo Navigation) Open Service
OSNMA	Galileo Open Service Navigation Message Authentication
PDOP	Position Dilution of Precision
SBDO	Stand-By Duty Officer

Acronym	Definition
SDD	Service Definition Document
SDM	Service Delivery Manager
SF	(Galileo OS) single-frequency (E1, E5a, E5b)
SIS	Signal in Space
SISA	Signal In Space Accuracy
SISE	Signal In Space Error vector (4-dimensional)
SNGU	Service Notice to Galileo Users
toE	Time of Ephemeris
UTC	Universal Time Coordinated
VPE	Vertical Positioning Error
WUL	Worst User Location

End of Document

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