



BSI Standards Publication

Space — Galileo Timing Receiver — Functional and Performance Requirements and associated Tests

National foreword

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Espace - Récepteur de signaux Galileo pour référence
temps - Exigences fonctionnelles et de performances,
et essais associés

Raumfahrt - Galileo Timing Receiver - Funktions- und
Leistungsanforderungen und zugehörige Tests

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European foreword

This document (EN 16605:2024) has been prepared by Technical Committee CEN/CLC/JTC 5 “Space”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2025, and conflicting national standards shall be withdrawn at the latest by June 2025.

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Introduction

The timing capabilities, which are inherent to all GNSS, constitute a paramount benefit allowing the timing solutions of excellent performance worldwide. Those capabilities have the particularity to be exploited by sectors which are strategic for the functioning of the modern society. These are the critical infrastructures such as Telecommunications, Energy and Finance. While timing represents in itself a small market compared to others if only timing receivers are taken into account, it is an enabler of critical infrastructures, and thus important for the entire European economy and society. In addition to those strategic sectors, timing is also used in a wide variety of applications including metrology, remote sensing and atmosphere research.

The importance of the timing capability has been considered by the European Commission substantial enough to give it the category of a proper Service in itself as part of the Galileo Service portfolio. This has been formalized at the level of an EU Regulation [62].

The Service definition undoubtedly starts by taking into account the needs of its intended users and be flexible to accommodate their evolutions. To that end, stakeholder's consultations and interactions with the user community took place and led to the identification of the need to increase robustness and trust in the timing products. This aspect has then been incorporated as a key feature for the Galileo Timing Service.

With the Service characteristics and associated performance targets specified, the implementation of the Service provision implies putting together all the necessary elements to be able to meet those targets and to ensure that they are maintained over the Service lifetime.

When all is ready, a formal Service declaration informs the users that they can, from then on, rely on it to develop their own applications.

The Galileo Timing Service concept relies on two fundamental pillars:

- dissemination of information dedicated at timing users, packaged in a Timing Service Message as part of the Galileo Signal in Space,
- standard for Galileo timing receivers, to ensure that the information provided is adequately processed as intended and the implementation of local barriers enhancing robustness.

The intent of this document is to specify Requirements and Tests for Galileo timing receivers as part of the Galileo Timing Service. The target users for the standard are all Galileo Timing users, with special focus on critical infrastructures and critical applications. The standard takes into account the specificities of the Galileo Timing Service. This is fundamental in order to ensure the end-to-end performance of the Galileo Timing Service for those users who make use of a receiver developed according to the standard. The Galileo Timing Service covers needs and requirements of timing and synchronization for most users, and it is driven by the critical infrastructure sectors of Energy, Telecom and Finance. The Galileo Timing Service foresees to support various service monitoring levels accordingly, which is reflected in the document.

Finally, it is worth recalling that although GNSS receivers are already being used in timing applications – in particular GPS since it was the first operational GNSS System – there is no associated standard. This will be then a first, with full support from European Commission, which gives testimony of how serious the Timing Service is taken into account at EU level.

1 Scope

This document specifies the functional and performance requirements and associated tests for Galileo timing receivers. The approach for this document is that of a performance based, meaning that no specific algorithm implementation is required. Instead, performance requirements are specified together with a corresponding test suite for verification.

This document is applicable to the Galileo chipset. This document does not apply to other sensors and/or additional processing that a higher synchronization Unit can implement on top of the Galileo chipset.

This document is applicable to the following aspects related to Galileo timing receivers:

- GNSS constellations and frequencies processed: Galileo Dual-Frequency. Other modes are optional, as explained below;
- time scales, including Galileo System Time and Coordinated Universal Time;
- Services Levels, this document covers the 2 levels of Service for GST and for UTC to be provided by Galileo Time Service in the first place. The document also anticipates a third Service Level to be provided in the future, for which an update of the document will be needed;
- user dynamics: fixed users, defined as static users with precise knowledge of the antenna position, is the baseline mode;
- processing of Timing Service Message disseminated by the Galileo System;
- local timing integrity barriers: As a minimum, Time Receiver Autonomous Integrity Monitoring processing (T-RAIM);
- robustness to interferences;
- Galileo Open Service Navigation Message Authentication processing;
- robustness to multipath.

This document does not apply to the processing of GPS constellation but this does not preclude Manufacturers to implement GPS processing within the Galileo timing receivers, even if not addressed in this document. The use of other GNSS constellations is not forbidden by this document but the requirements and tests are defined considering Galileo-only, including those related to the integrity of the timing solution.

This document does not apply to single-frequency modes. This does not preclude manufacturers to implement single-frequency modes within the Galileo timing receivers, even if not addressed in this document, as a back-up of the nominal Dual-Frequency mode, and reversion mechanisms. It is important to remark that the integrity of the timing solution is only specified for Galileo Dual-Frequency mode.

The Galileo timing receivers is only applicable to users operating in static conditions. This document does not apply to moving users.

On top of the functional requirements, performance requirements are specified in this document in terms of different key performance indicators such as:

- accuracy, availability and integrity requirements;
- local barriers, T-RAIM performances.

This document also provides the verification matrix and specifies the test suite to verify the most fundamental requirements of the Galileo timing receivers.

Finally, this document specifies a subclause dedicated to guidelines for the installation and maintenance of the Galileo timing receivers. This is a comprehensive subclause, including provisions for the antenna, cabling and receiver installation, as well as the calibration of time delays.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases (see also [43]) for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

accuracy

degree of conformance of the position, velocity and/or time with the true position, velocity and/or time of the GNSS user

Note 1 to entry: In the case of this document, the focus is placed on the accuracy of an estimated time, it is measured in nanoseconds and is provided as a statistic threshold (e.g. 2-sigma). The concept of accuracy in this document is equivalent to the one in other more general standards such as ISO/IEC Guide 99:2007.

3.1.2

availability

percentage of time that the services of the system are usable by the user

Note 1 to entry: Availability is an indication of the ability of the system to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigation/timing signals transmitted from external sources are available for use. It is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities. Availability is usually expressed in a % of time over a specified period.

Note 2 to entry: Availability = (Number_Epochs_Timing_Service_Available / Total_Number_of_Epochs) * 100

Note 3 to entry: For the particular case of the Availability of the Galileo Timing Service, the Availability concept is used for the availability of the Service Levels 1, 2 and 3 instead of signal availability.

3.1.3

back-up mode

operational mode of the synchronization unit hosting the Galileo timing receiver in which some of the functionality and/or input data are not available for the complete performances to be reached, but can still continue operating under certain functional constraints

3.1.4**Carrier to Noise ratio****C/N0**

SNR of a modulated signal consisting of the ratio of the power of the transmitted signal in the passband frequency over the power of the noise per unit bandwidth, expressed in dB-Hz

3.1.5**dynamic mode**

unitless specification of the position/time error propagation as an effect of the satellite position and pseudorange geometry towards the receiver, considering that solutions calculated using pseudoranges of close satellites have greater uncertainties compared with solutions calculated using distant satellites

3.1.6**dilution of precision****DOP**

dilution of precision is a term used to specify the position/time error propagation as an effect satellite position and pseudorange geometry towards the receiver. Solutions calculated using pseudoranges of close satellites have greater uncertainties compared with solutions calculated using distanced satellites. DOP is unitless

3.1.7**Galileo timing receiver**

electronic device, typically a chipset, that processes the Galileo satellite signals captured by an antenna, to provide accurate time information in the form of PPS signal and accompanying messages

3.1.8**generalist RF test laboratory**

laboratory in charge of assessing the performances of the Galileo timing receiver thanks to test scenario

3.1.9**GGTO**

GPS-Galileo time offset data, broadcasted by Galileo Satellites, usually expressed in nanoseconds

3.1.10**Global Navigation Satellite System****GNSS**

acronym designating satellite positioning systems, being the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage, including GPS, GLONASS, Galileo and Beidou

3.1.11**GNSS-specialized laboratory**

laboratory in charge of producing test scenarios for generalist RF test laboratories

3.1.12**Galileo System Time****GST**

continuous time scale maintained by the Galileo Central Segment and synchronised with TAI (International Atomic Time) with a nominal offset below 50 ns

3.1.13**holdover**

period of time in which two clocks run in an independent way relative to each other after an initial synchronization

3.1.14

holdover device

device within the synchronization unit which allows the holdover mode

3.1.15

holdover mode

operational mode of the synchronization unit hosting the Galileo timing receiver in which the time is running based on non-Galileo SIS timing computation from the last or present Epoch

3.1.16

holdover degradation

time and frequency difference between two clocks after the holdover period

3.1.17

holdover timeout

maximum time allowed for the synchronization unit hosting the Galileo timing receiver to work in holdover mode

Note 1 to entry: The maximum holdover period will depend on the type of local clock – local clock is affected by its own accuracy, accumulating time error with time - as well as the target Service monitoring level - higher Service monitoring level implies more stringent accuracy. The Synchronization Unit hosting the Galileo timing receiver should start counting the holdover time threshold, from the moment when the switch is performed.

3.1.18

integrity

measure of the trust that can be placed in the correctness of the information supplied by a navigation/timing system, including the ability of the system to provide timely warnings to users when the system should not be used for navigation/timing

3.1.19

interference

source of RF transmission that is within the frequency band used by a communication link, and that degrades the performances of this link

3.1.20

Issue Of Data

IOD

sort of a time stamp on the GNSS data that the receiver gets from the navigation message

3.1.21

jamming

competing signal that prevents the GNSS receiver from decoding the true satellite signal

3.1.22

missed detection

failure in the timing solution, not detected by T-RAIM which does not allow to comply with the intended service level

3.1.23

Maximum Tolerable Error

MTE

maximum timing error with regard to a certain timescale (UTC or GST) that is expected or acceptable for the user

3.1.24**navigation message**

message transmitted by the GNSS satellites to the users providing all the necessary information to allow the user to perform the positioning and timing service

3.1.25**performance**

extent to which a system is able to meet its output goals

3.1.26**pseudorange**

measurement, by the GNSS receiver, of the distance between a satellite antenna and the receiver antenna, biased by the error due to the difference between the satellite clock and the receiver clock

3.1.27**record & replay**

test techniques consisting of digitalizing GNSS signals and sensor measurements in real world campaigns so that they can be repeated later in suitable laboratory test benches

3.1.28**safety probability of failure**

likelihood of a failure of the timing solution during a certain time interval

3.1.29**Signal Noise Ratio****SNR**

ratio between signal power to the noise power, normally expressed in dB

3.1.30**spoofing**

transmission of signals intended to deceive PVT processing into reporting false PVT target data

3.1.31**static mode**

operational mode in which the center of phase of the omnidirectional antenna(s) connected to the Galileo timing receiver is(are) fixed and the Galileo timing receiver uses an accurately predetermined position of them for the computation of the time solution

3.1.32**synchronization unit**

system of the T&S user hosting the Galileo timing receiver which could comprise other components such as e.g. a local clock for Holdover Mode, visual interface with the user, etc

3.1.33**holdover time**

t_{holdover}

time interval starting with the instant the synchronization unit hosting the Galileo timing receiver starts operating in the holdover mode until the present, usually expressed in seconds

3.1.34

International Atomic Time

TAI

time reference coordinate calculated by the Bureau International de l'Heure on the basis of the readings of atomic clocks operating in various establishments in accordance with the definition of second, the unit of time of the system of international System of Units (SI), being a coordinate time scale defined in a geocentric reference frame with a unit increment of 1 s realized on the rotating geoid rotating as the scale unit

3.1.35

TDOP

dilution of precision for the timing solution, unitless

3.1.36

test scenario

scenario composed of GNSS SIS data resulting from recording activities to assess a Galileo timing receiver in the desired environments

3.1.37

time error

definition of a failure in timing is provided in 4.3.3

3.1.38

Time Of Day

TOD

sequence describing the hour, minute and second in the current day and which is incremented on the rising edge of the Galileo timing receiver 1PPS

3.1.39

Time Of Week

TOW

number of seconds, in 20 bits, that have occurred since the transition from the previous week. The TOW covers an entire week from 0 to 604799 seconds and is reset to zero at the end of each week

3.1.40

Time To Alert

TTA

maximum allowable time elapsed from the onset of an out of tolerance condition (i.e. timing error greater than MTE) until the equipment enunciates the alert, usually expressed in seconds/minutes

3.1.41

Time To Notify

TTN

notification time required for the system to flag a satellite as don't use and alert the user, usually expressed in seconds/minutes

Note 1 to entry: The difference between TTN and TTA is explained in 4.3.7.

3.1.42

Timing RAIM

T-RAIM

user algorithm that determines the integrity of the GNSS solution, being the timing version of RAIM algorithms applicable to timing receivers

3.1.43**Week Number****WN**

12 bits counter that gives the sequential week number from the origin of the Galileo time, covering 4096 weeks (about 78 years), being reset to zero to cover additional period modulo 4096

3.1.44**User Range Error****URE**

combination of orbit and clock errors, residual tropospheric error, residual ionospheric error, and local noise/multipath error, usually expressed in meters

3.1.45**Coordinated Universal Time****UTC**

$\text{TAI-UTC} = n$, where n is an integer number of seconds, called leap seconds, created to keep into account the variable rate of Earth's rotation rate

Note 1 to entry: As of March 2022, the value of n is 37 s.

3.1.46**UTC Offset****UTC0**

offset between the GNSST and UTC, usually expressed in nanoseconds

Note 1 to entry: In the case of Galileo, which is the GNSS constellation addressed in this Standard, the UTC Offset, is defined for Galileo as the offset between GST and UTC.

3.1.47**UTC(k) laboratory**

metrology laboratory maintaining a UTC(k) time scale traceable to UTC

3.1.48**verification**

provision of objective evidence that a system satisfies the specified requirement

Note 1 to entry: From ISO GUIDE 99 [68].

3.2 Abbreviated terms

Acronyms used in this document and needing a definition are included in the following table:

Table 1 — Abbreviated terms

Abbreviated terms	Full expression
ADC	Analog-to-Digital Converter
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
BIPM	Bureau International des Poids et Mesures
bUTC_Galileo	Prediction of UTC broadcast by Galileo
C/N0	Carrier to Noise ratio
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CGGTTS	Common GNSS Generic Time Transfer Standard
CW	Continuous Wave
DF	Dual Frequency
DO	Disciplined Oscillator
DOP	Dilution Of Precision
EC	European Commission
ECEF	Earth Centered Earth Fixed
EGALITE	EGNOS and Galileo Timing Service Extension and Consolidation
EGNOS	European Geostationary Navigation Overlay Service
EN	European Standard
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
FOC	Full Operational Capability
FTA	Fault Tree Analysis
GGTO	GPS-Galileo Time Offset
GMS	Galileo Mission Segment
GNSS	Global Navigation Satellite System
GNSST	GNSS Time
GPS	Global Positioning System
GPST	GPS Time
GSS	Galileo Sensor Stations
GST	Galileo System Time
G1G	Galileo First Generation

Abbreviated terms	Full expression
G2G	Galileo Second Generation
HW	Hardware
IBPL	Isotropy Based Protection Levels
ICD	Interface Control Document
IOD	Issue Of Data
IODUTC	Issue Of Data Coordinated Universal Time
ITRF	International Terrestrial Reference System
ITU	International Telecommunication Union
JRC	Joint Research Center
KPI	Key Performance Indicator
LNA	Low Noise Amplifier
LOS	Line Of Sight
MJD	Modified Julian Day
MOPS	Minimum Operational Performance Standard
MTE	Maximum Tolerable Error
NLOS	Non line Of Sight
NMA	Navigation Message Authentication
NMEA	National Marine Electronics Association
NTP	Network Time Protocol
OCXO	Oven-Controlled Crystal Oscillator
OS	Open Service
PDOP	Position Dilution Of Precision
PHM	Passive Hydrogen Masers
PMR	Professional Mobile Radio
PMU	Phasor Measurement Unit
PPP	Precise Point Positioning
PPS	Pulse Per Second
PSTN	Public Switched Telephone Network
PVT	Position Velocity and Time
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
RFI	Radio Frequency Interference
RG	Radio Guide

Abbreviated terms	Full expression
RINEX	Receiver INdependent EXchange
RSS	Root Sum Square
RTCA	Radio Technical Commission for Aeronautics
Rx	Receiver
R&R	Record and Replay
SBAS	Satellite Based Augmentation System
SDD	Service Definition Document
SDR	Software Defined Radio
SF	Single Frequency
SHS	Signal Health Status
SI	Système International d'unités (International System of Units)
SIS	Signal In Space
SISA	Signal In Space Accuracy
SL	Service Level
SNR	Signal-to-Noise Ratio
SPS	Symbols Per Second
STARLITE	Preparation of standards for Galileo timing receivers
SVID	Space Vehicle Identification
T-ARAIM	Timing ARAIM
T-IBPL	Timing IBPL
T-RAIM	Timing RAIM
TAI	International Atomic Time
TBC	To Be Confirmed
TBD	To Be Defined
TC	Test Case
TDOP	Time Dilution of Precision
TE	Time Error
TESLA	Timed Efficient Stream Loss-tolerant Authentication
TGD	Time Group Delay
TIC	Time Interval Counter
TOD	Time Of Day
TOW	Time Of Week
TS	Tender Specifications

Abbreviated terms	Full expression
TSM	Timing Service Monitoring
TTA	Time To Alert
TTFF	Time To First Fix
TTL	Transistor-Transistor Logic
TTN	Time To Notify
T&S	Time and Synchronization
UART	Universal Asynchronous Receiver-Transmitter
UCP	User Consultation Platform
UI	User Interface
URE	User Range Error
USB	Universal Serial Bus
USRP	Universal Software Radio Peripheral
UTC	Coordinated Universal Time
UTC0	UTC Offset
UV	Ultraviolet
VLBI	Very Long Baseline Interferometry
WG	Working Group
WN	Week Number
WP	Work Package

4 Galileo Timing Service

4.1 Introduction to timing receivers and timing references

This subclause provides an introduction to timing receivers and timing references, including the Pulse-Per-Second and Time Of Day generation in timing receivers. This document is focused on the Galileo chipset, also called “Galileo timing receiver”. The Galileo timing receiver is hosted by a synchronization unit, which could comprise other components such as e.g. a local clock for Holdover Mode, visual interface with the user, etc.

There are two relevant time references in the frame of Galileo Timing Service: the Galileo System Time (GST), and the Coordinated Universal Time (UTC). For the latter, Galileo broadcast in the Signal in Space the offset between GST and a realization of UTC obtained through a Timing Service Provider as combination of several European national UTC(k) time scales.

The mathematical foundation of GNSS timing can be found in Annex A of this document.

A GNSS timing receiver generates the following output signals (please refer to Figure 1):

- a One-Pulse-Per-Second (1PPS), for example, a TTL (Transistor-Transistor Logic) electrical signal aligned on the rising edge either to GST or to UTC as derived from GST; the user can normally select if he wants GST or UTC on the 1PPS; the 1PPS signal comes usually out of a dedicated connector on the receiver.

- a data message or “label” containing the Time Of Day (TOD), i.e. YYYY/MM/DD-HH:MM:SS for UTC, or WN+TOW for GST; receivers normally report both UTC TOD and GST TOD; the TOD message is generated immediately after the 1PPS, in order for the user to be able to relate the two events; the TOD is typically reported in the form of a NMEA sentence through a serial port of the receiver. The NMEA ZDA message [55] can be used for this purpose.
- Optionally, a frequency signal (for example at 10MHz) aligned (“disciplined”) to the 1PPS; the frequency signal comes usually out of another dedicated connector on the receiver; since the frequency signal just “follows” the 1PPS and anyway is not very often used, it can be ignored in this discussion.

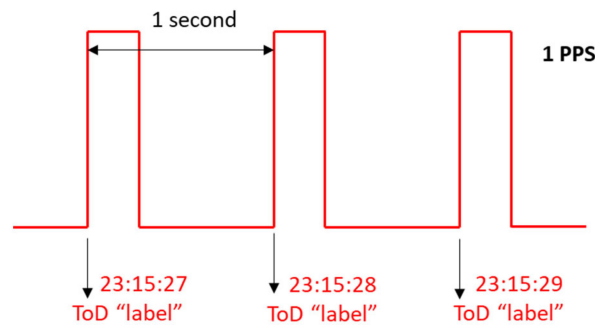


Figure 1 — Representation of 1PPS and TOD signals

In the context of the timing receiver output described in the 4.1, “UTC” is the prediction of the UTC realization transmitted by the GNSS; the receiver derives UTC from GST by subtracting an integer number of “leap seconds” (currently 18 s in Galileo) and by adding the predicted small offset between GST and UTC (modulo one second), called UTCO; leap second and UTCO information is contained in the GNSS navigation message; leap seconds do not affect the 1PPS but do affect the UTC TOD; UTCO only affects the 1PPS generation; normally UTCO is very small in Galileo (just a few ns), thus GST and UTC normally agree within a few ns (leap seconds aside). For receiver timing performances in the following chapters, UTC will refer to the UTC non materialized as defined and maintain by BIPM.

In a general way, one can distinguish between synchronization users and timing users. Synchronization users only need the 1PPS signal (aligned to GST, sometimes to UTC). They do not need TOD or can get it from other means such as NTP. Timing users need the 1PPS signal aligned to UTC and use the UTC TOD for time stamping. In the following, it will be assumed that “timing” includes both synchronization and time stamping.

The required maximum error (or “accuracy”) on the 1PPS (either vs GST or vs UTC) depends on the application.

Today, the typical required accuracy requested in several applications within critical infrastructure, is of the order of 1 microsecond: PMR and PSTN within Telecommunications, PMU within Energy and also for Finance applications. Upcoming applications such as Smart Grids (Electricity transmission), Satcom, digital cellular networks, or 5G (telecom) require an accuracy of 100 ns or better. A few “niche” applications exploit the highest accuracy obtainable from GNSS (a few ns), e.g. astronomical interferometry (VLBI). The highest accuracy is also seen as an enabler for future applications. It is expected that future applications may require accuracy levels in the order of those defined for Service Level 3 in this document. Detailed information on T&S User Needs can be found in [63].

The particularity of timing receivers related with the possibility of fixing the position and computing only the Time component of the PVT is explained in Annex A. Other aspects such as calibration of time delays and installation are covered in Annex B.

4.2 Galileo Timing Service – Accuracy and Availability

The Galileo Timing Service will perform at least as good as the current Galileo OS Time Determination capability in what respect the Accuracy (30ns UTC in current SDD) and the Availability metrics.

The Timing Accuracy and Availability performances actually offered by Galileo are already much better, as reported in the Galileo Quarterly Performance Reports, please refer to [28].

The Galileo Timing Service will ensure the commitments on Accuracy and Availability provided on the future version of Galileo Service Definition Document, covering GST and UTC, for Galileo timing receivers fulfilling this document.

This will be thanks to the limits established on the timing receiver contributions to Accuracy (through receiver noise and calibration errors) and Availability (limited unavailability due to the receiver itself) through this document.

4.3 Galileo Timing Service – Integrity capability

4.3.1 General

As described above, the Galileo Timing Service concept includes integrity capability providing a level of trust to users.

To do so, the Galileo Ground Segment collects the signals broadcast by the Galileo constellation for the computation of Timing Flags specific for the Timing Service. The Timing Flags, together with the necessary information devoted to timing users, will be disseminated in the Galileo SIS, in a dedicated Word, the Timing Service Message (TSM).

This subclause describes the Timing Integrity capability of Galileo timing receivers which relies in the following pillars:

- processing of Timing Service Message;
- local barrier, T-RAIM.

Timing Integrity may use any other relevant source and process in addition to these two pillars.

4.3.2 Definition of a Fault-Free Timing solution

In order to define a fault-free timing solution, it is considered that the user requires the following information simultaneously and continuously:

- a 1PPS aligned either to GST or to UTC (as selected by the user) deviating less than a predefined Maximum Tolerable Error (MTE) from the selected reference (GST or true UTC);
- a correct GST TOD (WN+TOW) corresponding to the integer second nearest to the 1PPS, and reported immediately after the 1PPS;
- a correct UTC TOD (YYYY/MM/DD-HH:MM:SS) corresponding to the integer second nearest to the 1PPS, reported immediately after the 1PPS, including correct transitions over leap second application (:59,:60,:00,:01 or :57,:58,:00,:01).

Different MTE values to satisfy needs in different sectors can be defined as “Service Levels”, as shown in the tables in 5.3.6:

- Service Level 1: GST MTE of 1000ns and UTC MTE of 1000 ns
- Service Level 2: GST MTE of 100ns and UTC MTE of 100 ns

- Service Level 3: GST MTE of 15ns and UTC MTE of 30 ns

NOTE While SL1 and SL2 will be available in the short term, as of the Timing Service Declaration, SL3 will be implemented in a second step. The present version of the document is intended to SL1 and SL2. An update will be made for SL3.

4.3.3 Definition of a faulty timing solution

In contrast to the fault-free, a faulty timing solution can be defined as follows:

Definition of faulty timing solution:

At some instant in time (i.e. at some second), at least one of the following events occurs without being alerted within TTA:

- *the 1PPS, deviates more than a predefined Maximum Tolerable Error (MTE) from the selected reference (GST or true UTC); or*
- *the GST TOD (WN+TOW) corresponding to the integer second nearest to the 1PPS is incorrect compared to the true TOD; or*
- *the UTC TOD (YYYY/MM/DD-HH:MM:SS) corresponding to the integer second nearest to the 1PPS is incorrect compared to the true TOD, including an incorrect transition over a leap second application*

The Galileo Timing Service and the associated integrity barriers, relying at least on the processing of Timing Flags and T-RAIM as local barrier, is capable to mitigate the three aforementioned types of failures [18].

The Galileo Timing Service will ensure that, for Galileo timing receivers fulfilling this document, the probability of a faulty timing solution is lower than 10^{-5} per hour, and this for each Service Level.

4.3.4 High-Level Architecture of Galileo Timing Service

Figure 2 provides an overview of the Architecture for the Galileo Timing Service.

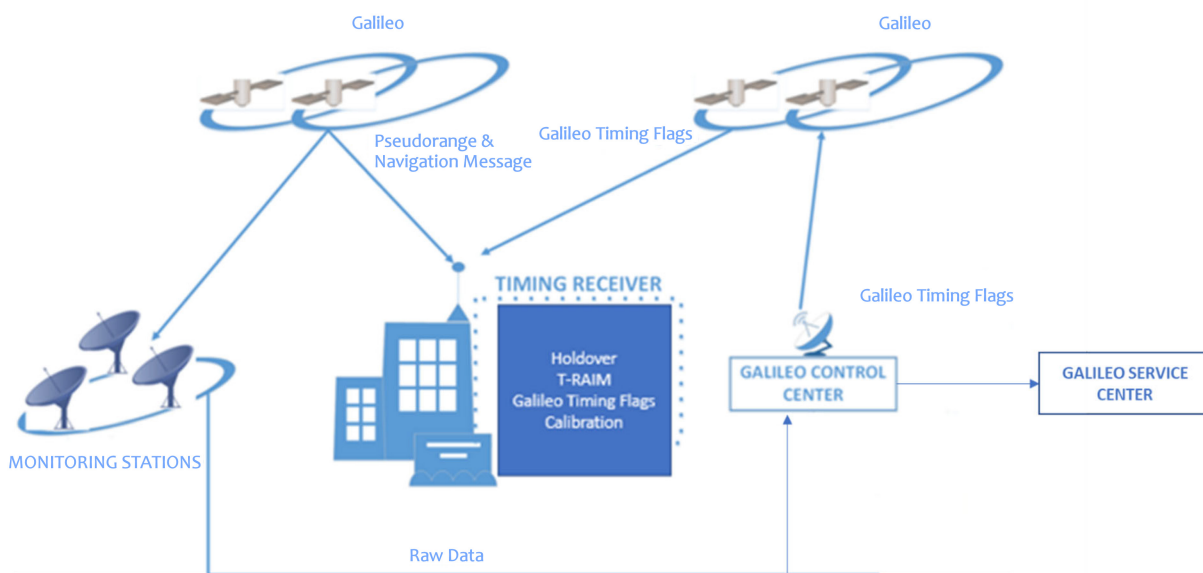


Figure 2 — Galileo Timing Service Architecture [30]

The standard, un-augmented GNSS signals for the user are pseudoranges and navigation messages received from the GNSS satellites (top left in the previous figures).

The user receives the Galileo TSM (including timing flags) from the Galileo SIS (top right in the previous figure). Each Galileo satellite distributes flags for the whole Galileo constellation.

The flags are calculated based on information from a network of Monitoring Stations providing global coverage. A Monitoring Station for timing includes a multi-band station with calibrated time delays. Calibrated means that the total delay of all Galileo pseudorange types supported by the architecture have been measured beforehand, where the delay includes the pseudorange full path along the GNSS antenna, the antenna cable, and the receiver itself. It is foreseen that some Monitoring Stations will have access to UTC realizations (i.e. UTC(k) laboratories), in order to compare with redundancy, the timing solution from GNSS using UTC(k) as truth. Information on the Monitoring Stations can be found in Galileo documentation.

Raw data from the Monitoring Stations (pseudoranges and navigation messages, bottom, centre in Figure 2) are streamed in real-time to a processing centre. The raw data are processed to generate Galileo timing flags for uplink to the satellites. The TSM is also provided to the Galileo Service Centre. Additional information could be available in Galileo documentation.

The user receiver processes the standard Galileo signals, plus the TSM dedicated to timing users. The Time algorithm of the receiver is as a minimum, based on a combination of local barrier (T-RAIM) approach and the processing of the TSM.

4.3.5 Timing Flags processing

4.3.5.1 Description of the processing

The Galileo Timing Service will disseminate Timing Flags for Galileo Dual-Frequency users in the Galileo SIS computed by a network of reference stations, with some of them (for redundancy purposes) having access to UTC realizations to also monitor events which could impact the timing solution for the UTC scale. Three Service Levels for the Integrity Monitoring are defined, based on Maximum Tolerable Errors (MTE). These Service Levels have been carefully selected to cover the User Needs of the different T&S applications and their feasibility has been assessed based on dedicated projects including experimentation [27]. See Table 4.

The timing flags will inform the users - within a given TTN Time To Notify - whenever the above MTEs are not respected. Due to the complexity of the broadcast mechanism in the Galileo SIS, the TTN is expected to be initially below 30 min and will be improved over time thanks to future evolutions in the Galileo System. Note that the TTN is improved with respect to the nominal Galileo Navigation Message update rate of a single satellite thanks to disseminating the Timing Flags of all the satellites in the Navigation Message of all the Satellites.

In parallel, the Timing receiver will implement local barriers. T-RAIM algorithms are capable of detecting a faulty solution in very short time [37]. In addition, they can react to local effects, beyond those covered at system level [68], [73], [7], [72], [47], [74] and [70].

At each epoch, the exclusion process based on the processing of timing flags shall be performed before applying T-RAIM algorithm, and even before the computation of the timing solution. Temporally, both barriers, Timing Flags and T-RAIM, work in parallel.

4.3.5.2 Timing Flags Definition

A description of the Timing Service Monitoring message is provided in Annex D as a reference in anticipation of the Programme level documentation. The most up to date definition of the TSM will be published by the Galileo Programme.

4.3.6 Galileo timing receiver Decision Logic

4.3.6.1 General

The processing at receiver level of the Timing Flags broadcast as part of TSM shall consider the following key principles as depicted in Figure 3:

- Galileo timing receiver shall continuously decode the TSM and always apply the most recent TSM;
- once the receiver detects that the time solution is not correct, violating one or more of the MTEs of the Monitoring Levels, it will inform the user. The synchronization unit hosting the Galileo timing receiver can then switch to the time solution provided locally by a holdover device (providing the output meets the Service Level performance), or continue providing the GNSS solution maintaining the alert to the user, or simply stop;
- the detection can be done either through the local barriers (e.g. T-RAIM) or through the Timing Flags. Any other relevant process may be added to those barriers;
- holdover capabilities may enable delivery of different Services Levels. Holdover solution shall be notified to user if no longer able to support the Service Level requirements;
- holdover time shall be monitored with integrity check of the local clock. In case of probability of error threshold is exceeded the holdover period shall be stopped or an alert shall be provided to the user;
- when in holdover mode, the synchronization unit hosting the Galileo timing receiver cannot switch back to the Galileo solution unless the following conditions are met:
 - o local check shows that again, the Timing Error is below the MTE;
 - o timing Flags in TSM (the flag for a given satellite, received through the TSM of all satellites), for the corresponding SL, are back to “Use” (in all TSMs) after a period of at least $2 \times \text{TTN}$ since the first detection by the local barrier. This later check is needed to ensure that the situation is again the same as before the fault is detected (and thus all commitments are again applicable);
- if the switch to holdover mode was due to the setting to “Don’t Use” of one or more timing Flags in the TSM, since a quarantine time equal to TTN is required as per requirement REQ_PERFO_QUARANTINE_01, it implies that the minimum time in which the synchronization unit hosting the Galileo timing receiver can stay in holdover mode shall be two times the Galileo TTN: $2 \times \text{TTN}$. Considering the minimum time in which the synchronization unit hosting the Galileo timing receiver can stay in holdover mode equal to TTN would be too stringent. The reason is that additional time shall be accounted for the detection function within the Galileo system, plus a minimum margin to cope with potential broadcast glitches;
- on the other hand, the total time that the synchronization unit hosting the Galileo timing receiver may have to stay in holdover mode can be as high as the duration of the fault plus 100 min¹, where the duration of the fault can be either its actual duration or the time until the fault is restored by the System (whatever happens first);
- the synchronization unit hosting the Galileo timing receiver can continue in holdover mode up to a timeout limit. The timeout depends on the target Service Level and the accuracy of the local oscillator. Beyond the validity timeout limit the timing solutions for the Service Levels are not guaranteed. Following the above definitions, this will happen when the holdover solution can no longer guarantee

¹ Maximum time to refresh the TSM of all satellites in the constellation.

that the error remains below MTE with a probability similar to that guaranteed by the GNSS solution, that is, 10^{-5} failures per hour as detailed in 5.4.4.1;

- holdover time could be set up as a part of the configuration of each receiver, depending on the target Service Level and on the quality of the holdover device.

Figure 3 depicts an overview of a part of the processing logic.

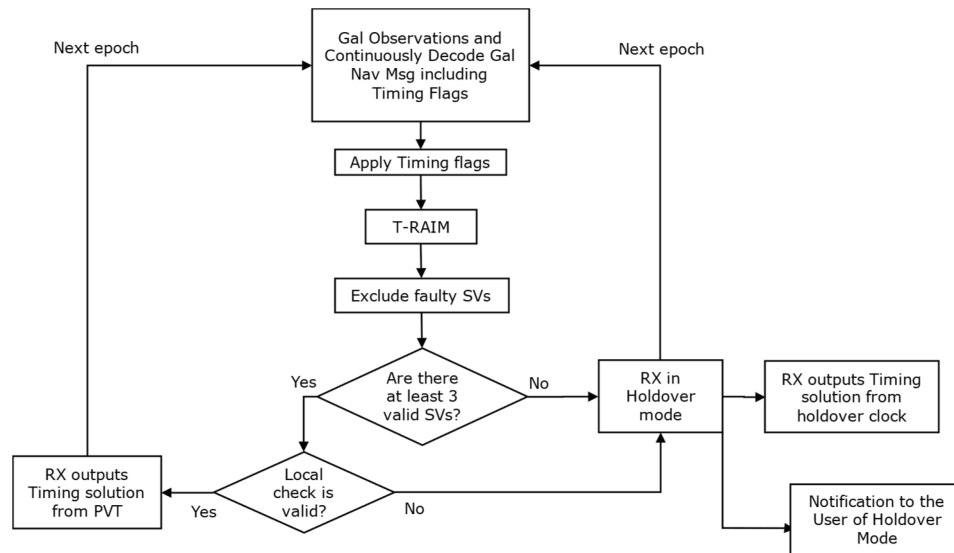


Figure 3 — Galileo timing receiver, part of the processing Decision Logic with respect to T-RAIM and Timing Flags processing

Note that in the previous figure, 3 valid satellites are requested as this is a minimum number of satellites for applying T-RAIM algorithms by conducting consistency checks.

Note that the application of the Timing Flags in the previous figure is explained in detail and depicted in additional Figures in 4.3.6.3.

4.3.6.2 Conditions to use specific satellites when Switch-on

When the Receiver is switched-on, the conditions to use a specific satellite in the Timing Solution are:

- all the TSM received indicate that the Satellite can be used;
- local barriers (as a minimum, T-RAIM) does not discard the satellite.

There is no need to wait TTN to start using satellites since the combined probability of having a fault before start-up, having no satellites in view updated with the latest value of the Timing flag before TTN, and the missed detection probability of the local barriers, is extremely low, that is, well below the integrity threshold.

4.3.6.3 Processing Galileo SIS OS Status Flags and Processing Logic for Galileo timing receivers

The definition of Signal Health Status (SHS), Data Validity Status (DVS) and Signal-In-Space-Accuracy (SISA) is provided in the Galileo OS Service Definition Document [31] as well as the mapping between these Flags and the OS SIS Status.

The Galileo timing receiver shall take into account those flags depending on the intended Service Level. The requirements associated to the detailed processing are defined in 5.3.6. In short, the logic is as follows:

- SHS shall be processed and applied for all Service Levels;
- DVS shall not be processed and applied by SL1 users. DVS shall be processed and applied by SL2 (and SL3 users in future);
- SISA shall not be processed by neither SL1 nor SL2. TBC for SL3 users.

Figure 4 and Figure 5 show the combined processing logic of Galileo OS SIS Status Flags and Galileo TSM GST and UTC Status Flag for each SL.

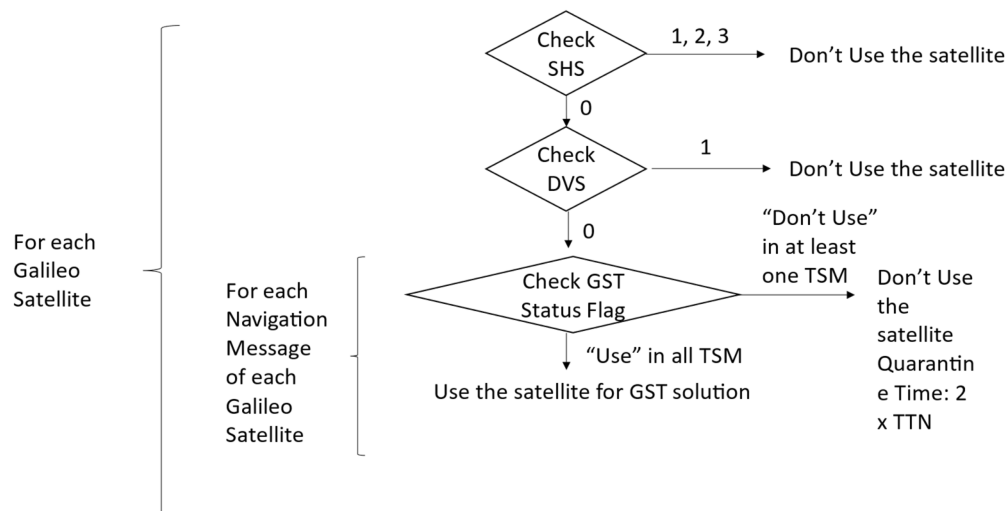


Figure 4 — Processing Logic of Galileo OS SIS Status Flags and Galileo TSM GST Status Flag for SL2 and SL3 users

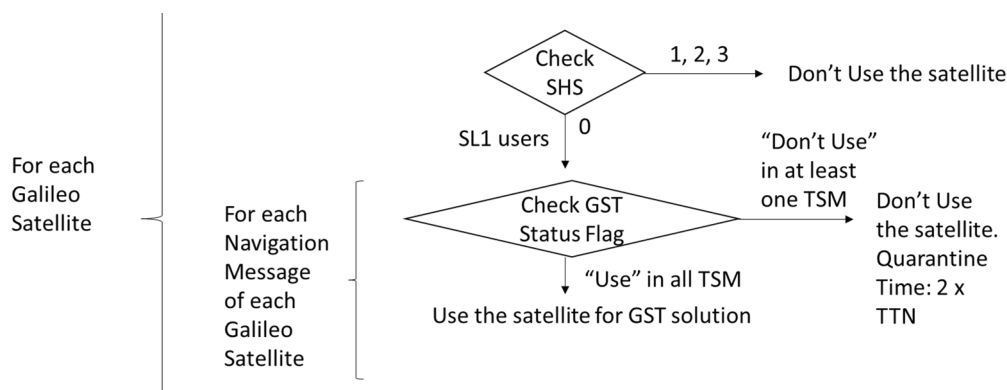


Figure 5 — Processing Logic of Galileo OS SIS Status Flags and Galileo TSM GST Status Flag for SL1 users

Figure 6 and Figure 7 show the combined processing logic of Galileo OS SIS Status Flags and Galileo TSM UTC Status Flag. Note that as per UTC flag definition, the flag informs about the delta GST-UTC so both flags are to be considered for the UTC timing solution.

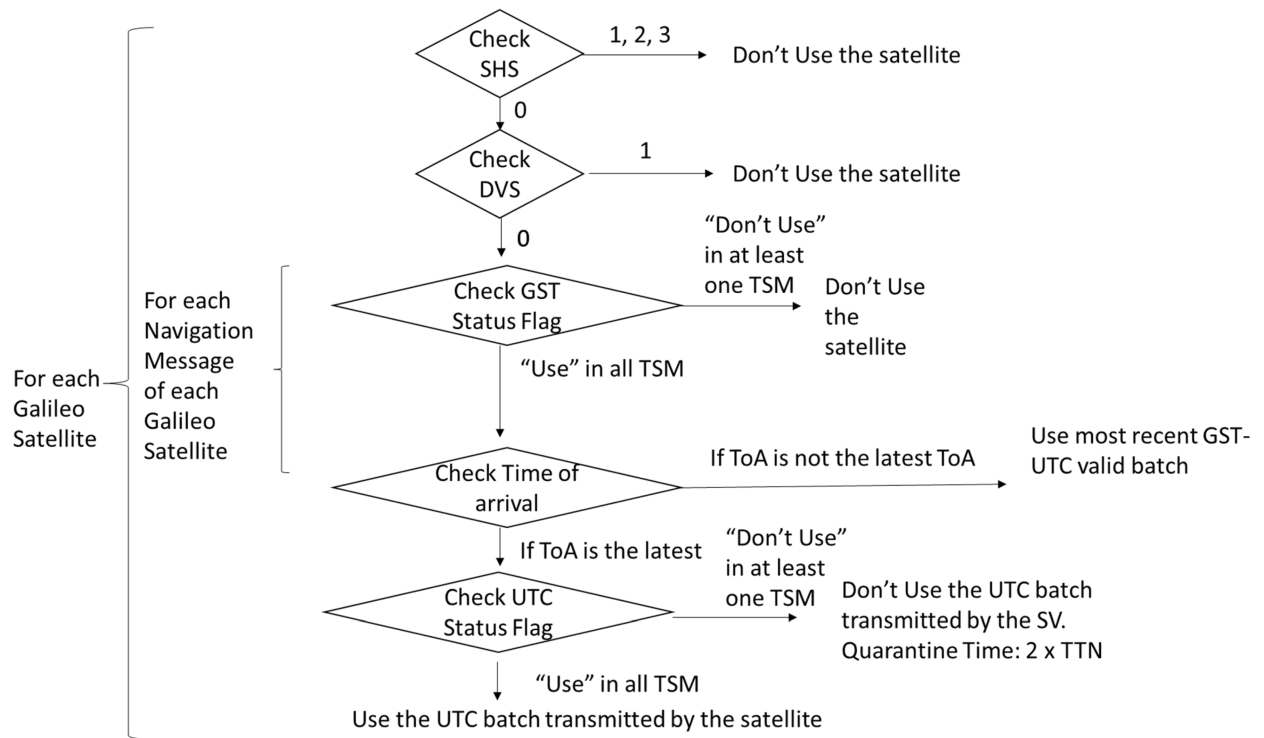


Figure 6 — Processing Logic of Galileo OS SIS Status Flags and Galileo TSM UTC Status Flag for SL2 and SL3 Users

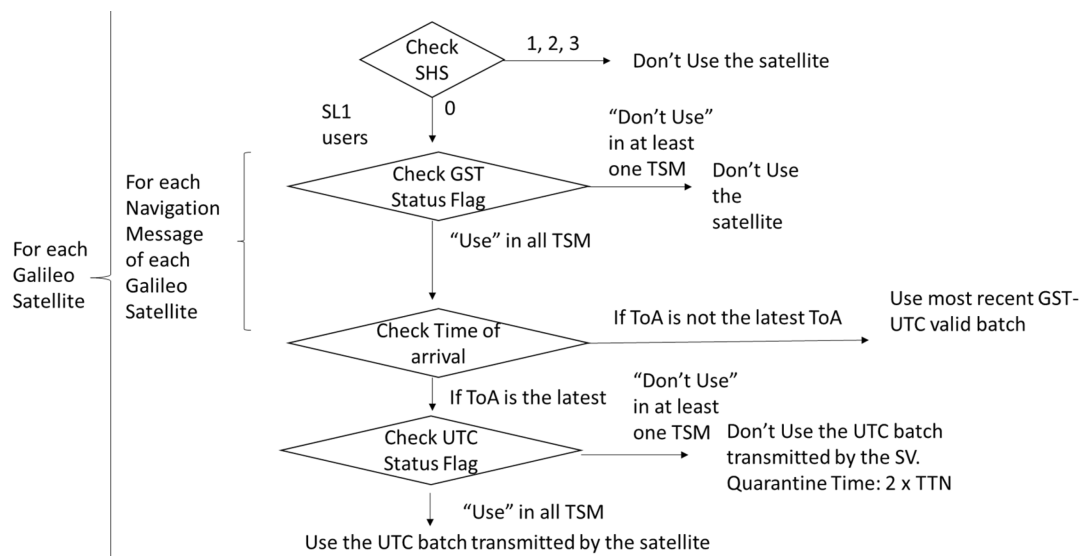


Figure 7 — Processing Logic of Galileo OS SIS Status Flags and Galileo TSM UTC Status Flag for SL1 Users

A future version of the Galileo OS Service Definition Document [2] will include the Galileo Timing Service, will indicate the combined use of the Galileo Timing Service Flags and the Galileo SIS OS Status Flags and will be the Master document detailing the processing.

4.3.7 Time To Alert and Time To Notify

Time-To-Alert for the Galileo Timing Service is defined as the delay in which the Galileo timing receiver raises an alert whenever the MTE of the corresponding Service Level is not met. Taking into account that the integrity processing is composed of two level of barriers working in parallel: local (T-RAIM) and system (timing flags), the Time To Alert is defined by the barrier which is triggered first. Local barriers such as T-RAIM can trigger in shorter time (order of seconds).

The TTN (Time-To-Notify) is defined as the delay in which the Galileo timing receiver will receive an alert in the TSM of the Galileo Navigation Message of any satellite whenever the MTEs are not met by the Galileo System. It needs to account for the dissemination time through the SIS. The Galileo Timing Service will alert of a failure in the SIS delivered, initially in less than 30 min for SL1 and SL2, through the TSM. This TTN will gradually be reduced over time.

4.3.8 T-RAIM Processing

T-RAIM allows, from GNSS receivers in position-lock mode, computing the distribution of time recovery from all visible individual satellites, and to reject the outliers. As stated in [45] choosing the masking angle is a trade-off between reduced satellite availability and increased integrity level of the time estimate. In this document a masking angle of 5° is the baseline since open sky conditions are applicable.

For liability and safety timing applications, and in particular for T&S for critical infrastructure, integrity of the timing determination service is necessary to ensure trustworthiness on the service. T-RAIM algorithms have been used in timing applications to improve the timing solution by detecting and excluding faulty satellites. T-RAIM is a robustness measure to complement the timing flags broadcast by the system and can cope with local effects. T-RAIM is a denomination commonly used to refer to RAIM-like algorithms for timing. When referring to the aforesaid algorithms, “timing version” mean the same algorithm, conceptually, but with the adaptation derived from the fact that the clock component rather than any spatial component shall be protected for static user. Therefore, any algorithm step that operates in the measurement domain (e.g. chi-squared test on the residuals) remains the same, and those steps that operate in the position-time domain (e.g. computation of the protection level) are modified to address the clock component(s) rather than the horizontal or vertical ones. T-RAIM algorithms are based on redundancy in the GNSS time solution [11] and monitoring residuals from time-only solutions. Using T-RAIM has been shown to help maintain the synchronization signal stability during satellites anomalies, even under extreme conditions [44]. T-RAIM algorithms are based on detecting, and eventually excluding, faulty measurements (this is, the ones for which the value exceeds an alarm threshold level) from the solution. Faulty measurement shall be notified to the Galileo timing receiver output.

Another interesting RAIM-like candidate technique is IBPL [5]. As with the aforementioned techniques, IBPL adaptation to timing is straightforward and it could be called TIBPL.

No specific constrain about T-RAIM design is targeted with the present standard.

In turn, the Galileo timing receiver is requested to pass the robustness tests defined in the standard. This is following a performance-based approach for the document rather than a prescriptive approach for the algorithm to be implemented.

5 Requirements for Galileo timing receivers

5.1 Definitions

Relevant definitions for the Requirements laid down in Clause 5 can be found in 3.1.

5.2 Minimum Equipment Characteristics

Table 2 depicts:

- a summary of the Galileo Timing Service end-to-end targets performances, for which the Timing receivers fulfilling the requirements in this standard will be able to benefit (for accuracy and integrity);
- and a matrix of the Minimum Equipment Characteristics to fulfil each of the Service Levels.

Table 2 — Summary of Galileo Timing Service end-to-end targets achievable thanks to the Standard (Accuracy and Integrity)

Requirement	Service Level 1	Service Level 2	Service Level 3
Maximum Tolerable Error vs “true” GST (ns) including receiver contributions	1000	100	15
Nominal GST accuracy (95 %, ns), including receiver contributions ^a	5	5	5
Maximum Tolerable Error vs “true” UTC (ns) including receiver contributions	1000	100	30
Nominal UTC accuracy (95 %, ns), including receiver contributions ^b	10	10	10
^a Target to be achieved with G2G. timing receivers not fulfilling the requirements in this Standard would not be able to benefit from this level of end-to-end performance. ^b Target to be achieved with G2G. timing receivers not fulfilling the requirements in this Standard would not be able to benefit from this level of end-to-end performance.			

Table 3 — Summary of Minimum Equipment Characteristics to meet the Service Levels

Requirement	Service Level 1	Service Level 2	Service Level 3
Galileo tracking	MANDATORY	MANDATORY	MANDATORY
Compensation of total chain delay	MANDATORY	MANDATORY	MANDATORY
Generation of raw observables	MANDATORY ^a	MANDATORY ^c	MANDATORY
Multi-frequency	MANDATORY ^b	MANDATORY ^d	MANDATORY
T-RAIM ^c	MANDATORY	MANDATORY	MANDATORY
Processing of broadcast Galileo GST/UTC timing flags	MANDATORY	MANDATORY	MANDATORY
Calibration (of time delays) Level required (see B.3)	1 (MANDATORY)	2 (MANDATORY)	3 (MANDATORY)
Minimum antenna location	Open sky, fixed known position (at 5cm level) ^d	Open sky, fixed known position (at 5 cm level) ^e	Open sky, fixed precisely (at 5cm level) known position
Reporting of GST/UTC estimation accuracy	MANDATORY	MANDATORY	MANDATORY
Galileo OS-NMA processing to ensure Authentication	MANDATORY	MANDATORY	MANDATORY
^a Required only to assess the results of the TC-13 test. The generation of a RINEX file is recommended to provide raw observables. ^b Multi-frequency for SL1 and SL2 could not strictly be needed since the Maximum Tolerable Error is easily reached by Single-Frequency Galileo timing receivers. Nevertheless, as the Timing Flags disseminated by the Galileo Timing Service are defined for Dual-Frequency users, the Galileo Timing Service with Integrity capability will be offered only to Dual-Frequency Users and then, the Galileo timing receiver Standard will focus on Dual-Frequency users only. ^c Additional local barriers on top of T-RAIM are also allowed. ^d Fixed known antenna position is the baseline although for SL1 and SL2, it is not strictly needed to ensure MTE (integrity). Nominal error shall still be below few cm to ensure accuracy performance. On the contrary, for SL3 MTE it is strictly needed a precise known antenna position at the sub-decimeter level. ^e From ISO GUIDE 99 [68].			

Tables 2 and 3 reflect the end-to-end target performances that the Galileo Timing Service can achieve with timing receivers fulfilling the requirements in this document. Tables 2 and 3 are not a summary of Requirements applicable to the Galileo timing receivers. The Requirements explicitly applicable to Galileo timing receivers under this document are specified in 5.3 and 5.4.

In Table 3, fixed position means static users (non-moving) for which the position of the antenna is known.

Note that generation of raw observables is compulsory for Service Level 3 since it is needed to precisely compute the Antenna position. Generating raw observations in a commonly known format would help very much the users the configuration of the equipment. Using an online PPP service for such computation is recommended but other alternative technologies are suitable, for example, post-processing RTK.

NOTE The present version of the Standard is intended to SL1 and SL2. An update will be made for SL3. Nevertheless, the present version already advances requirements to support SL3.

The following subclauses develop the Functional and Performance Requirements in detail.

5.3 Functional Requirements

5.3.1 Constellations Processed

REQ_FUNCT_CONST_01: The Galileo timing receiver shall start-up with and process Galileo constellation SIS according to the Galileo OS SIS ICD [32].

NOTE 1 Current version of the Galileo OS SIS ICD is provided in [32]. At the time of this writing, it does not include the TSM for the Galileo Timing Service. A future version of the Galileo SIS ICD, or an equivalent document including the TSM will be issued.

NOTE 2 The Galileo Timing Service performance commitments will be included in a future version of Galileo SDD (current version: [31]).

NOTE 3 This document does not cover the processing of GPS constellation but this does not preclude Manufacturers to implement GPS processing within the Galileo timing receivers, even if not addressed in this document. The use of other GNSS constellations is not forbidden by this document but the requirements and tests are defined considering Galileo-only.

5.3.2 Frequencies Processed

REQ_FUNCT_FREQ_01: The Galileo timing receiver shall be able to track dual-frequency Galileo signals, as a minimum E1+E5a or E1+E5b.

REQ_FUNCT_FREQ_02: The Galileo timing receiver shall process as a minimum dual-frequency iono-free pseudoranges.

IMPORTANT Single-Frequency modes are not covered by this document. This does not preclude Manufacturers to implement single-frequency modes within the Galileo timing receivers, even if not addressed in this document, as a back-up of the nominal Dual-Frequency mode, and reversion mechanisms. It is important to remark that the integrity of the Timing solution is only ensured for Dual-Frequency Mode.

5.3.3 Back-up Modes

Holdover mode is a valid back-up mode for the synchronization unit hosting the Galileo timing receiver upon a failure in the GNSS timing solution provided the performance requirements specified in 5.4 are still met. The fulfilment of the performance requirements in holdover mode would be a requirement for the synchronization unit hosting the Galileo timing receiver, but not for the Galileo timing receiver chipset itself, which is the subject of this document.

NOTE In this respect, a failure in the GNSS timing solution failure occurs when the performance requirements in 5.4 are not met by Galileo only mode or when the time flags for less than a minimum number of Galileo satellites are set to Don't Use.

5.3.4 Dynamics of the User

REQ_FUNCT_DYN_01: The Galileo timing receiver shall be operated in static conditions.

REQ_FUNC_DYN_02: The Galileo timing receiver shall be configurable in “fixed” or “free” antenna position mode; in “free” mode the antenna position shall be estimated together with the local clock offset; in “fixed” mode a set of input antenna coordinates shall be used by the receiver and only the local clock offset shall be estimated. Fixed mode is the Baseline mode covered in this document, for which the performance requirements are defined. The Requirements specified in this document do not apply to “free” mode.

NOTE 1 Examples of precise antenna location computation are given in the Guidelines for Installation and Maintenance in Annex B. The precise computation of the antenna position would be the responsibility of the User. For example, PPP Techniques can be used for the precise computation of the antenna position in particular for Service Level 3. The requirements and tests in this document consider “known” mode.

REQ_FUNC_DYN_03: In “fixed” position mode the Galileo timing receiver shall be able to use and store in memory 3D coordinates as estimated and configured by the user, with a resolution equivalent or better than 1 cm when translated in Cartesian ITRF coordinates.

REQ_FUNC_DYN_04: In “fixed” position mode, the receiver shall be able to obtain the timing solution when at least three Galileo satellites in view are available.

In the situation defined in REQ_FUNC_DYN_04, the integrity requirements for SL3 in this document are not applicable since for them, more than three satellites in view (TBD the minimum number) may be necessary.

NOTE 2 The Galileo timing receiver can also provide an output with less than 3 satellites in view with a warning.

5.3.5 Time Scales

REQ_FUNCT_TIMESCALE_01: The Galileo timing receiver shall be able to obtain the timing solution aligned to GST or to UTC, as configured by the user, and to generate an output 1PPS signal accordingly.

5.3.6 Processing of Timing Flags and Integrity Requirements

The Galileo timing receiver decision logic processing, expected by the Galileo Timing Service, is described in detail in Sect 4.3.6. This subclause provides the requirements applicable to the Galileo timing receiver that shall be implemented, derived from such decision logic processing.

REQ_FUNCT_TIMINGFLAGS_01: The Galileo timing receiver shall be either configurable or developed to provide a Timing Solution according to one of the following Service Levels in Table 4.

Table 4 — Service Levels

Service Level	Maximum Tolerable Error for GST (ns)	Maximum Tolerable error for UTC (ns)
1	1000	1000
2	100	100
3	15	30

If not configurable, the Galileo timing receiver shall process the Timing Flags according to the Service Level targeted by the product.

REQ_FUNCT_TIMINGFLAGS_02: The Galileo timing receiver shall continuously decode the Galileo OS SIS, including the TSM when available.

REQ_FUNCT_TIMINGFLAGS_03: The Galileo timing receiver shall process the following data related with timing integrity contained in the TSM, as described in Annex D:

- GST status flag for each active SVID with a capacity of 36 SVIDs flag processed in parallel;
- UTC status flag;
- IODUTC.

NOTE 1 The dissemination of the timing flags is expected on E1 and on E5b.

REQ_FUNCT_TIMINGFLAGS_04: The applicable Timing Flags are the ones decoded from Galileo E1 or E5b.

REQ_FUNCT_TIMINGFLAGS_05: The Galileo timing receiver shall apply the GST and UTC status flags for the exclusion of faulty satellites from the Timing solution.

REQ_FUNCT_TIMINGFLAGS_06: When two different GST-UTC batches are on broadcast (this will be the nominal case every time there is an update), the receiver shall apply the latest data set (latest Time Of Arrival as measured by the receiver) as soon as it has been confirmed valid by all the TSM received.

This means that in order to include a satellite, all TSM shall indicate “Use”, and not only the latest one.

Validity checks should include consistency checks against parameter sets broadcast by other satellites (in particular, it is recommended that the receiver is always conducting checks between the UTC parameters disseminated by all the satellites), and OSNMA authentication of the received message.

REQ_FUNCT_TIMINGFLAGS_07: The Galileo timing receiver shall interpret each GST status flag disseminated in Galileo E1 or E5b as specified in Table 5.

Table 5 — GST status flags interpretation in Galileo E1 or E5b

GST status flag	Definition	Interpretation
000	Not OK	Don't Use for SL 1 Don't Use for SL2 Don't Use for SL3
001	Timing service level 1	Use for SL 1 Don't Use for SL2 Don't Use for SL3
010	Timing service level 2	Use for SL 1 Use for SL2 Don't Use for SL3
011	Reserved for Timing Service Level 3	Use for SL 1 Use for SL2 Use for SL3
100	Spare	—
101	Spare	—
110	Spare	—
111	Monitoring not available	—

REQ_FUNCT_TIMINGFLAGS_08: The Galileo timing receiver shall interpret each UTC status flag disseminated in Galileo E1 or E5b as specified in Table 6.

Table 6 — GST-UTC status Flags interpretation in Galileo E1 or E5b

GST-UTC status flag	Definition	Interpretation
000	Not OK	Don't Use for SL 1 Don't Use for SL2 Don't Use for SL3
001	Timing Service Level 1	Use for SL 1 Don't Use for SL2 Don't Use for SL3
010	Timing Service Level 2	Use for SL 1 Use for SL2 Don't Use for SL3
011	Reserved for Timing Service Level 3	Use for SL 1 Use for SL2 Use for SL3
100	Spare	—
101	Spare	—
110	Spare	—
111	Spare	—

For both GST and UTC status flags, the Galileo timing receiver can use the satellites flagged as “Use” for the Service Level in which the Receiver is operating as per the previous tables.

REQ_FUNCT_TIMINGFLAGS_09: The applicable GST/UTC status flags are the ones referred to the same Service Level, or higher, for which the Galileo timing receiver has been configured or developed.

NOTE 2 A receiver can make use of a set of satellites provided all satellites in the set are marked as “Use” for a Service Level equal or higher than the intended one.

REQ_FUNCT_TIMINGFLAGS_10: A satellite marked as “Don't Use” in the GST status Flag for the configured Service Level in the Navigation Message of any satellite shall be excluded from the Timing Solution aligned to GST provided by the Galileo timing receiver.

NOTE 3 A satellite marked as “Don't Use” is either “Not OK”, or marked to be usable only for a Service Level less stringent than the one applicable, or “Monitoring not available”.

REQ_FUNCT_TIMINGFLAGS_11: A satellite marked as “Don't Use” in the GST Flag or in the UTC Flag for the configured Service Level in the Navigation Message of any satellite shall be excluded from the Timing Solution aligned to UTC provided by the Galileo timing receiver.

In this requirement, not using a satellite marked as “Don't Use” in its UTC Status Flag means not using the GST-UTC conversion parameters disseminated by that satellite.

The previous requirements imply that if different values of Timing Flags for the same satellite have been received and are active for the same satellite, the most conservative Flags should be applied.

REQ_FUNCT_TIMINGFLAGS_12: If the GST status Flag for a satellite set to “Don't Use” is received for the configured Service Level, the satellite shall not be included again in the GNSS GST nor UTC Timing solution until the GST status Flag for that satellite is set to “Use” again in the Navigation Message of all visible satellites.

REQ_FUNCT_TIMINGFLAGS_13 If the UTC status Flag for a satellite set to “Don’t Use” is received for the configured Service Level, the GST-UTC conversion parameters disseminated by that satellite shall not be used again in the GNSS UTC Timing solution until the UTC status Flag for that satellite is set to “Use” again in the Navigation Message of all visible satellites.

NOTE 4 Once the receiver detects that the time solution is not correct, violating one or more of the MTEs of the Monitoring Levels, it will inform the user. The synchronization unit hosting the Galileo timing receiver can then either switch to the time solution provided locally by a holdover device (providing the output meets the Service Level performance), or continue providing the GNSS solution maintaining the alert to the user, or simply stop.

Other situations in which the synchronization unit hosting the Galileo timing receiver could switch to the solution provided by the holdover device, or alert the user, or simply stop are:

- the Timing Flags for all the Galileo Satellites are set to Don’t Use;
- the number of available satellites to compute the Timing Solution is less than the minimum number of satellites defined in 5.4.3;
- available cross checks between different solutions show a non-tolerable discrepancy between different timing solutions. Available cross checks could be GNSS vs Local Oscillator or others.

REQ_FUNCT_TIMINGFLAGS_14: The barriers for detection of a satellite leading to a failure in the timing solution by the Galileo timing receiver shall include both local barriers (at least T-RAIM) and the application of the timing flags information received through TSM.

Holdover

The synchronization unit hosting the Galileo timing receiver should start counting the holdover time t_{holdover} , from the moment when the switch is performed. This would be a requirement for the synchronization unit hosting the Galileo timing receiver, but not for the Galileo timing receiver chipset itself.

The maximum holdover period will depend on the type of local Holdover Mode. In case local Holdover Mode is based on local clock, local clock is affected by its own accuracy, accumulating time error with time. In any case, holdover period shall adapt to the target Service monitoring level, higher Service monitoring level implies more stringent accuracy.

REQ_FUNCT_TIMINGFLAGS_15

The Galileo timing receiver shall indicate to the synchronization unit to switch back to the GNSS solution only if the following conditions are met:

- local check of the GNSS timing solution is again accomplishing the MTE of the service level configured for the operation;
- timing Flags indicate “Use” after a period time of at least $2 \times \text{TTN}$ since the first detection by the local barrier.

NOTE 5 This later period of time of $2 \times \text{TTN}$ is needed to ensure that the situation is again the same as before the fault is detected (and thus all commitments for the Service Level are again applicable). This period accounts for the detection function within Galileo, plus a minimum margin for the TSM broadcast.

The above conditions imply that when switched to Holdover Mode, the synchronization unit hosting the Galileo timing receiver shall stay in Holdover Mode a minimum time of $2 \times \text{TTN}$.