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Foreword

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1 Scope

Based on the March 2003 GALILEO system definition, in the present document, as proposed in [1]:

- the potential benefits of using Galileo (alone or combined with GPS) on service performance: in particular the availability improvements for in urban/indoor environment are highlighted.
- the expected complexity differential between 3GPP mobiles utilizing A-GPS and those that might utilize a combination of A-GPS plus “Assisted GALILEO” is described.
- the changes that might be needed to 3GPP standards to support “assisted Galileo” in addition or in combination with the currently specified assisted GPS are identified
- from the 3GPP community point of view, the desirable characteristics of GALILEO that would minimize the impact to 3GPP mobiles when introducing the extension of A-GPS techniques to GALILEO are proposed.

These informations will allow 3GPP to decide whether or not to initialise 3GPP standard changes to introduce GALILEO. The final 3GPP standard modifications should be reassessed against the final GALILEO definition.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[<seq>] <doctype> <#>[([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

[1] S2-022472: “Work Item Description: Study into applicability of GALILEO for LCS” (http://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_26_Toronto/Tdocs/s2-022472.zip)

[2] GPS Standard Positioning Service - Performance Standard - October 2001

[3] Department of Defense World Geodetic System 1984
Its Definition and Relationships with Local Geodetic Systems.
U. S. National Imagery and Mapping Agency
NIMA TR8350.2 - Third Edition - Amendment 1 - 3 January 2000

[4] 3GPP TS 23.271: “Functional Stage 2 Description of LCS”

[5] 3GPP TS 03.71: “Location Services (LCS) – Functional Description – Stage 2 – Release 1999”

[6] 3GPP TS 25.331: “Radio Resource Control (RRC) - Protocol Specification“

[7] 3GPP TS 29.002: “Mobile Application Part (MAP) Specification”

[8] 3GPP TS 29.198: “Open Service Access - Application Programming Interface - Part 6: Mobility”

[9] 3GPP TS 24.080: “Mobile Radio Interface Layer 3 – Supplementary Services Specification”

3 Definitions, symbols and abbreviations

3.1 Definitions

3.2 Symbols

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

A	Interface between 2G-MSC and BSS
Gb	Interface between 2G-SGSN and BSS
Iu	Interface between RAN and CN
Iupc	Interface between RNC and SAS (Standalone SMLC)
Lc	Interface between gateway MLC and gsmSCF (CAMEL interface)
Le	Interface between External User and MLC (external interface)
Lg	Interface between Gateway MLC - VMSC, GMLC - MSC Server, GMLC - SGSN (gateway MLC interface)
Lh	Interface between Gateway MLC and HLR (HLR interface)
Um	GERAN Air Interface
Uu	UTRAN Air Interface

3.3 Abbreviations

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

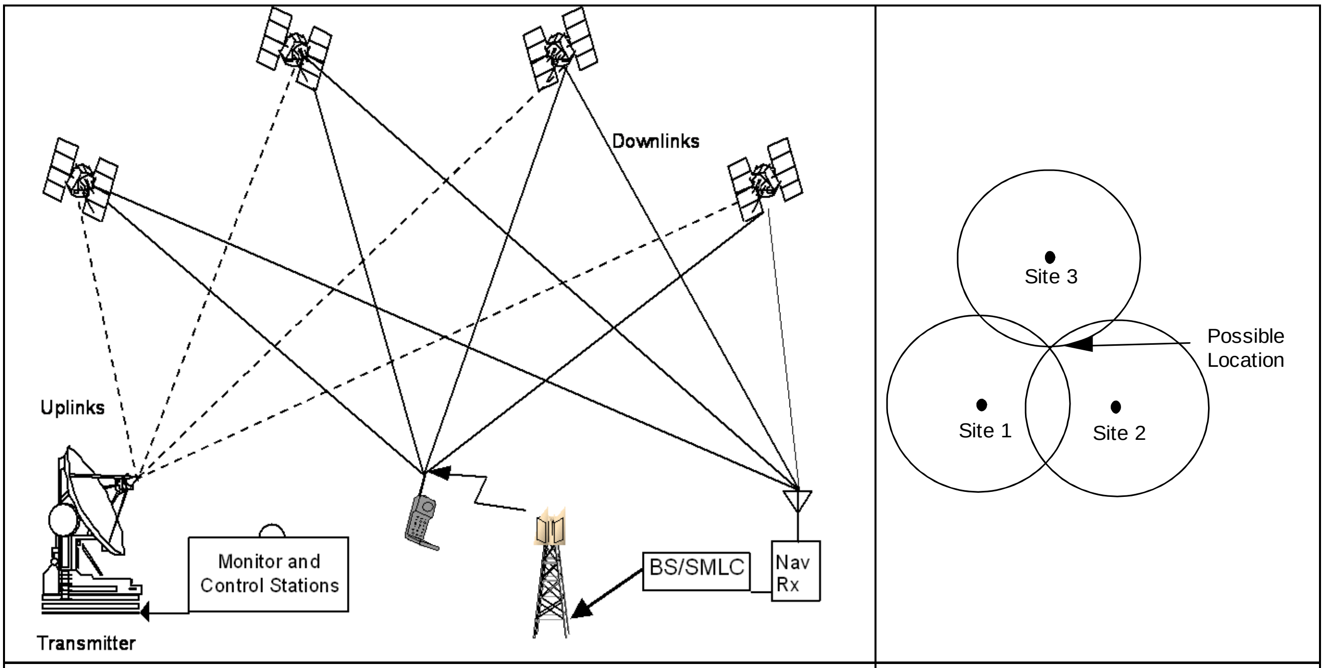
BOC	Binary Offset Carrier
BPSK	Bipolar-Phase Shift Key
CN	Core Network
DME	Distance Measuring Equipment
E-OTD	Enhanced Observed Time Difference
ESA	European Space Agency
Ffs	For further study
GERAN	GSM EDGE Radio Access Network
GLONASS	GLObal Navigation Satellite System (Russia)
GMLC	Gateway MLC

GNSS	Global Navigation Satellite System
GOC	Galileo Operation Center
GPS	Global Positioning System
GTRF	Galileo Referential Terrestrial Frame
HLR	Home Location Register
HSS	Home Subscriber Server
IE	Information Element
IERS	International Earth Rotation Service
IGS	International GPS Service
IPDL	Idle Period Downlink
ITRF	Inertial Terrestrial Reference Frame
LCAF	Location Client Authorization Function
LCCF	Location Client Control Function
LCCTF	Location Client Co-ordinate Transformation Function
LCF	Location Client Function
LCS	Location Services
LSAF	Location Subscriber Authorization Function
LSBcF	Location System Broadcast Function
LSBF	Location System Billing Function
LSCF	Location System Control Function
LSOF	Location System Operations Function
LSPF	Location Subscriber Privacy function
Mcps	Mega chips per second
MLC	Mobile Location Center
MSC	Mobile services Switching Centre
NGS	National Geodetic Survey
NIMA	National Imagery and Mapping Agency
OSA	Open Service Access
OTDOA	Observed Time Difference Of Arrival
PCF	Positioning Calculation Function
PLMN	Public Land Mobile Network
PRCF	Positioning Radio Control Function
PRN	Pseudo-Random Noise
PRRM	Positioning Radio Resource Management
PRS	Public Regulated Service
PSMF	Positioning Signal Measurement Function
RAN	Radio Access Network
RNSS	Radio-Navigation Satellite Service
RRC	Radio Resource Control
SAR	Search And Rescue
SAS	Standalone SMLC
SBAS	Satellite Based Augmentation System
SGSN	Serving GPRS Support Node
SIS	Signal In Space
SoL	Safety-of-Life Service
SPS	Standard Postioning Service
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
USNO	US Naval Observatory
UTC	Universal Time Co-ordinated
UTRAN	Universal Terrestrial Radio Access Network
VSAT	Very Small Aperture Terminal
WAAS	Wide Area Augmentation System
WGS 84	World Geodetic System 1984

4. Benefits on Location-Based Service Performance

4.1 Navigation Satellite Based Location Principles

Navigation constellations provide a means to determine position, velocity, and time around the globe. These constellations use satellites emitting radio signals to the receiver to determine the position of the receiver. A satellite system consists of satellites, receivers, and monitor and control stations as shown in Figure 4.1-1.



A typical Navigation Satellites Positioning System | **TOA Positioning System**

Figure 4.1-1: A typical Navigation Satellites Positioning System / TOA Positioning System

The four satellites shown in Figure 4.1 emit radio signals from space. Each satellite's signal is modulated by a navigation message that includes accurate time and a description of the satellite's position. Positioning measurement of the receiver is based on the time of arrival (TOA) principle. When 4 or more satellites are in line of sight from the receiver (or receiving antenna), the latitude, longitude, and altitude of the receiver are determined.

The right Figure is used to depict a simplified two-dimensional view of this principle. A TOA system determines the position based on the intersection of the distance (or range) circles. The range is calculated from the signal transmission time, which is derived by multiplying the time by the speed of the signal. Three range measurements determine a unique position. Geometric accuracy is the highest within the triangle formed by the centers of the three circles. The accuracy gradually decreases as one moves away from the triangle. Navigation satellite based location uses the same principle, where the circle becomes the sphere in space and a fourth measurement is required to solve the receiver-clock offset. Because the receiver and satellite clocks are unsynchronized prior to the measurement, the signal transmission time determined by the receiver is not the true transmission time. As a result, the corresponding range measurement becomes a pseudorange measurement.

Although the satellite clocks are unsynchronised, the individual clocks are modelled to centimetre-level accuracy by the ground network. As a result, both the receiver position and clock offset can be derived from the equations below:

$$p_1 = \sqrt{(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2} + c(dT_1 - dt)$$
$$p_2 = \sqrt{(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2} + c(dT_2 - dt)$$
$$p_3 = \sqrt{(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2} + c(dT_3 - dt)$$
$$p_4 = \sqrt{(x-x_4)^2 + (y-y_4)^2 + (z-z_4)^2} + c(dT_4 - dt)$$

where (x_1,y_1,z_1), (x_2, y_2, z_2), (x_3, y_3, z_3) and (x_4, y_4, z_4) are the known satellite positions, p_1, p_2, p_3 and p_4 are measured pseudoranges, c is the speed of light, dT_1, dT_2, dT_3, dT_4 are the known satellite clock bias terms from GPS time, and dt is the unknown receiver clock offset from GPS time. The satellite clock bias terms are derived by the receiver from the satellite navigation message. For simplicity, several error terms have been left out in the above equations. The square-root term represents the geometric range between the satellite and receiver, and all the other terms contribute to the measurement being a pseudorange.

There are four main functions for a conventional Navigation satellite based receiver:

1) Measuring distance from the in line of sight satellites to the receiver by determining the pseudoranges (code phases);

2) Extracting the time of arrival of the signal from the contents of the satellite transmitted message;

3) Computing the position of the satellites by evaluating the ephemeris data at the indicated time of arrival.;

4) Determining the position of the receiving antenna and the clock bias of the receiver by using the above data items using an iterative solution.

As described in next sections, the GALILEO system has been designed to improve the performances of these functions, namely:

- the GALILEO Signal In Space (SIS) provides better TOA accuracy, Attenuation Robustness and Multipath Rejection capabilities for determining the pseudoranges.

- the accuracy of the Navigation data or Satellite transmitted messages (ephemeris, ionopsheric delay, …) are improved,

- the GALILEO SIS is interoperable with the GPS SIS in order to offer more satellites simultaneously in view.

4.2 GALILEO Signal In Space Performance

4.2.1 GALILEO Attenuation Robustness

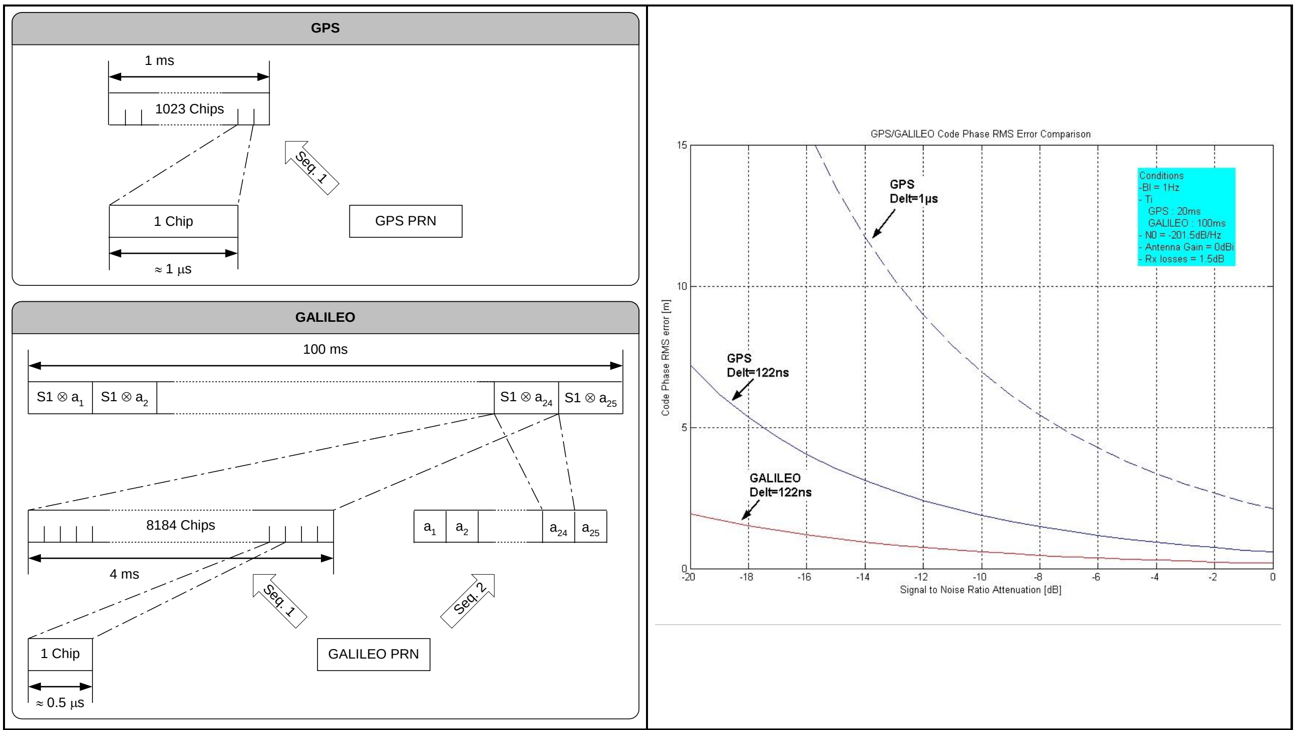
In order to measure the distance between the satellite and the UE, it is necessary to acquire and then track the Navigation Signal In Space. In this case, one of the main drivers is the robustness of the signal in presence of attenuation created by the environment, namely, urban canyons, indoors or foliage. The Galileo SIS has been designed to improve the acquisition and tracking performances and offer a location service wherever required by costumers. In particular, the Galileo signals are transmitted with significantly more power than the current GPS signal (5 dB improvement). These features will provide improved availability and accuracy for the Location Based Services.

The figure 4.2.1-1 summarises the GPS and current GALILEO Signal In Space modulation:

- For the record the GPS L1 is Bipolar-Phase Shift Key [BPSK] modulated with a 1023 chip Pseudo Random Noise (PRN) at 1.023 MHz known as the C/A code. This C/A code sequence repeats each millisecond. The transmitted PRN code sequence is actually the Modulo-2 addition of a 50-Hz message and the C/A code.

- For GALILEO L1, the current baseline includes one pair of signals, one signal without any data (so-called pilot signal), the other one using the same waveform carrying a navigation message of 100 bps. The GALILEO L1 is Binary Offset Carrier 2.046 Chips per second and Offset Carrier at 2,046 MHz [BOC(2,2)] modulated with a 8184 * 25 chips Pseudo Random Noise (PRN) at 2.046 MHz. This code sequence repeats each 100 millisecond. It is noted that GALILEO modulation is not yet frozen.

In addition, the figure shows the significant improvement of accuracy performance offered by GALILEO over GPS in similar signal reception conditions.



GPS and GALILEO Signal In Space Modulation

GPS/GALILEO Code Phase RMS Error Comparison

Figure 4.2.1-1: GPS / GALILEO - Signal In Space Modulation - Code Phase RMS Error

Using the GALILEO Pilot signal without Navigation data, special processing (coherent integration time greater than 20 ms) can be used without requesting assistance to data wipe off Navigation data as for GPS. The “GPS Delt=1µs” indicates the performances of a UE equipped with GPS 2MHz bandwidth. The two other curves illustrate the performances for a UE equipped with a 8 MHz bandwidth, and confirms the GALILEO SIS benefit with regard to the GPS SIS.

In addition, it can be highlighted that thanks to the length of 100 ms for the code sequence, if the UE can be synchronised to an absolute time with an accuracy around 100 ms by the network, the UE does not need to decode the Navigation Data message to remove the time ambiguity.

4.2.2 GALILEO Multipath Rejection Improvement

Multipath is a reflection phenomenon affecting the propagation of the signals broadcast from the satellite and disturbing the measurements made by the user equipment. The effects of multipath can be a total loss of a satellite signal or significant errors on the user position. These effects are especially critical in high density urban environment where multiple reflecteurs may affect the user position determination.

The figure 4.2.2-1 displays the multipath effects on the satellite range measurement error in a typical configuration (Carrier to Multipath power ratio of 6 dB).

The “Standard GPS Processing” curve shows the maximum effect for a UE equipped with 2 MHz bandwidth Standard GPS receiver. For example, the maximum error will be around 70 meters. In this case, most of the multipaths occurring in a urban environment (multipath delays below 430 m) will affect user positioning.

With improved techniques (GPS, Narrow Correlator, delt=122ns) requiring wider receiver bandwidth (8MHz), the effects of multipath will be reduced in amplitude but many disturbances will still affect positioning performance.

The “Galileo, delt=122ns” curve shows the maximum effect for a UE equipped with Galileo receiver. In this case, the receiver bandwidth is also 8 MHz. The maximum error is less than 20 meter and many typical reflections in urban environment are not affecting the processing (very small impact for multipath delays above 80 m). This feature will provide improved accuracy and availability for the Location Based Services.

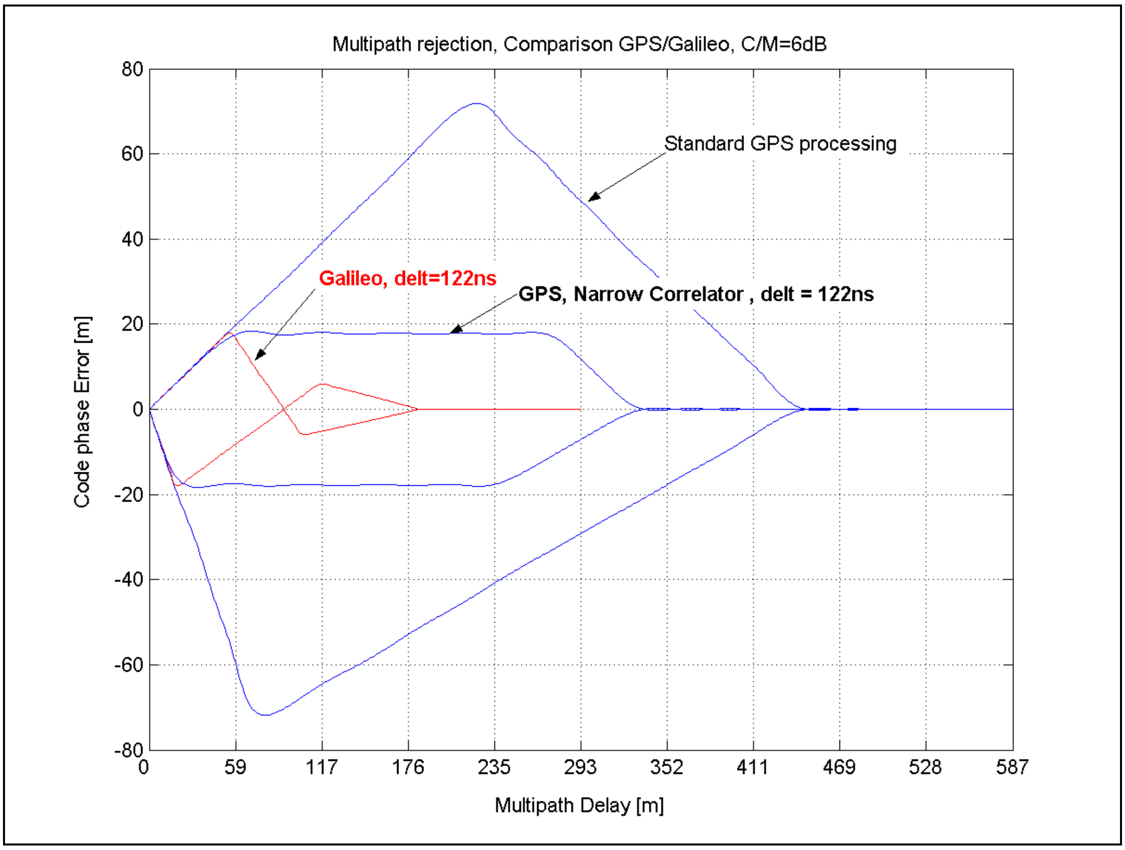


Figure 4.2.2-1: Multipath and Code Phase Error

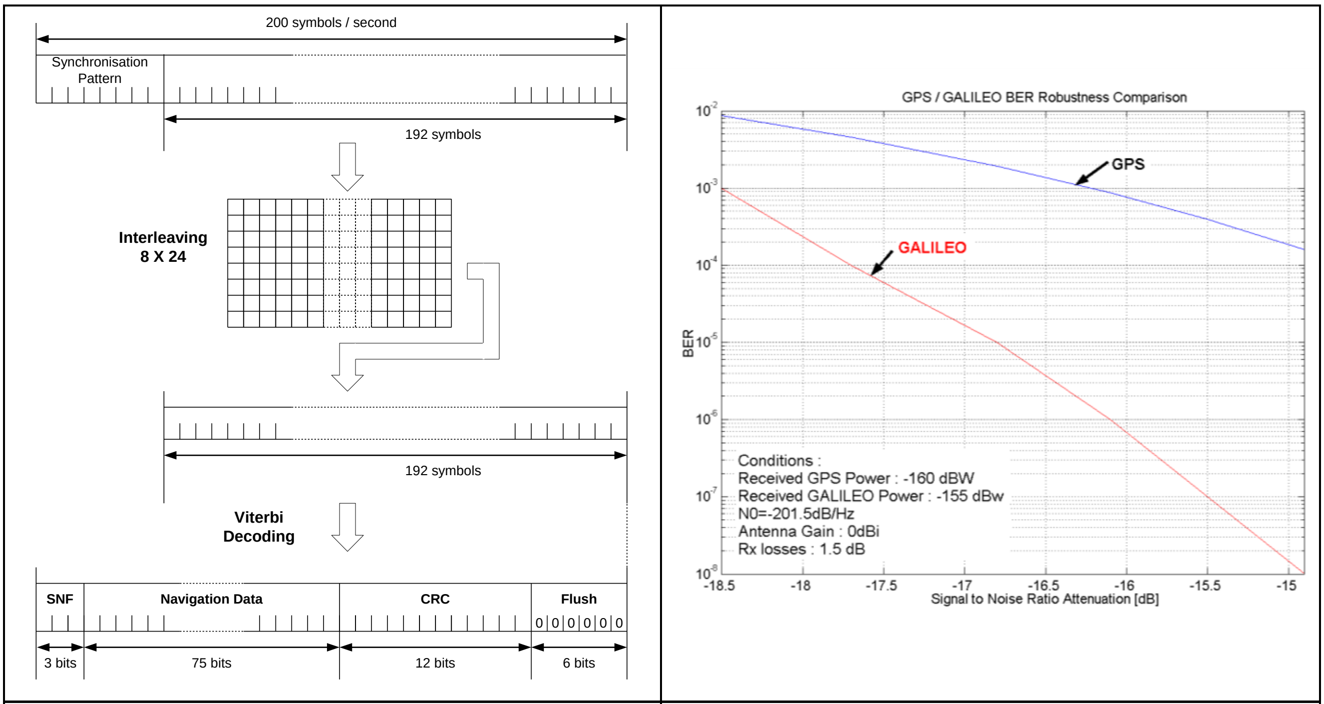
4.2.3 GALILEO Bit Error Rate Improvement

The Galileo Navigation Message broadcast by a satellite has been designed in order that a UE can determine if it has always the relevant Navigation data for this satellite, and so avoiding to request them from to the PLMN. In fact, each GALILEO Navigation Message includes a field called “Satellite Navigation Frame” (SNF). This field is modified each time that modifications are made in the data broadcast by this satellite. Thanks to the GALILEO signal definition and the data coding, the GALILEO Bit Error Rate is by far lower than the GPS BER. This lower BER authorises also a better behaviour in stand-alone mode.

The Figure 4.2.3-1 summarises the process to acquire the Galileo Navigation data, namely, each second,

- A predefined synchronisation pattern of 8 symbols is transmitted.

- The following 192 symbols, after interleaving and Viterbi Decoding, provide 96 data bits. The impact of the Signal to Noise ratio attenuation on the GPS BER and GALILEO BER are displayed in the following figure that shows the benefit of the Galileo SIS in case of attenuation.



GALILEO L1 Navigation Data Message **GPS/GALILEO BER Robustness Comparison**

Figure 4.2.3-1: Galileo L1 Navigation Data Message – GPS/Galileo BER Robustness Comparison

4.3 Navigation Accuracy Performance

4.3.1 Introduction

The following section presents simulation results on the typical user location performance that can be expected when using GALILEO alone or in combination with GPS, namely:

- the simulations hypotheses and results are explained,
- the Assisted GPS Performance are recalled,
- the Assisted GALILEO Performance are presented,
- the combined Assisted GPS / Assisted GALILEO Performance are highlighted.

4.3.2 Simulations Hypotheses and Results

Common hypotheses have been used for all the simulations, namely:

- Simulation computed using 5 minutes samples over 24-hour sample interval.
- The total URE has been considered as constant and no linked to the elevation.
- Average value has been used however the Ionosphere error varies from best to worst sites,
- No multipath.

Results should be used only as trend showing GALILEO performance compared to GPS performance using the same hypotheses, and no as committing performance neither for GALILEO nor for GPS.

4.3.3 Assisted GPS Performance

In order to show the GALILEO benefits on Location Based Service performance with regard to the Assisted GPS performance, some computed Assisted-GPS performance are recalled hereafter.

The following GPS reference orbit slot assignments and the error contributions to the total URE for a GPS SPS single frequency user have been extracted from [2].

Table 4.3.3-1. Reference Orbit Slot Assignments as of the Defined Epoch

SLOT	RAAN	Argument of Latitude	SLOT	RAAN	Argument of Latitude	SLOT	RAAN	Argument of Latitude
A1	272.847°	268.126°	**C1**	32.847°	111.876°	**E1**	152.847°	197.046°
A2	272.847°	161.786°	**C2**	32.847°	11.796°	**E2**	152.847°	302.596°
A3	272.847°	11.676°	**C3**	32.847°	339.666°	**E3**	152.847°	66.066°
A4	272.847°	41.806°	**C4**	32.847°	241.556°	**E4**	152.847°	333.686°
B1	332.847°	80.956°	**D1**	92.847°	135.226°	**F1**	212.847°	238.886°
B2	332.847°	173.336°	**D2**	92.847°	265.446°	**F2**	212.847°	345.226°
B3	332.847°	309.976°	**D3**	92.847°	35.156°	**F3**	212.847°	105.206°
B4	332.847°	204.376°	**D4**	92.847°	167.356°	**F4**	212.847°	135.346°

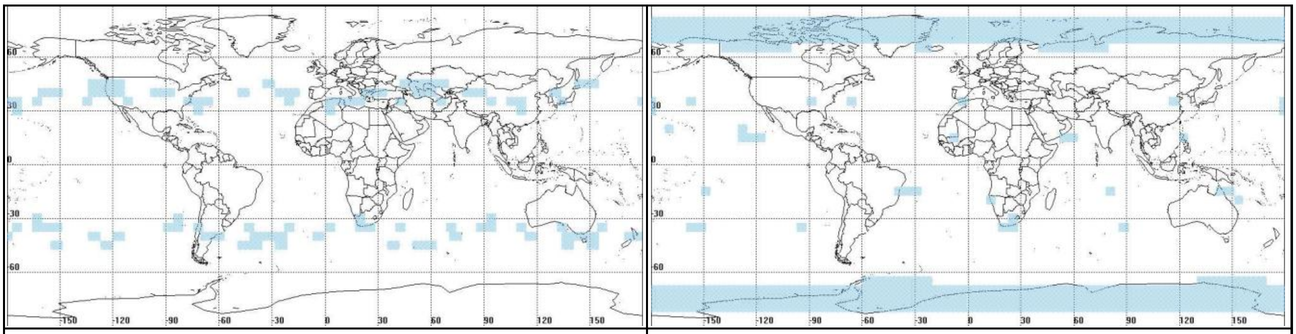
Epoch: 000Z, 1 July 1993
Greenwich Hour Angle 18m 36m 14.4s
Referenced to FK5/J2000.00 Coordinates

Eccentricity: 0.00
Semi-major Axis: 26559.7 kilometers

Table 4.3.3-2. Elements of GPS SPS User Range Error

RMS Contribution (m)	Troposhere Model	Ionoshere Model - Global Average	Orbit June 2000	Nav Message Curve Fit	Satelite Clock June 2000	Receiver Noise	Total URE
GPS SPS	0.25	7.00	0.57	0.20	1.43	0.80	7.2

Assuming a masking angle of 5°, the light blue/shaded areas in the following figure show location where 95% horizontal (resp. vertical) errors are greater than 10 meters (resp. 17 meters).



95% Horizontal Errors over 10 meters | **95% Vertical Errors over 17 meters**

Figure 4.3.3-1: GPS Single Frequency - 5° Masking Angle

4.3.4 Assisted GALILEO Performance

The GALILEO constellation includes 27 satellites defined as a Walker 27/3/1 constellation with the following characteristics:

- Semi-major Axis: 29993.707 kilometres
- Inclination: 56°
- Eccentricity: 0.

As the GALILEO satellite inclination /altitude (56° / 23616 km) are higher than the GPS satellite inclination / altitude (55° / 20181 km), GALILEO provides a better coverage for the higher latitudes.

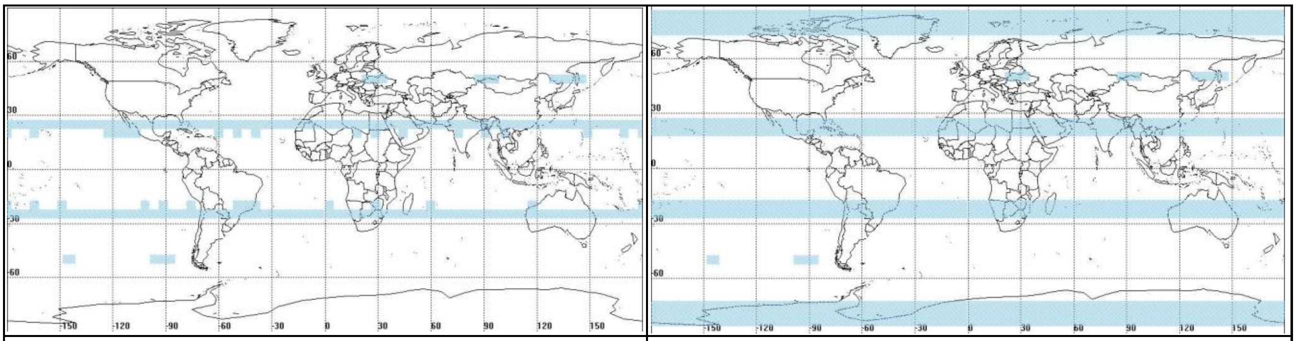
Table 4.3.4-1 summarises the error contributions to the total URE for a GALILEO Single Frequency user receiver:

- The remaining GALILEO Ionophere error is lower than the remaining GPS Ionopshere error because GALILEO will used an improved model with parameters updated more often.
- The Orbit and Satellite Clock error are lower than for the GPS satellites, thanks to permanent estimation and an average update every 90 minutes.
- Thanks to the GALILEO Signal definition, the RMS GALILEO receiver noise will be lower than for the GPS. In addition the acquisition and tracking will be better as explained in section x.

Table 4.3.4-1: Elements of GALILEO User Range Error

RMS Contribution (m)	Troposhere Model	Ionoshere Model - Global Average	Orbit Nav Message Curve Fit Satelite Clock	Receiver Noise	Total URE
GALILEO L1	0.25	3.00	0.65	0.40	3.1

Assuming a masking angle of 5°, the light blue/shaded areas in the following figure show location where 95% horizontal (resp. vertical) errors are greater than 4 meters (resp. 7 meters) for all-in-view receivers.



95% Horizontal Errors over 4 meters 95% Vertical Errors over 7 meters

Figure 4.3.4-1: GALILEO Single Frequency - 5° Masking Angle

The results show, under the same conditions, a two-fold improvement of accuracy when using GALILEO as a replacement of GPS for positioning. However, this is not the purpose to substitute GALILEO to GPS but rather to complement it to provide additional benefits to users. The following section analyses this solution.

4.3.5 Combined Assisted GPS / Assisted GALILEO Performance

A UE able to receive the GPS SIS and GALILEO SIS will obtain improved performance, namely because:

- 24 GPS + 27 GALILEO will offer better robustness against masking,
- GPS Receiver Noise will be decreased, as shown in section 4.2.1.
- The GALILEO Ionosphere corrections could be used instead of the GPS Ionophere corrections.

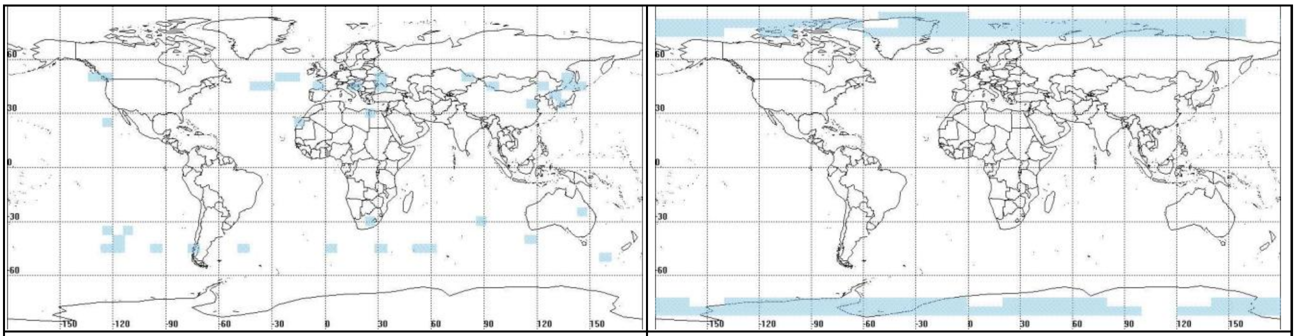
In addition, two constellations will increased the robustness against a single constellation global failu re.

Table 4.3.5-1 summarises the error contributions to the total URE for a combined GPS/GALILEO Single Frequency user receiver:

Table 4.3.5-1. Elements of Combined User Range Error

RMS Contribution (m)	Troposhere Model	Ionoshere Model - Global Average	Orbit	Nav Message Curve Fit	Satelite Clock	Receiver Noise	URE
GPS SPS	0.25	3.00	0.57	0.20	1.43	0.50	3.4
GALILEO L1	0.25	3.00	0.65			0.40	3.1

Assuming a masking angle of 5°, the light blue/shaded areas in the following figure show location where 95% horizontal (resp. vertical) errors are greater than 2.6 meters (resp. 4.6 meters) for all-in-view receivers.



95% Horizontal Errors over 2.6 meters **95% Vertical Errors over 4.6 meters**

Figure 4.3.5-1: GPS + GALILEO - 5° Masking Angle

The GPS Standard Performances assume a masking angle of 5° only. A building 4.6 meters high will create a masking angle lower than 5° only if the distance between the house and the UE is greater than 42 meters. In the case of the mobile communication applications, we can suppose that the masking angle will, in most cases, be significantly higher.

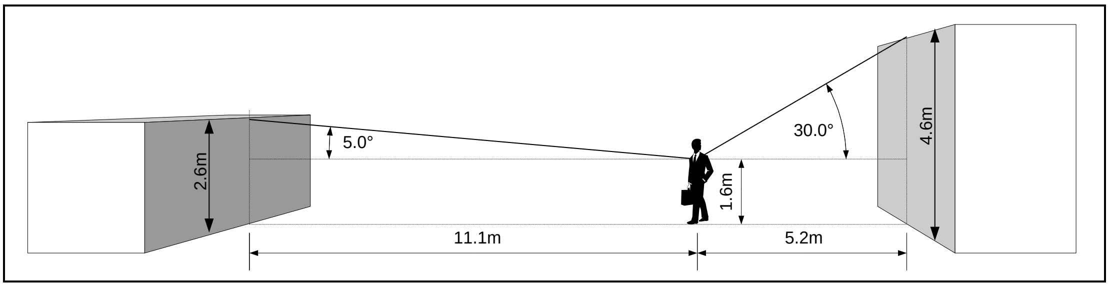
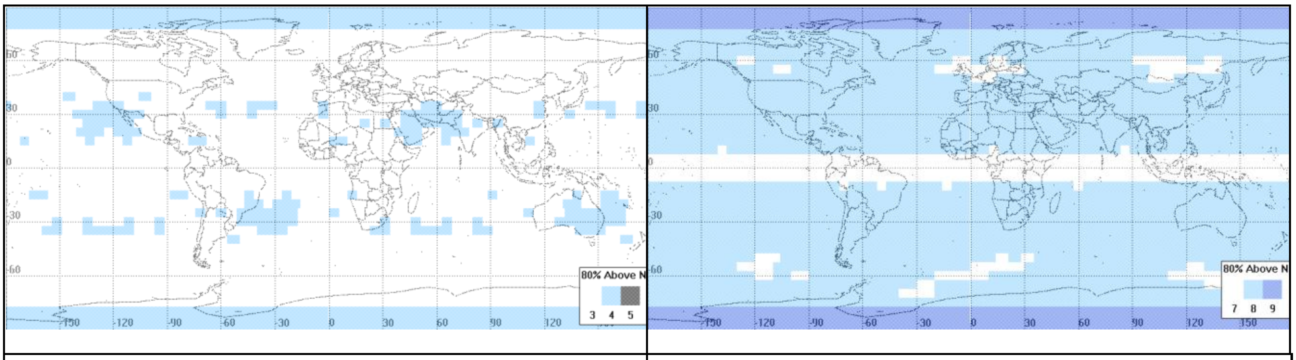


Figure 4.3.5-2: Masking Angle Concept

The figure 4.3.5-3 shows the impact of the masking angle on the number of satellites in view, for the GPS Only solution and for the GPS + GALILEO solution. With a masking angle of 30°, we can notice that 80% of the time there are only three, sometimes four visible satellites if only GPS is used. On the contrary, there are at least 7 satellites 80% of the time when the two constellations are used.

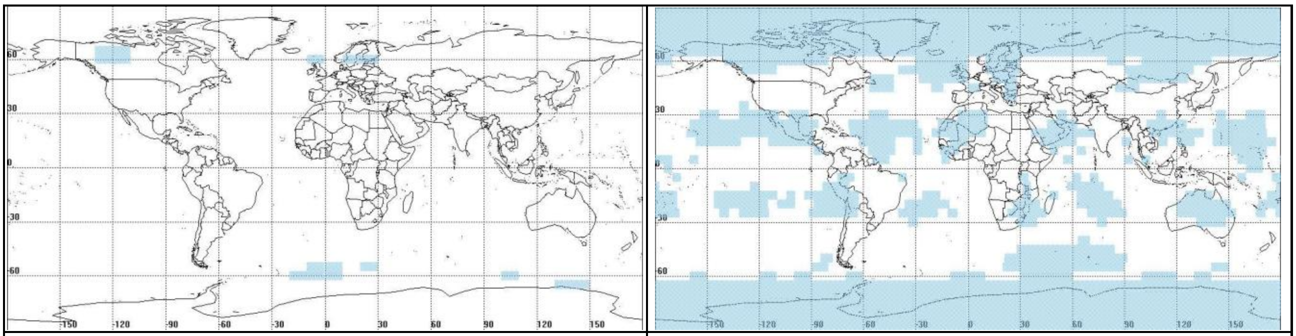


GPS Only | GPS + GALILEO

Figure 4.3.5-3: Number of Satellites In View for 30° Masking Angle

Assuming a masking angle of 30°, the light blue/shaded areas in the following figure show location where 95% horizontal (resp. vertical) errors are greater than 10 meters (resp. 17 meters) for all-in-view receivers. Analyses have been computed using 5 minutes samples over 24-hour sample interval.

The 95 % Horizontal Errors over 10 meters performance achieved using the **two constellations with a 30° masking angle** (Figure 4.3.5-4) is roughly **identical** to the achieved 95 % Horizontal Errors performance using only the **GPS constellation with a 5° masking angle** (Figure 4.3.2-1).



95% Horizontal Errors over 10 meters | 95% Vertical Errors over 17 meters

GPS + GALILEO - 30° Masking Angle

Figure 4.3.5-4: GPS + GALILEO - 30° Masking Angle

The following table summarises the various "Worst Site 95% Errors Statistics" depending on the constellation and the masking angle.

Table 4.3.5-2: Comparison of End-User Performance

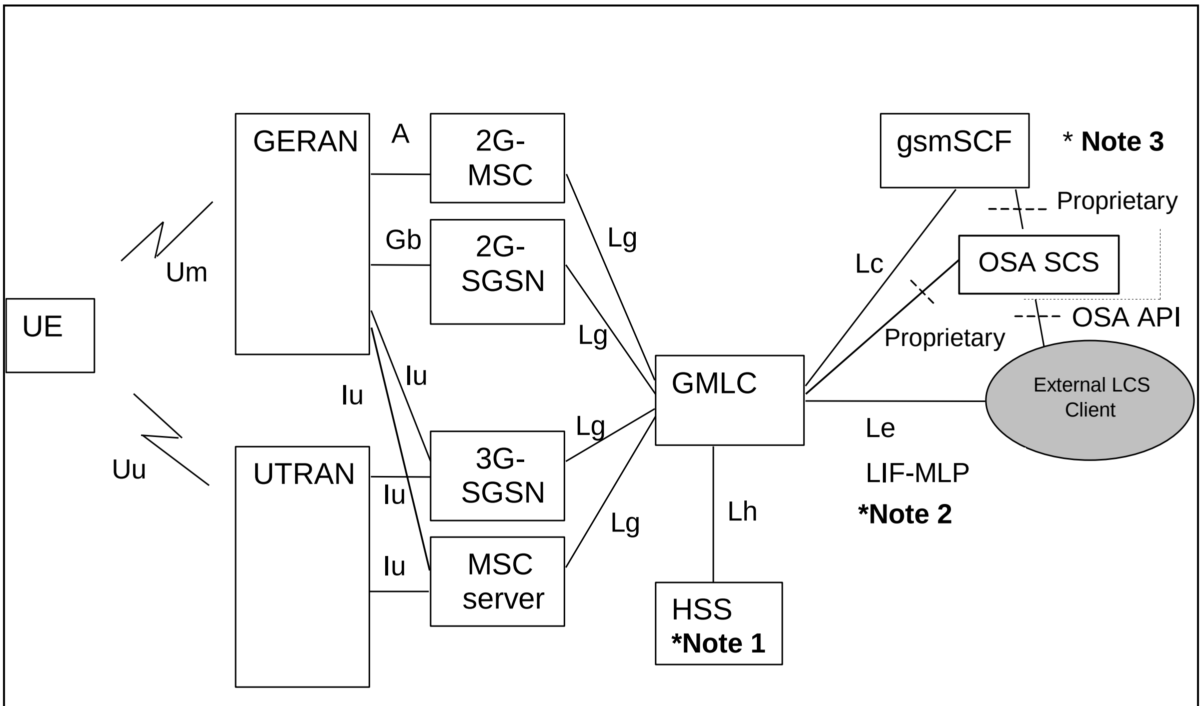
GPS SPS	GALILEO L1	Masking Angle	Worst Site 95% Horizontal Errors Statistics	Worst Site 95% Horizontal Errors Statistics
✓		5°	11.0 meters	20.0 meters
	✓		5.0 meters	8.0 meters
✓	✓		2.8 meters	5.0 meters
✓	✓	30°	12.0 meters	30.0 meters

The availability and/or accuracy of the LCS services will be improved by the simultaneous used of the Assisted GPS and the Assisted GALILEO.

5 Identification of the architecture impacts with present GALILEO definition

5.1 Function Identification

The following figure extracted from the Technical Specification "Functional Stage 2 Description of LCS" [4] recalls the general arrangement of LCS in GERAN and UTRAN.



NOTE 1: HSS includes both 2G-HLR and 3G-HLR functionality. LCS is included in the overall network architecture in TS 23.002 [20].

NOTE 2: LIF-MLP may be used on the Le interface

NOTE 3: As one alternative the LCS client may get location information directly from GMLC, which may contain OSA Mobility SCS with support for the OSA user location interfaces. See TS 23.127 [26] and TS 29.198 [27, 28, 29 and 30].

Figure 5.1-1: General arrangement of LCS

Table 5.1-1 shows a summary of the Functional Groups and Functional Blocks for Location services. Table 5.1-2 and figure 5-2 show the generic configuration for LCS and the distribution of LCS functional blocks to network elements. The PNSMF, PNDAF and PNADF functions have been added.

In the Table 5.1-1, the grey cells indicate functions that can be impacted by the use of Galileo.

Table 5.1-1: Summary of Functional Groups and Functional Blocks for Location services

Functional Group	Functional Component	Full Name of Functional Block	Abbrev.
Loc. Client	Location Client Component	(External) Location Client Function	LCF
		Internal Location Client Function	LCF-internal
LCS Server in PLMN	Client Handling Component	Location Client Control Function	LCCF
		Location Client Authorization Function	LCAF
	System Handling Component	Location System Control Function	LSCF
		Location System Billing Function	LSBF
		Location System Operations Function	LSOF
		Location System Broadcast Function	LSBcF
	Subscriber Handling Component	Location Subscriber Authorization Function	LSAF
		Location Subscriber Privacy function	LSPF
	Positioning Component	Positioning Radio Control Function	PRCF
		Positioning Calculation Function	PCF
		Positioning Signal Measurement Function	PSMF
		Positioning Navigation Signal Measurement Function	PNSMF
		Positioning Navigation Data Acquisition Function	PNDAF
		Positioning Navigation Assistance Data Function	PNADF
		Positioning Radio Resource Management	PRRM

The Positioning Navigation Signal Measurement Function (PNSMF) is responsible for measuring the Satellite Navigation Signal In Space in order to provide pseudo-distance, namely the transmission delay.

The Positioning Navigation Data Acquisition Function (PNDAF) is responsible for acquiring the Satellite Navigation Data transmitted by the Navigation Satellites.

The Positioning Navigation Assistance Data Function (PNADF) is responsible for providing the relevant Satellite Navigation data to the UE.

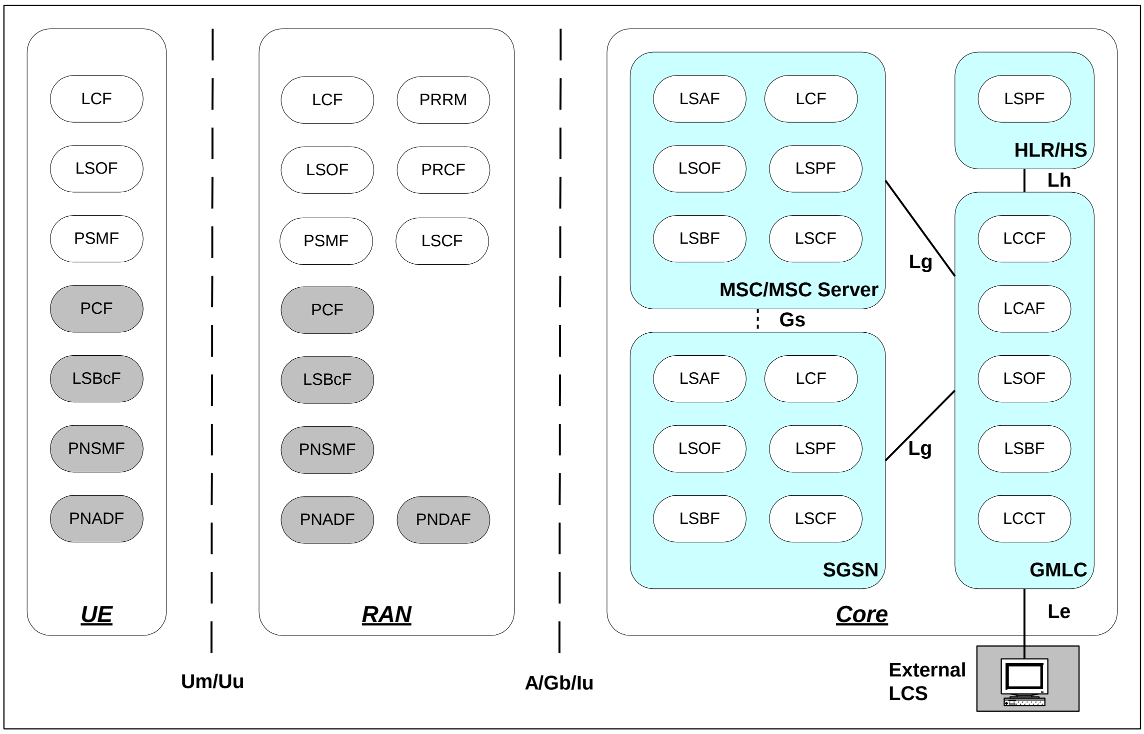


Figure 5.1-1: Generic LCS Logical Architecture

The following table summarises the LCS Functional Entities impacted by the adjunction of GALILEO.

Table 5.1-2: LCS Functional Entities impacted by GALILEO

§	Abbreviation	Full Name of Functional Block	UE	RAN	CN	Client
5.2	**LSBcF**	Location System Broadcast Function	X	X		
5.3	**PNSMF**	Positioning Navigation Signal Measurement Function	X	X		
5.4	**PNDAF**	Positioning Navigation Data Acquisition Function	X	X		
5.5	**PCF**	Positioning Calculation Function	X	X		
5.6	**PNADF**	Positioning Navigation Assistance Data Function		X		
5.7	**LCF**	Location Client Function				X

5.2 Impacts on Location System Broadcast Function (LSBcF)

As a UE shall be localised in case of emergency, even if it is not associated with one HLR, the Galileo capability shall be provided by the handset itself, in addition of the other methods.

Although the Galileo Navigation data are very similar to the GPS Navigation data, it is not always possible to map the Galileo data with the present GPS standard fields because some Galileo data request more bits. Two approaches are possible:

- to create a “GPS like field” using the Galileo available information, for example, two Galileo health status can be summarised in one bit,
- to define new messages adapted to Galileo.

In case of simultaneously use of the GPS and Galileo satellites, more satellites could be in view and so it should be possible to send the information for all the in view satellites, namely until 22 satellites. For the moment the number of satellites is limited by the coding to 16 or 12.

In case of MS-Assisted UE, the existing messages could be used if the type of satellite (GPS or Galileo) is standardised. Namely it is for the moment possible to describe 64 satellites but their type is by default GPS while the description text indicates that a satellite can be GPS, WAAS, GLONASS.

5.3 Impacts on Positioning Navigation Signal Measurement Function (PNSMF)

In order to receive the Galileo signal, the UE Navigation receiver should have 8 MHz sampling instead of 2 MHz sampling for receiving the GPS signal. This could have an impact on the power consumption. Even if special processing techniques exist to lower the power consumption in such a configuration, a further optimised signal could be desirable.

With the present definition of the Galileo Pilot Tone signal, if the UE is always synchronised and assisted by the PLMN, it is only necessary to track the Galileo Pilot Tone Signal, and so comparable hardware is necessary to track a Galileo satellite or a GPS satellite. If the UE cannot be always synchronised by the PLMN, it is necessary to track also the Galileo Navigation Signal. In this case the necessary signal acquisition and tracking hardware to track one Galileo satellite is roughly double and in addition the tracking performance will be less robust against attenuation. In order to achieve optimal location performance, without the constraint to have a tightly synchronisation between UE and PLMN, it is suggested in chapter 7, to modify the Galileo Pilot Tone Signal.

The number of tracking channels could be increased to try to track each visible satellite in each constellation in order to have the best location performances. But in order to reduce the consumption and the chip size, the actual number of tracking channels can be kept with a dynamic allocation between GPS and Galileo to cope with the best and visible satellites. This allocation will use the acquisition assistance or the ephemeris provided for all the theoretically visible satellites. The adjunction of Galileo in this case, will have no impact on the Navigation Signal Measurement.

5.4 Impacts on Positioning Navigation Data Acquisition Function (PNDAF)

This function is mandatory in the RAN to collect the assistance data (satellite navigation receiver connected to the SAS). In the UE terminal, this function is necessary only if the UE should work as a standalone navigation receiver. In this case, the UE shall implement a Viterbi decoding algorithm as described in section 4.1.3.

5.5 Impacts on Positioning Calculation Function (PCF)

The use of Galileo satellites instead of GPS satellites or in complement of GPS satellites has very small impacts on the Positioning Calculation Function.

The main one is the fact that potentially, a position could be computed using a maximum of 22 satellites. The already existing algorithm to select the “N-best satellites” should be improved.

The other impacts concern only the necessary adaptation linked with the remaining difference between the GPS and Galileo navigation data. For the moment the identified deltas are:

- Coding offset for orbit inclination (55° instead of 54°),
- Initial time not fixed. For GPS, it is at midnight UTC(USNO) on the night of January 5, 1980/ morning of January 6,1980.
- GALILEO Satellites Health of 8 bits instead of 6 bits for GPS Satellites Health.

As it is highlighted in the Annex B, the WGS84 and the GTRF geodetic reference systems, will be two realisations of the ITRF. So for the Location Based Services, they can be considered as identical.

GALILEO range measurement are performed with respect to the Galileo Reference Time. When combining GALILEO and GPS measurements, it is necessary to account for the different in time reference between the two systems. There are two ways to do this. The time difference can be transmitted by the GALILEO system and directly used when computation the combined position solution. Another solution is to consider this difference as an unknown and to solve for it using an additional satellite measurement. However, this second solution can be detrimental when the number of available satellites is already reduced in difficult urban environment.

It is therefore suggested that the Galileo system provides this deviation in order to improve the performances in case of use of Galileo and GPS simultaneously.

5.6 Impacts on Positioning Navigation Assistance Data Function (PNADF)

This function implemented in the RAN shall be customised to manage the Galileo constellation. It shall be able to identify the satellite type (GPS or Galileo) and to provide the relevant information collected by a Navigation Receiver network.

5.7 Location Client Function (LCF)

If the Location Client Function has the capability for selecting the location method, as it is requested in the OSA API, this capability shall be also available for Galileo.

6 Identification of the impacts on LCS standards with present GALILEO definition

6.1 Introduction

The following sections identify the main impacts on the 3GPP standard:

- UE GALILEO Support Capability declaration through the Um/Uu interfaces,
- MS-Based or MS-Assisted GALILEO Data Customisations,
- Other interfaces.

6.2 UE GALILEO Support Capability

6.2.1 GERAN Um Interface - A Mode / Gb Mode / Iu Mode

When the Access Network is a GERAN, the actual UE supported LCS capabilities are summarised in the following table.

Table 6.2.1-1: MS Positioning Capabilities Information Element

TS 24.008		TS 24.008		TS 44.118	
GERAN A Mode / CS		GERAN Gb Mode / PS		GERAN Iu Mode	
IE	MS Classmark 3	IE	PS LCS Capability	IE	MS Positioning Capability
Format	Fixed	Format	Fixed	Format	Variable
Length	5 bits	Length	5 bits	Length	0 to 15 bits
Bit 1	MS Conventional GPS	Bit 1	MS Conventional GPS	Bit 1	MS Conventional GPS
Bit 2	MS Based GPS	Bit 2	MS Based GPS	Bit 2	MS Based GPS
Bit 3	MS Assisted GPS	Bit 3	MS Assisted GPS	Bit 3	MS Assisted GPS
Bit 4	MS Based E-OTD	Bit 4	MS Based E-OTD	Bit 4	MS Based E-OTD
Bit 5	MS Assisted E-OTD	Bit 5	MS Assisted E-OTD	Bit 5	MS Assisted E-OTD

In GERAN A Mode, it is foreseen a fixed 5 bit field in the “MS Classmark 3” Information Element to indicate the supported location methods.

In GERAN Gb Mode, it is also foreseen a fixed 5 bit field in the “PS LCS Capability” Information Element to indicate the supported location methods.

In GERAN Iu Mode, it is foreseen a variable field in the “MS Positioning Capability” Information Element to indicate the supported location methods. For the moment 5 bits are allocated for the supported methods.

The GALILEO support capability could be introduced in the GERAN Iu Mode in increasing the length of the “MS Positioning Capability” IE. For the GERAN A Mode and GERAN Gb Mode, it will be necessary to use the Supplementary Services capabilities.

6.2.2 UTRAN Uu Interface

The Radio Resource Control protocol for the UE-UTRAN radio interface is defined in the Technical Specification “Radio Resource Control (RRC) - Protocol Specification“ [6]. The following Information Elements are used to inform the PLMN about the UE positioning capabilities.

Table 6.2.2-1: UE Positioning Capabilities Information Element

Information Element/Group name	Type and reference
Standalone location method(s) supported	Boolean
UE based OTDOA supported	Boolean
Network Assisted GPS support	Enumerated ('Network based', 'UE based', 'Both', 'None')
Support for GPS timing of cell frames measurement	Boolean
Support for IPDL	Boolean
Support for Rx-Tx time difference type2 measurement	Boolean
Support for UP measurement validity in CELL_PCH and URA_PCH states	Enumerated

As it is noted in [6], RRC messages may be extended in future versions of this protocol, either by adding values for choices, enumerated and size constrained types or by adding information elements. So, the location methods based on GALILEO can envisaged without problems.

6.3 MS-Based or MS-Assisted GALILEO Data Customisations

On the Uu/Um/Iupc interfaces, Information Elements (IE) are defined to carry the MS-Based or the MS-Assisted positioning calculation GPS data. New dedicated Information Elements can be defined for the GALILEO satellites or it may be possible to use the existing Information Elements for GALILEO if it is possible to identify the type of satellites.

In the 3GPP standards, all the already existing Navigation Satellites are mentioned but all the information are coded implicitly for the GPS satellites. In this case no mean has been foreseen to identify the type of satellites although it is possible to identify 64 satellites. To cope with the same type of problem, the Satellites Based Augmentation System (SBAS) standard has introduced a PRN Mask Assignments to allow the selection of 64 satellites among 210 navigation satellites.

Table 6.3-1: SBAS PRN Mask Assignment

PRN Slot	Assignment
1-37	GPS/GPS Reserved
38-61	GLONASS
62-119	Future GNSS
120-138	GEO/WAAS
139-210	Future GNSS/GEO/WAAS/Pseudolites

The same approach could be used in the 3GPP standard, and only one new Information Element could be introduced to identify the type of satellite, namely GPS or GALILEO, when the UE supports GALILEO.

To select one or the other solution, the impacts on the radio traffic should be assessed.

6.4 Other Interfaces

6.4.1 Lg Interface

The Technical Specification "Mobile Application Part (MAP) Specification" [7] defines that the following information are transmit from one PLMN to another to precise the UE LCS capabilities.

```
SupportedLCS-CapabilitySets ::= BIT STRING {
     lcsCapabilitySet1 (0),
     lcsCapabilitySet2 (1),
     lcsCapabilitySet3 (2) } (SIZE (2..16))
-- Core network signalling capability set1 indicates LCS Release98 or Release99 version.
-- Core network signalling capability set2 indicates LCS Release4.
-- Core network signalling capability set3 indicates LCS Release5 or later version.
-- A node shall mark in the BIT STRING all LCS capability sets it supports.
-- If no bit is set then the sending node does not support LCS.
-- If the parameter is not sent by an VLR then the VLR may support at most capability set1.
-- If the parameter is not sent by an SGSN then no support for LCS is assumed.
-- An SGSN is not allowed to indicate support of capability set1.
-- Other bits than listed above shall be discarded.
```

In order to precise that the UE support GALILEO, it will be necessary to define a new set.

6.4.2 OSA API Interface

In the Technical Specification "Open Service Access - Application Programming Interface - Part 6: Mobility" [8], the following location methods are identified.

> 10.1.6 Location Methods
>
> List of supported location methods. Possible values (other values are permitted):
> - "Time of Arrival"
> - "Timing Advance"
> - "GPS"
> - "User Data Lookup"
> - "Any Time Interrogation"

In order to allow the support of GALILEO, additional string values could be added.

6.4.3 Supplementary Services

In the Technical Specification "Mobile Radio Interface Layer 3 – Supplementary Services Specification" [9], the PLMN can request location method through the Um interface to the GSM MS. The following supported location methods are described using the following notation in [9].

```
LocationMethod::= ENUMERATED {
    msBasedEOTD         (0),
    msAssistedEOTD      (1),
    assistedGPS         (2),
    ...,
    msBasedOTDOA        (3)
    }
-- exception handling:
-- When this parameter is received with value msBasedEOTD or msAssistedEOTD and the MS
-- is camped on an UMTS Service Area then the receiver shall reject it
-- with a return error cause of unexpected data value.
-- When this parameter is received with value msBasedOTDOA and the MS
-- is camped on a GSM Cell then the receiver shall reject it with a return error cause of
-- unexpected data value.
-- an unrecognized value shall be rejected by the receiver with a return error cause of
-- unexpected data value.
```

Additional enumeration can be added to define the location methods based on Galileo, for example, "assistedGALILEO (4)" and "msBasedGALILEO (5)".

7 Feedback on present GALILEO definition

Some feedbacks concerning the present GALILEO definition have been raised in this document and are summarised hereafter.

1 With the present Navigation Pilot Tone definition, it is possible to achieve a Navigation solution without acquiring the Navigation Data Signal when the user equipment can dispose of absolute time with a 100 ms accuracy. In poor environment, it can be difficult to decode this Navigation Data Signal.

   It would be very useful to improve the design of the Pilot Tone to solve this time ambiguity regardless of the available network synchronization and to increase the minimum signal power at the Earth's surface.

2 With the present GALILEO modulation, acquiring and tracking one GALILEO satellite requires more electrical power than for one GPS satellite.

   It is desirable to investigate other modulation in order to obtain the same consumption or less than for GPS.

3 When GALILEO is combined with GPS, with the present GALILEO definition, it is necessary to use one satellite to estimate the deviation between the Galileo Reference Time and the GPS Reference Time.

   It is suggested that GALILEO provide an estimation of the deviation of the Galileo Reference Time with regard to the GPS Reference Time in order to improve the performance when combining GPS and GALILEO.

4 The GALILEO Navigation data are roughly identical to the GPS Navigation data but some differences have been identified. If they can be removed, the development and validation costs of UE supporting GALILEO in addition of GPS could be reduced.

   It is suggested that even if the format are differents, GALILEO use the same Navigation data than GPS in order that there are only impacts on the UE Navigation signal acquisition and tracking parts. In addition, it should be possible to adapt future GPS data and algorithms for GALILEO.

As stated in the GALILEO High Level Document, the Galileo Open Service (OS) will be provided free of direct user charge. This requirement will be part of the concession agreement currently under preparation.

It is expected that the Galileo Operating Company or concession holder will obtain revenues from commercial services for some specific applications requiring additional added value features. A complementary revenue stream is being studied in the form of chipset royalties on some receivers representing a fraction of a Euro. Final decisions will be taken by the Galileo concessionaire following guidance from the European Commission and taking into account the competitive environment of GPS.

8 Conclusions

This Technical Report has shown that the use of GALILEO alone or with GPS improves greatly the availability and the accuracy of the LCS Services provided by the PLMN in difficult situations such as urban or indoors environments where a limited number of satellites are visible and signal can be greatly attenuated.

The current standards support the use of GPS for location services. The technical report highlights the many similarities of GALILEO with GPS and the interoperability offered to jointly use both constellations in the future. In addition, the analysis carried out on the impact of enabling GALILEO in the standards indicated that the UMTS standards have already the flexibility to allow this type of extension. This means that the 3GPP standards could be modified without impairing the existing systems.

It was also noted that some characteristics of the current GALILEO signal could further be improved to optimise the impacts on the UE costs and autonomy. It is suggested that the GALILEO system designers consider these potential improvements before freezing the GALILEO definition..

Annex A:
GALILEO System Description

A.1 Context

Recognising the strategic importance of satellite navigation and its potential applications, Europe decided to develop Galileo. The introduction of satellite navigation services on a very large scale cannot be envisaged if users become fully dependent on a single system, outside European control. Galileo represents the European objective of autonomy in such a strategic and crucial technology. Galileo will also offer, alongside an open service similar to the GPS civilian service, new features to improve and guarantee services, thereby meeting the needs of critical, safety of life, or commercial applications. Galileo services are required to be fully compatible and interoperable at user level with other GNSS services, with no common failure mode between systems. This combined use of Galileo and other GNSS systems will offer better performances for all kinds of user communities all over the world.

Galileo will provide the first satellite positioning and navigation system specifically for civil purposes. At present, there are two radio navigation satellite networks: the US Global Positioning System (GPS) and the Russian GLONASS systems.

It is crucial for Europe and the whole world to have a choice independent of, but complementary and interoperable with, the current US GPS. In addition, the scale of future navigation needs and the requirement for global coverage cannot be satisfied by a single system alone.

The following sections recall the GALILEO system current status and definitions (March 2003). More information could be found on the GALILEO European Union Commission site http://europa.eu.int/comm/dgs/energy_transport/galileo/

A.2 Implementation and Management

The Galileo infrastructure is being implemented in three phases:

- Development and In-Orbit Validation (2002-2005)
- Deployment (2006-2007)
- Commercial Operations (from 2008)

The Galileo Joint Undertaking is a novel company charged with managing the programme's development phase (2002-2005) and with preparing the way for the deployment and operational phases. The founding members of the Joint Undertaking are the European Community and the European Space Agency. The European Investment Bank and private companies can join, and the participation of third countries is also anticipated in its statutes. A number of third countries have already expressed their interest in being associated to the programme in this way.

The Joint Undertaking will supervise the development of the space and ground infrastructure and will prepare the market for the forthcoming commercial operation of Galileo. In view of the many commercial spin-offs associated with the growing satellite navigation service markets in many areas, the programme will be managed during the deployment phase (2006-2007) and the commercial operation phase (after 2008) by a private entity. The Galileo Joint Undertaking will therefore issue a call for tender in order to select the private consortium to be awarded the concession for the deployment and operation of the system.

During the Commercial Operations Phase (2008 onwards), private-sector revenues will range from value-added services sold to operators and collected by the concession holder or Galileo Operating Company, to the exploitation of intellectual property rights and royalties.

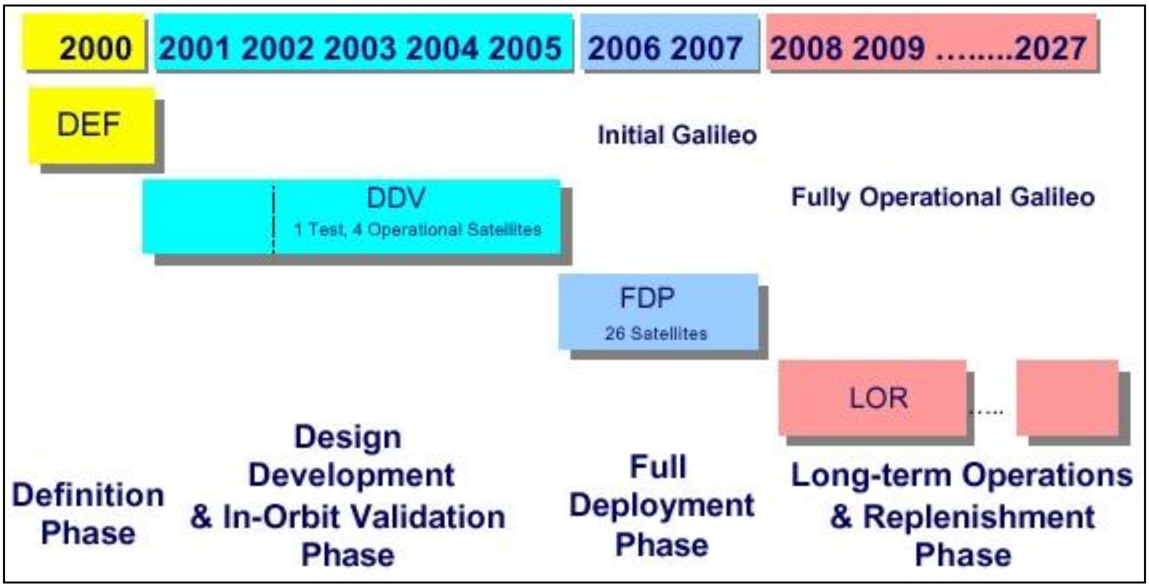


Figure A.2-1: GALILEO System Development Schedule

A.3 Space and Ground Infrastructure

The core of the Galileo system is the global constellation of satellites in medium Earth orbit.

The satellites will use proven innovative technologies. The body will rotate around its Earth-pointing (yaw) axis for its solar wings to rotate and point towards the Sun (generating peak power of 1500 W). After the initial constellation is established, further launches will replace failed satellites and replenish the system as the original satellites reach their ends of life.

Two Galileo Control Centres in Europe will control the constellation, as well as the synchronisation of the satellite atomic clocks, integrity signal processing and data handling of all internal and external elements. A dedicated global communications network will interconnect all the ground stations and facilities, making use of terrestrial and VSAT satellite links.

Data transfer to and from the satellites will be performed through a global network of Galileo Uplink Stations, each with Telemetry, Telecommunications and Tracking Station and a Mission Uplink Station. Galileo Sensor Stations around the globe will monitor the quality of the satellite navigation signal. The Galileo Communications Network will relay information from these stations to the two Ground Control Centres.

Regional components will independently provide the integrity of the Galileo services. Regional service providers using authorised integrity uplink channels provided by Galileo will disseminate regional integrity data. The system will guarantee that a user will always be able to receive integrity data through at least two satellites with a minimum elevation angle of 25º.

Local components will enhance the above with local data distribution by means of terrestrial radio links or existing communication networks, in order to provide extra accuracy or integrity around airports, harbours, railheads and in urban areas. Local components will also be deployed to extend navigation services to indoor users.

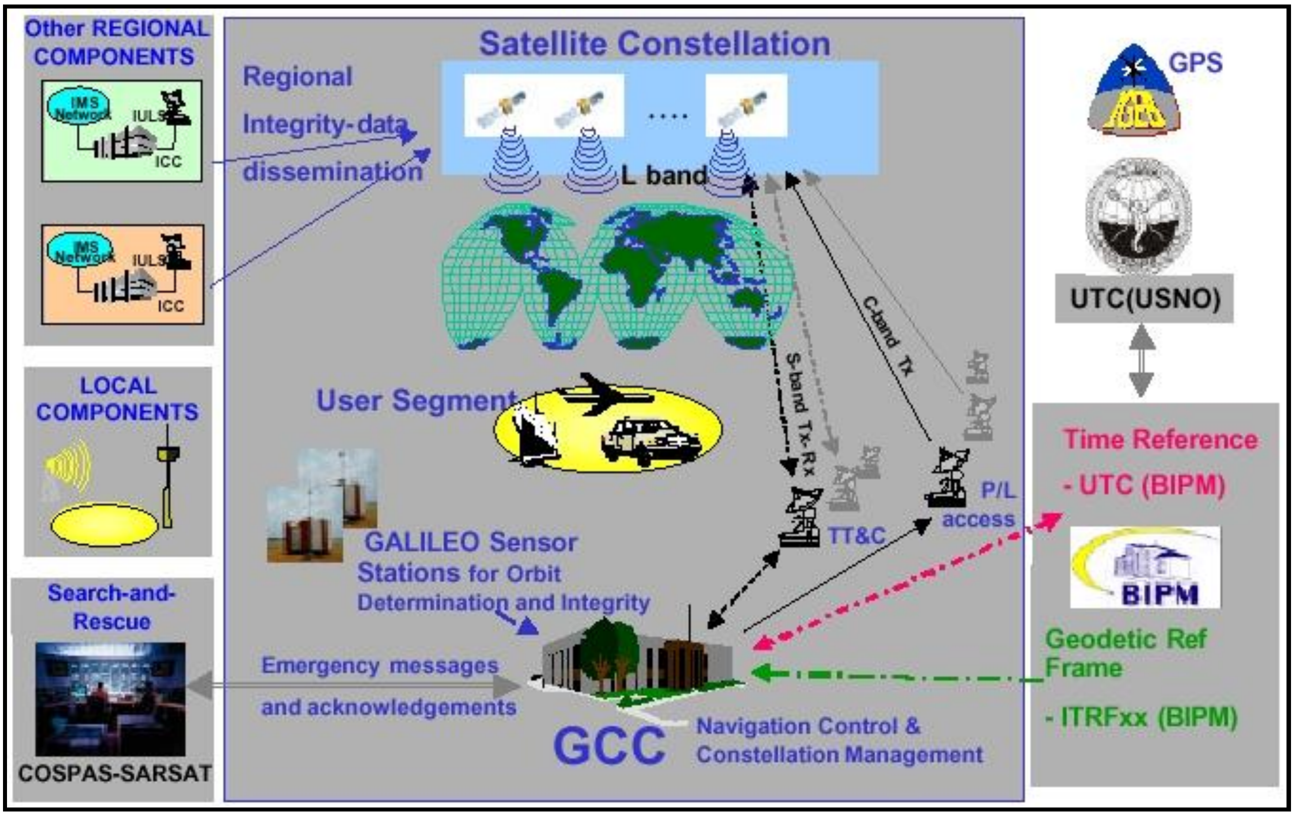


Figure A.3-1: GALILEO SYSTEM ARCHITECTURE

A.4 Galileo Services

1. The Galileo Open Service (OS) is defined for mass-market applications. It will provide signals for timing and positioning, free of charge. The Open Service will be accessible to any user equipped with a receiver, with no authorisation required. Position accuracy and availability will be superior to those of GPS and its planned evolutions (GPS IIF and GPS III). It will enable users with small, low-cost receivers to determine their location to within a few meters. It is foreseen that most receivers will use both Galileo and GPS signals -this will offer users significantly improve service performance in urban areas.

2. The Safety-of-Life Service (SoL) will be used for most transport applications where lives could be endangered if the performance of the navigation system is degraded without real-time notice. The Safety-of-Life Service will provide the same accuracy in position and timing as the Open Service. The main difference is the worldwide high-integrity level for safety-critical applications, such as maritime, aviation and rail, where guaranteed accuracy is essential.

This service will increase safety, especially where there are no traditional ground infrastructure services. This world-wide seamless service will increase the efficiency of companies operating on a global basis - airlines and transoceanic maritime companies. The Safety-of-Life Service will be certified and its performances will be obtained by using certified dual-frequency receivers. Under such conditions, the future Galileo Operating Company (GOC) will guarantee SoL.

3. The Commercial Service (CS) is aimed at market applications requiring higher performance than offered by the Open Service. It will provide added value services on payment of a fee. CS is based on adding two signals to the open access signals. This pair of signals is protected through commercial encryption, which will be managed by the service providers and the future Galileo Operating Company (GOC). Access will be controlled at the receiver level, using access-protection keys.

Typical value-added services include data broadcasting; service guarantees; precise timing services; the provision of ionosphere delay models and local differential correction signals for extreme-precision position determination. Many of these services will be developed by third-party, regional service providers, which will buy the right to use the commercial signals from the Galileo Operating Company (GOC).

4. The Public Regulated Service (PRS). Galileo is a civil system providing a robust and access-controlled service for governmental applications. Groups such as police, fire, ambulance, military and customs can use it. Applications cover transport of hazardous goods and customs control. Civil bodies will control access to the encrypted PRS. Access by region or user group will follow the security policy rules applicable in Europe.

PRS is required to be operational at all times and in all circumstances, notably during periods of crisis, when other services may be jammed. PRS is separate from the other services, so they can be denied without affecting PRS operations. A major PRS driver is the robustness of its signal, which will protect it against jamming and spoofing.

A.5 GALILEO Signal Design and Frequency Plan

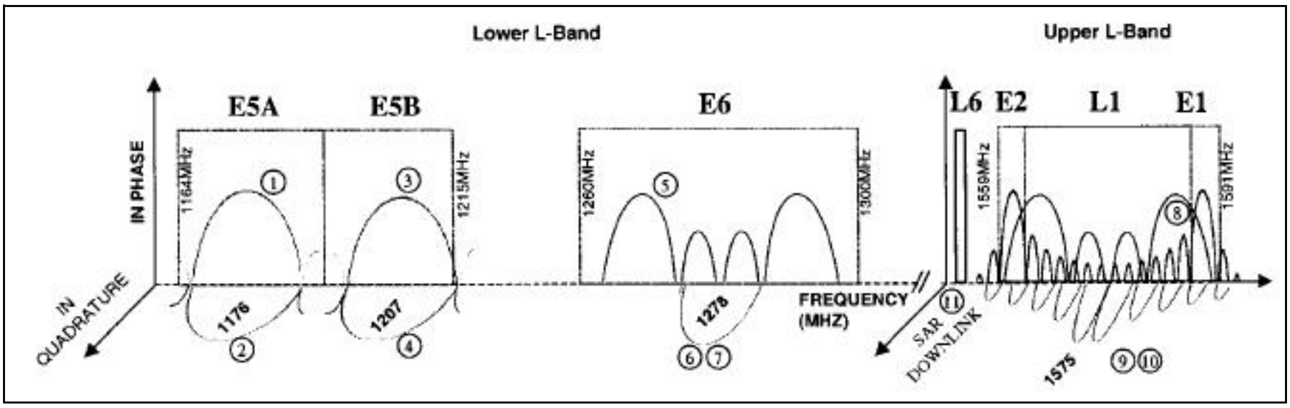


Figure A.5-1: Galileo Signal In Space Description

Galileo will provide 10 signals in the frequency ranges 1164-1215 MHz (E5a and E5b), 1215-1300 MHz (E6) and 1559-1592 MHz (E2-L1-E1), in the Radio-Navigation Satellite Service (RNSS) allocated frequency bands. Details are described below.

Four signals will be transmitted in the band 1164-1215 MHz:

- One pair of signals centred on 1176.450 MHz, in the 1164 - 1188 MHz frequency range (E5a)[1]:
    - 1 signal carrying a low data rate navigation message (25 bps), represented by the signal ①
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, represented by the signal ②
- One pair of signals centred on 1207.140 MHz, in the 1188 - 1215 MHz frequency range (E5b)
    - 1 signal carrying a navigation message of 125 bps, also supporting integrity and SAR data, represented by the signal ③
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, represented by the signal ④

The signals in E5a and E5b would be generated coherently, therefore giving the possibility to process them together for (1) increased accuracy, (2) redundancy (to mitigate interference from DMEs).

The multiplexing scheme of E5a and E5b signals is under study.

Three signals will be transmitted in the band 1260-1300 MHz (E6), centred on 1278.750 MHz:

- 1 split-spectrum[2] signal secured through governmental-approved encryption, designed for governmental applications requiring a continuity of service even in times of crisis, represented by the signal ⑤
- One pair of signals protected through commercial encryption providing high ambiguity resolution capabilities for differential applications, among which:
    - 1 signal carrying a navigation message of 500 bps supporting value-added data for commercial purpose, represented by the signal ⑥
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, represented by the signal ⑦ by the same waveform than previous signal

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[1] This band, also called L5, will also support GPS modernised signals which, together with Galileo signals will allow cheap bi-mode GPS/Galileo receivers able to track up to 60 satellites

[2] Split spectrum signals are used for either for selective service denial or interference minimisation between to RNSS systems sharing the same central frequency carrier

The multiplexing scheme of E6 signals is under study

Three signals will be transmitted in the band 1559-1591 MHz (E2-L1-E1), centred on 1575.42 MHz:

- 1 flexible split-spectrum signal secured through governmental-approved encryption, designed for governmental applications requiring a continuity of service even in times of crisis, represented by two different waveforms (signal ⑧)
- One pair of signals[3], among which:
    - 1 signal carrying a navigation message of 100 bps, also supporting integrity and SAR messages, represented by the signal ⑨
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, by the signal ⑩, by the same waveform than previous signal

The multiplexing scheme of E2-L1-E1 signals is under study.

Table A.5-1 summarizes all signals characteristics. Data rates are still under consolidation in the frame of the Galileo design studies carried out by ESA.

Table A.5-1:Galileo Signal Characteristics

Signal Id.	Signals	Central Frequency	Modulation	Chip Rate	Code Encryption	Data Rate[4]	Data Encryption
1	Data Signal in E5a	1176 MHz	BPSK(10)	10 Mcps	No	50 sps/25 bps	No
2	Pilot Signal in E5a	1176 MHz	BPSK(10)	10 Mcps	No	No Data	
3	Data Signal in E5b	1207 MHz	BPSK(10)	10 Mcps	No	250 sps/125 bps	No[5]
4	Pilot Signal in E5b	1207 MHz	BPSK(10)	10 Mcps	No	No Data	
5	Split-Spectrum Signal in E6	1278 MHz	BOC(10.5)	5 Mcps	Yes - Governmental Approved	250 sps/125 bps	Yes
6	Commercial Data Signal in E6	1278 MHz	BPSK(5)	5 Mcps	Yes - Commercial[6]	1000 sps/500 bps	Yes
7	Commercial Pilot Signal in E6	1278 MHz	BPSK(5)	5 Mcps	Yes -Commercial[7]	No Data	
8	Split-Spectrum Signal in L1	1575 MHz	BOC(n,m)[8]	m Mcps	Yes - Governmental Approved	250 sps/125 bps	Yes
9	Data Signal in L1	1575 MHz	BOC(2.2)	2 Mcps	No	200 sps/100 bps	no[9]
10	Pilot Signal in L1	1575 MHz	BOC(2,2)	2 Mcps	No	No Data	

Minimum received power on the ground (by a 0 dBi antenna) would be -158 dBW for each signal except -155 dBW for signals ⑤ and ⑧.

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[3] This band is already supporting GPS SPS signals, which, together with Galileo signals will allow cheap bi-mode GPS/Galileo receivers able to track up to 60 satellites.

[4] Using a 1/2 rate Viterbi convolutional coding scheme

[5] A capability of encryption for integrity is envisaged and may be activated pending results on potential market interest for integrity

[6] This encryption may be maintained or removed pending on market analysis results

[7] This encryption may be maintained or removed pending on market analysis results

[8] n and m operational values are the subject of on-going technical trade-offs

[9] A capability of encryption for integrity is envisaged and may be activated pending results on potential market interest for integrity

Annex B:
WGS84 and GTRF Geodetic Reference System

GPS provides positions in World Geodetic System 1984 (WGS 84) developed by the National Imagery and Mapping Agency (NIMA). GPS permanent control station co-ordinates (GPS Operational Control Segment and NIMA stations) infer this reference frame. The latest realisation is referred to as WGS84 (G1150) where G1150 is the GPS week (January 2002) when the reference frame was last updated.

GALILEO will provides positions in Galileo Referential Terrestrial Frame (GTRF) based on the International Earth Rotation Service (IERS) Terrestrial Reference Frame (ITRF). GALILEO permanent control station co-ordinates will infer this reference frame in order to establish the GTRF autonomously from other reference frames.

Nevertheless, as the WGS84 and the GTRF will be two accurate realisations of the ITRF, the co-ordinates in the two frames from a mobile user point of view will be the identical.

NIMA developed the geodetic solution for WGS 84 by holding a subset of International GPS Service for Geodynamics IGS stations to their ITRF coordinates. NIMA has estimated that the systematic differences between WGS84 (G873) and ITRF 94 are less than 2 cm [3]. The differences are noted to be statistically insignificant. National Geodetic Survey (NGS) provides a transformation between WGS84 (G873) and ITRF2000 (year 2000 realisation), showing minimal differences (see next chart computed using HDTP v2.6 software written by Dr. Richard Snay of NGS). Differences are even less with WGS84 (G1150).

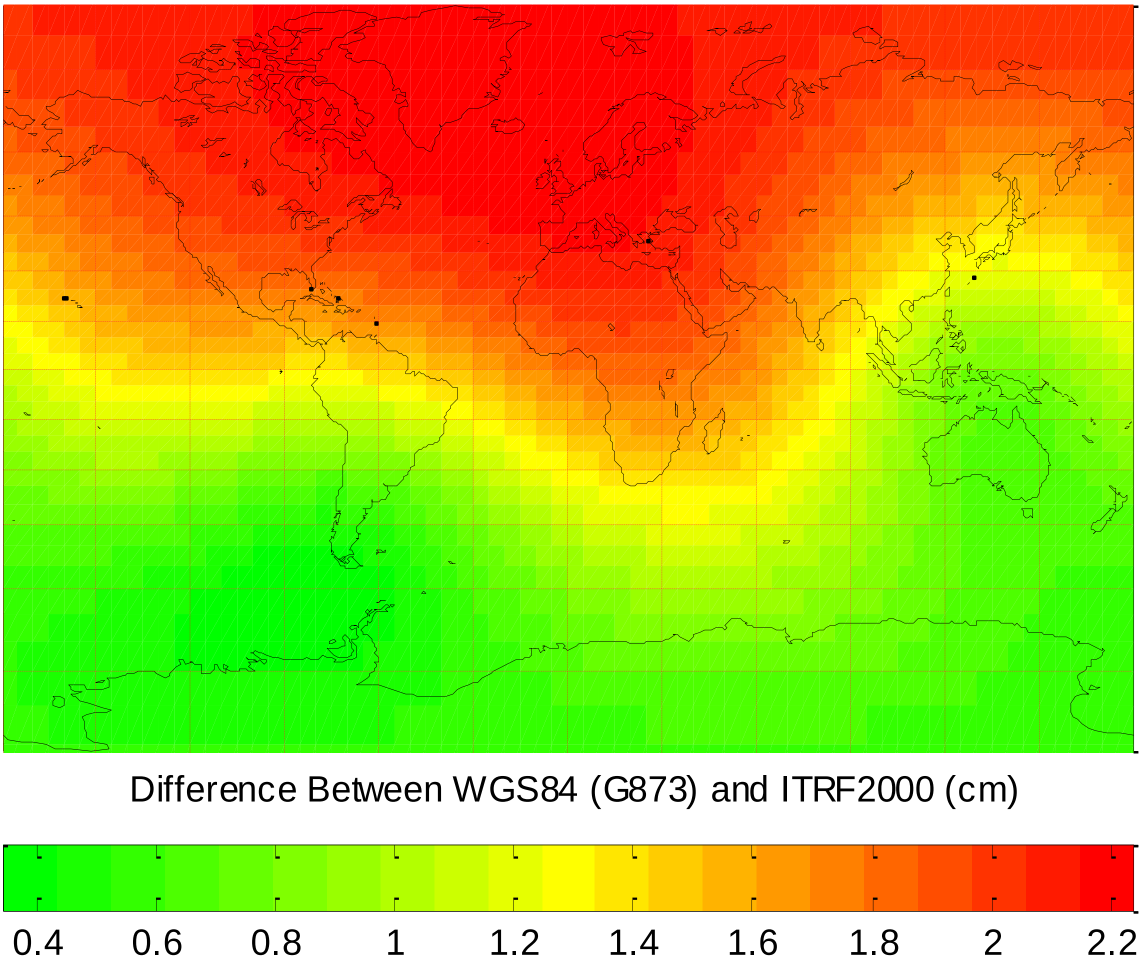

Figure B-1: Difference between WGS84 (G873) and ITRF2000

Annex C:
Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
02/04/03	SA2#31		--	--	Comments made at SA2#30 incorporated	-	0.0.1
09/04/03	SA2#31		--	--	Comments made at SA2#31 incorporated	0.0.1	0.0.2
10/04/03	SA2#31		--	--	Late LCS WG SA2#31 comments incorporated	0.0.2	0.1.0
11/04/03	SA2#31		--	--	SA2#31 plenary session comments incorporated	0.1.0	0.2.0
09/05/03	SA#20		--	--	First presentation for Information	0.2.0	1.0.0