GALILEO OPEN SERVICE
SIGNAL-IN-SPACE INTERFACE
CONTROL DOCUMENT
(OS SIS ICD)

Issue 2.2 | November 2025

#EUSpace

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Document Change Record

Reason for change	Issue	Revision	Date
First issue	Draft	0	May 2006
CBOC Modulation added, 'lossless atmosphere' assumption removed from Tx power definition (issue under study), SAR data, update of the bit allocations of some F/NAV and I/NAV pages, editorial corrections etc.	Draft	1	February 2008
Update of the 'Terms of Use and Disclaimers' section and namely the licensing policy for R&D and standardisation purposes as well as commercial purposes. Assignment of the primary and secondary codes to satellites in section in section 3.6. More details on the I/NAV alert page content in section 4.3.2.3. Clarification of the power sharing between the different Galileo signal components in section 2.7. Addition of Galileo E1 sub-carriers plots in section 2.3.3 Clarification that Galileo E5a and E5b signals can be processed as QPSK signals in section 2.3.1.2. Update of the acronym list with QPSK in Annex A. In section 4.2.4, for Page Type 6, parameter 'i' has been replaced by ω, the argument of perigee. In section 5.1.2, Time of Week an entire week from 0 to 604799 seconds, not up to 604800.	Issue 1	0	February 2010
Licence Agreement has been made easier to be adopted by licensees. Terms of use and disclaimers have been amended accordingly.	Issue 1	1	September 2010
"Reference Documents" section 1.3 added. Update of the constellation description and Earth radius in section 1.4. Correction of DC_{X-Y} and $rect_T(t)$ definitions in Table 4. E1-B, E1-C and E5 Primary Codes now delivered only in the electronic version of this ICD: sections 3.4.1, 3.4.2 and Annex C. Secondary Codes $CS100_{37}$ to $CS100_{39}$ added in Table 22. I/NAV usage updated in section 4.1.1. Correction of "Dummy Data (2/2)" bits allocation in Table 56. Correction of "start bit" value (equal 0 instead of 1) in part (5/8) of long RLM in Table 65. Added "start bit" value (equal 1) in Table 66. Correction of "GTRF coordinates" formula in Table 68 (last row): "y" is the sum of the two terms. Updated description of GST start epoch in section 5.1.2. Section 5.1.6 (Ionospheric Correction) reviewed. Clarification of "Day Number" value range in Table 75. Confirmation of "Data validity Status Bit" values in Table 81.	Issue 1	2	October 2015

Reason for change	Issue	Revision	Date
E1 B/C Signal Health Status parameter definition updated in Sections 5.1.9.3 and 5.1.10. Updates of section 5.3 relevant to the SAR Return Link Message to include RLM data content. New Annex D "FEC Coding and Interleaving Numerical Examples" added. Correction of expression "(ΔA)1/2"(Difference with respect to the square root of the nominal semi-major axis) of Table 48 into the correct expression "Δ(A1/2)" The license agreement has been revised and simplified. Miscellaneous minor typographical and wording corrections.			
Section 2.7 has been reworded to clarify that the Galileo satellites provide a specified power level on ground starting from 5 degrees satellite elevation angle. Annex H: Authorisation Concerning the OS SIS ICD IPRs has been updated and 6 items (rows) have been added to the table in section H.12, which contains the list of OS SIS ICD related Intellectual Property Rights, to reflect the new licenses granted to the EU on 6 patents.	Issue 1	3	December 2016
With this issue three new features are introduced to the I/NAV message transmitted within the Galileo E1 OS signal (Secondary Synchronisation Pattern, Reduced Clock and Ephemeris and Reed-Solomon Outer Forward Error Correction). The following changes have been made to introduce all the necessary elements: • I/NAV Nominal Sub-Frame Layout within section 4.3.3 updated • New I/NAV word types (16, 17, 18, 19, 20) added within section 4.3.5 • New section 5.1.9.5 describing Secondary Synchronisation Pattern introduced • New section 5.1.11 describing Reduced Clock and Ephemeris Data introduced • New section 5.1.13 describing Protection of I/NAV Clock and Ephemeris Data by means of Reed-Solomon Outer Forward table Correction • New Annex E (Reference Algorithm for Exploitation of FEC2 Reed-Solomon Words) and Annex F(Reference Algorithm for Exploitation of FEC2 Reed-Solomon Words) added In addition, sections 2.3.2 (E6 signal) and 2.7 (Received Power Levels on Ground) have been updated and a new Annex H (Authorisation Concerning use of the Galileo Trade Marks) has been added.	Issue 2	0	January 2021
This release includes some updates: updating of Signal Health Status definition to support the new Extended Operations Mode (EOM), introducing the ARAIM Integrity Support Message to the I/NAV message transmitted in E1, adding references to OSNMA ICD and NTCM documents. New Annex G, old Annex G becomes Annex H. Old Annex H is removed due to obsolescence. New Annex I. The	Issue 2	1	October 2023

Reason for change	Issue	Revision	Date
following changes have been made: • New ARAIM Integrity Support Message introduced in section 4.3.7 • I/NAV Nominal Sub-Frame Layout within section 4.3.3 updated • New I/NAV word type 22 added within section 4.3.5 • New I/NAV ARAIM Integrity Support message Structure added in section 4.3.7 • New ARAIM Integrity Support Data definition added in section 5.2 • New Annex G *(ISM Checksum Numerical Example)* added • EOM introduced in section 5.1.9.3 and Table 84 updated with new interpretation for SHS=2 status • Update of Annex A and Annex B • Replacing Annex H with old Annex G, removing authorization of Galileo trademarks, due to obsolescence • New Annex I, dealing with the Galileo PRN Codes Assignment process • Update of several equations, mainly in terms of notation, not changing the result, function or algorithm • Update of Eq. 1 to introduce a missing square root			
This release includes some updates: including corrections from errata sheet, correcting additional typos, aligning formatting where needed, introducing the E5a-Quasi Pilot (QP) signal. The following changes have been made: • Typo deletion "=" in Eq. 7 • Update of Figure 3, Figure 6 and Figure 7 introducing argument (t) to signal streams • Update of introducing (t) argument • Change of verb to presence tense in first paragraph of section 3.6.1 • Formatting update of Table 30, Table 32 and Table 36 • Update of I/NAV Word Type 3 title • Insertion of subscripts $E1B$ and $E5b$ in CRC fields of Table 56 • Formatting update of Table 67 • Reduction of SVID range in Table 98 • The paragraph numbering for the subsections of 5.2.3.1 is corrected • The description of the ISM Time of Week in 5.2.3.1.4 is changed • The Table 35 Header is modified to specify the fields of F/NAV page type 6 related to the specific SVID • Correction of Eq. 21 updating the term ΔtLS • New section 2.3.1.4 describing E5a-QP signal and adaptation of 2.3.1 structure, including a new introduction • E5a-QP power levels added in section 2.7, table 12 • E5a-QP code length added in section 3.1, table 14	Issue 2	2	November 2025

Reason for change	Issue	Revision	Date
• New section 3.4.2 added introducing E5a-QP codes generation • E5a-QP codes assignment to satellites added in section 3.6.1 • Annex C modified to include E5a-QP codes, including a new electronic annex C.9 with the E5a-QP codes in hexadecimal format (C9_E5aQP.txt) • Section 1.3 with Reference documents updated to include the G2 QP signals ICD information			vi

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1 Introduction

1.1 Document Scope

The present European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document (OS SIS ICD) Issue 2.2 contains the publicly available information on the Galileo Signal-In-Space. It is intended for use by the Galileo user community and it specifies the interface between the Galileo Space Segment and the Galileo User Segment.

1.2 Document Overview

The present document is organised as follows:

- Chapter 1 is this introduction which provides the scope of the document and an overview of the Galileo system

- Chapter 2 provides the Signal-In-Space radio frequency characteristics

- Chapter 3 provides the characteristics of the spreading codes

- Chapter 4 provides the message structures

- Chapter 5 provides the characteristics of the navigation message data contents

1.3 Reference Documents

[RD1] European GNSS, Galileo Open Service, Ionospheric Correction Algorithm for Galileo Single Frequency Users.
http://www.gsc-europa.eu/electronic-library/programme-reference-documents

[RD2] COSPAS – SARSAT, Specification for Cospas – Sarsat 406MHz Distress Beacons, C/S T.001

[RD3] European GNSS, Galileo Open Service Navigation Message Authentication (OSNMA) Signal-In-Space Interface Control Document (SIS ICD).
http://www.gsc-europa.eu/electronic-library/programme-reference-documents

[RD4] European GNSS, Galileo Open Service, NTCM-G Ionospheric Model Description.
http://www.gsc-europa.eu/electronic-library/programme-reference-documents

[RD5] European GNSS, Galileo High Accuracy Service Signal-In-Space Interface Control Document (HAS SIS ICD)
http://www.gsc-europa.eu/electronic-library/programme-reference-documents

[RD6] European GNSS, Galileo Open Service, Galileo Second Generation (G2) – Evolution of Quasi-Pilot Signals and Interface Control Information (G2 QP TN)
http://www.gsc-europa.eu/electronic-library/programme-reference-documents

1.4 Galileo System Overview

Galileo is the European global navigation satellite system providing a highly accurate and global positioning service under civilian control. It is interoperable with GPS and GLONASS, the two other current global satellite navigation systems.

The fully deployed Galileo system consists of 24 operational satellites and up to 6 active spares, positioned in three circular Medium Earth Orbit planes.

The nominal values of the main parameters for the Galileo constellation are defined in Table 1.

Table 1: Main orbit characteristics of the nominal Galileo constellation

Parameter	Explanation	Value
$e_{nominal}$	Nominal orbit eccentricity	0
$i_{nominal}$	Nominal orbit inclination with reference to the equatorial plane	56°
$A_{nominal}$	Nominal orbit semi-major axis	29 600 000 m

Galileo provides enhanced distress localisation and call features for the provision of a Search and Rescue (SAR) service interoperable with the COSPAS – SARSAT system.

Galileo also provides the ARAIM Integrity Support Messages (ISMs), which are broadcast through the Galileo E1-B signal component.

Figure 1 specifies the radio-frequency air interface between space and user segments. Three independent CDMA signals, named E5, E6 and E1, are permanently transmitted by all Galileo satellites. The E5 signal is further sub-divided into two signals denoted E5a and E5b.
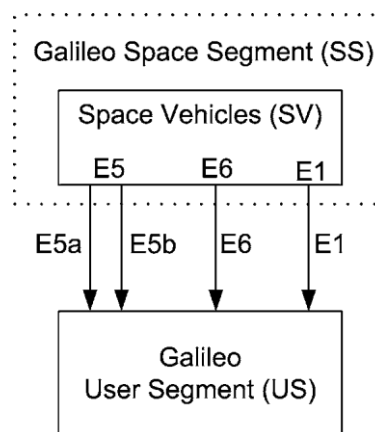
Figure 1: Space Vehicle/Navigation User Interface

2. Galileo Signal Characteristics

2.1 Frequency Plan

2.1.1 Frequency Bands

The Galileo navigation Signals are transmitted in the four frequency bands indicated in Figure 2. These four frequency bands are the E5a, E5b, E6 and E1 bands. They provide a wide bandwidth for the transmission of the Galileo Signals.
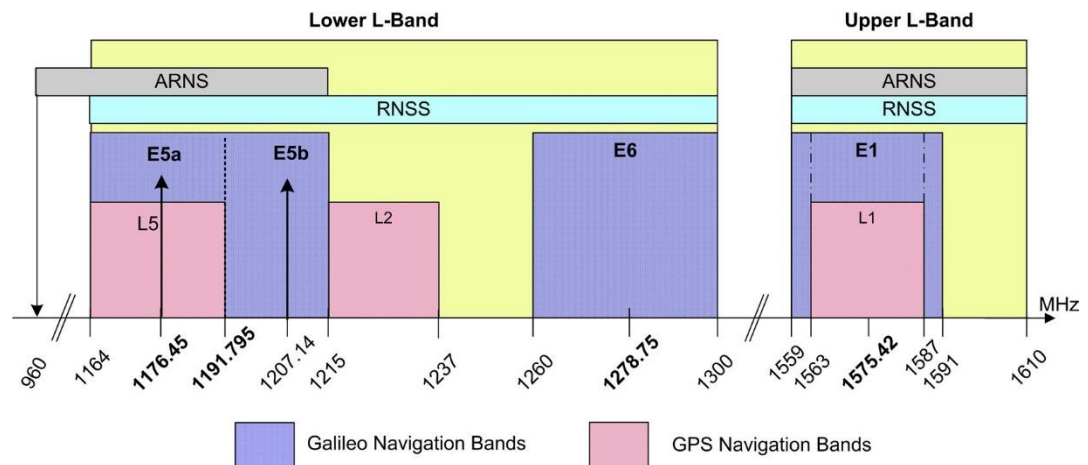
Figure 2: Galileo Frequency Plan

The Galileo frequency bands have been selected in the allocated spectrum for Radio Navigation Satellite Services (RNSS) and in addition to that, E5a, E5b and E1 bands are included in the allocated spectrum for Aeronautical Radio Navigation Services (ARNS), employed by Civil-Aviation users, and allowing dedicated safety-critical applications.

2.1.2 Carrier Frequencies

Galileo carrier frequencies are shown in Table 2. The names of the Galileo signals are the same than the corresponding carrier frequencies.

Table 2: Carrier Frequency per Signal

Signal	Carrier Frequency (MHz)
E1	1575.420
E6	1278.750
E5	1191.795
E5a	1176.450
E5b	1207.140

Note: The E5a and E5b signals are part of the E5 signal in its full bandwidth.

2.1.3   Receiver Reference Bandwidths

The receiver reference bandwidths centred on the carrier frequencies of Table 2 are specified in Table 3. Those reference bandwidths are considered when computing the correlation losses provided in paragraph 2.8.

Table 3: Galileo Signals Receiver Reference Bandwidths

Signal	Receiver Reference Bandwidth (MHz)
E1	24.552
E6	40.920
E5	51.150
E5a	20.460
E5b	20.460

2.2 Signal Polarisation

The transmitted signals are Right-Hand Circularly Polarised (RHCP).

2.3 Modulation

In the following sections, modulation expressions are given for the power normalised complex envelope (i.e. base-band version) $s_x(t)$ of a modulated (band-pass) signal $S_x(t)$. Both are described in terms of their in-phase s_{X-I} and quadrature s_{X-Q} components by the following generic expressions in Eq. 1.

$$S_x(t) = \sqrt{2P_X}\left[s_{X-I}(t)\, cos(2\pi f_x\, t) - s_{X-Q}(t)\, sin(2\pi f_x\, t) \right]$$

$$s_X(t) = s_{X-I}(t) + j\, s_{X-Q}(t)$$

Eq. 1

Table 4 defines the signal parameters used in this chapter, with the indices:

- 'X' accounting for the respective carrier (E5, E5a, E5b, E6 or E1) and

- 'Y' accounting for the respective signal component (B, C, I or Q) within the signal 'X'.

Table 4: Signal Description Parameters

Parameter	Explanation	Unit
f_X	Carrier frequency	Hz
P_X	RF-Signal power	W
L_{X-Y}	Ranging code repetition period	chips
$T_{C,X-Y}$	Ranging code chip length	s

Parameter	Explanation	Unit
$T_{S,X}$	Sub-carrier period	s
$T_{S,X-Y}$	Sub-carrier period	s
$T_{D,X-Y}$	Navigation message symbol duration	s
$R_{C,X-Y}$	$= 1/T_{C,X-Y}$ Code chip rate	Hz
$R_{S,X}$	$= 1/T_{S,X}$ Sub-carrier frequency	Hz
$R_{S,X-Y}$	$= 1/T_{S,X-Y}$ Sub-carrier frequency	Hz
$R_{D,X-Y}$	$= 1/T_{D,X-Y}$ Navigation message symbol rate	Hz
$S_X(t)$	Signal band-pass representation	N/A
$C_{X-Y}(t)$	Binary (NRZ modulated) ranging code	N/A
$D_{X-Y}(t)$	Binary (NRZ modulated) navigation message signal	N/A
$sc_{X-Y}(t)$	Binary (NRZ modulated) sub-carrier	N/A
$e_{X-Y}(t)$	Binary NRZ modulated navigation signal component including code, sub-carrier (if available) and navigation message data (if available); $(= c_{X-Y}(t)\, sc_{X-Y}(t)\, D_{X-Y}(t))$	N/A
$s_X(t)$	$= s_{X-I}(t) + j\, s_{X-Q}(t)$ Normalised (unit mean power) baseband signal	N/A
$c_{X-Y,k}$	kth chip of the ranging code	N/A
$d_{X-Y,k}$	kth symbol of the navigation message	N/A
DC_{X-Y}	$= T_{D,X-Y}/T_{C,X-Y}$ Number of code chips per symbol	N/A
$|i|_L$	Equals i modulo L	N/A
$[i]_{DC}$	Integer part of i/DC	N/A
$rect_T(t)$	Function "rectangle" which is equal to 1 for $0 \leq t < T$ and equal to 0 elsewhere	N/A

2.3.1   E5 Signal

The E5 signal comprises the E5a-I, E5a-Q, E5b-I and E5b-Q signal components, transmitted as a composite signal through the AltBOC modulation and labelled as E5ab-IQ, as described in the sections 2.3.1.1, 2.3.1.2 and 2.3.1.3, and the E5a-QP component, described in section 2.3.1.4. The E5a-QP is transmitted by a subset of

Galileo satellites. The specific list of satellites transmitting E5a-QP is provided in https://www.gsc-europa.eu/galileo/services/galileo-open-service/quasipilot.

2.3.1.1 *E5ab-IQ Modulation Scheme*

The diagram in Figure 3 provides a generic view of the E5 signal AltBOC modulation generation.
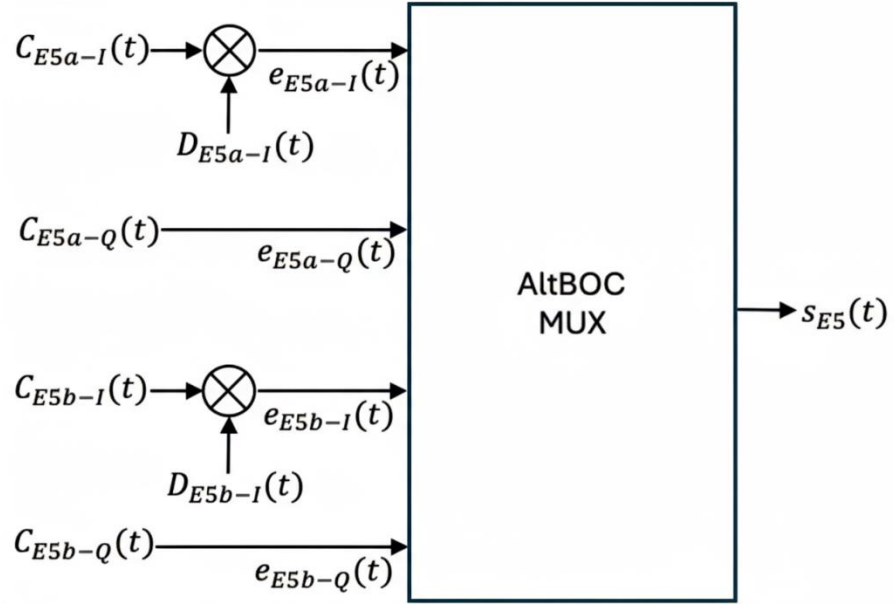
Figure 3: Modulation Scheme for the E5 Signal

The E5 signal components are generated according to the following:

- e_{E5a-I} from the F/NAV navigation data stream D_{E5a-I} modulated with the ranging code C_{E5a-I}

- e_{E5a-Q} (pilot component) from the ranging code C_{E5a-Q}

- e_{E5b-I} from the I/NAV navigation data stream D_{E5b-I} modulated with the ranging code C_{E5b-I}

- e_{E5b-Q} (pilot component) from the ranging code C_{E5b-Q}

The respective definitions are following (Eq. 2):

$$e_{E5a-I}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E5a-I,|i|_{L_{E5a-I}}} D_{E5a-I,[i]_{DC_{E5a-I}}} \text{rect}_{T_{C,E5a-I}}(t - i\,T_{C,E5a-I}) \right]$$

$$e_{E5a-Q}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E5a-Q,|i|_{L_{E5a-Q}}} \text{rect}_{T_{C,E5a-Q}}(t - i\,T_{C,E5a-Q}) \right]$$

Eq. 2

$$e_{E5b-I}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E5b-I,|i|_{L_{E5b-I}}} D_{E5b-I,[i]_{DC_{E5b-I}}} \text{rect}_{T_{C,E5b-I}}(t - i\,T_{C,E5b-I}) \right]$$

$$e_{E5b-Q}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E5b-Q,|i|_{L_{E5b-Q}}} \, \text{rect}_{T_{C,E5b-Q}}(t - i\,T_{C,E5b-Q}) \right]$$

The Galileo satellites transmit the E5 signal components with the ranging codes chip rates and symbol rates stated in Table 5.

Table 5: E5 Chip Rates and Symbol Rates

Signal (Parameter X)	Component (Parameter Y)	Ranging Code Chip-Rate $R_{C,X-Y}$ (Mchip/s)	Symbol-Rate $R_{D,X-Y}$ (symbols/s)
E5a	I	10.230	50
E5a	Q	10.230	No data ('pilot component')
E5b	I	10.230	250
E5b	Q	10.230	No data ('pilot component')

2.3.1.2 *E5ab-IQ Modulation Type*

The wideband E5 signal is generated with the AltBOC modulation of side-band sub-carrier rate $R_{S,E5} = 1 / T_{S,E5} = 15.345$ MHz (15 x 1.023 MHz) according to the expression in Eq. 2 with the binary signal components e_{E5a-I}, e_{E5a-Q}, e_{E5b-I} and e_{E5b-Q} as defined in Eq. 3.

Note that E5a and E5b signals can be processed independently by the user receiver as though they were two separate QPSK signals with a carrier frequency of 1176.45 MHz and 1207.14 MHz respectively.

$$
\begin{aligned}
s_{E5}(t) = &\frac{1}{2\sqrt{2}} \left(e_{E5a-I}(t) + j\,e_{E5a-Q}(t) \right) \left[sc_{E5-S}(t) - j\,sc_{E5-S}\left(t - \frac{T_{s,E5}}{4} \right) \right] + \\
&\frac{1}{2\sqrt{2}} \left(e_{E5b-I}(t) + j\,e_{E5b-Q}(t) \right) \left[sc_{E5-S}(t) + j\,sc_{E5-S}\left(t - \frac{T_{s,E5}}{4} \right) \right] + \\
&\frac{1}{2\sqrt{2}} \left(\bar{e}_{E5a-I}(t) + j\,\bar{e}_{E5a-Q}(t) \right) \left[sc_{E5-P}(t) - j\,sc_{E5-P}\left(t - \frac{T_{s,E5}}{4} \right) \right] + \\
&\frac{1}{2\sqrt{2}} \left(\bar{e}_{E5b-I}(t) + j\,\bar{e}_{E5b-Q}(t) \right) \left[sc_{E5-P}(t) + j\,sc_{E5-P}\left(t - \frac{T_{s,E5}}{4} \right) \right]
\end{aligned}
$$

Eq. 3

The respective dashed signal components $\bar{e}_{E5a-I}$, $\bar{e}_{E5a-Q}$, $\bar{e}_{E5b-I}$ and $\bar{e}_{E5b-Q}$ represent product signals according to Eq. 4:

$$
\begin{aligned}
\bar{e}_{E5a-I} &= e_{E5a-Q}\,e_{E5b-I}\,e_{E5b-Q} & \bar{e}_{E5b-I} &= e_{E5b-Q}\,e_{E5a-I}\,e_{E5a-Q} \\
\bar{e}_{E5a-Q} &= e_{E5a-I}\,e_{E5b-I}\,e_{E5b-Q} & \bar{e}_{E5b-Q} &= e_{E5b-I}\,e_{E5a-I}\,e_{E5a-Q}
\end{aligned}
$$

Eq. 4

The parameters sc_{E5-S} and sc_{E5-P} represent the four-valued sub-carrier functions for

the single signals and the product signals respectively:

$$sc_{E5-S}(t) = \sum_{i=-\infty}^{\infty} AS_{|i|_8} \, rect_{T_{S,E5}\,/\,8}\,(t - i\,T_{S,E5}\,/\,8)$$

$$sc_{E5-P}(t) = \sum_{i=-\infty}^{\infty} AP_{|i|_8} \, rect_{T_{S,E5}\,/\,8}\,(t - i\,T_{S,E5}\,/\,8)$$

Eq. 5

The coefficients AS_i and AP_i are according to Table 6.

Table 6: AltBOC Sub-carrier Coefficients

i	0	1	2	3	4	5	6	7
$2 \cdot AS_i$	$\sqrt{2}+1$	1	-1	$-\sqrt{2}-1$	$-\sqrt{2}-1$	-1	1	$\sqrt{2}+1$
$2 \cdot AP_i$	$-\sqrt{2}+1$	1	-1	$\sqrt{2}-1$	$\sqrt{2}-1$	-1	1	$-\sqrt{2}+1$

One period of the sub-carrier functions sc_{E5-S} and sc_{E5-P} is shown in Figure 4:
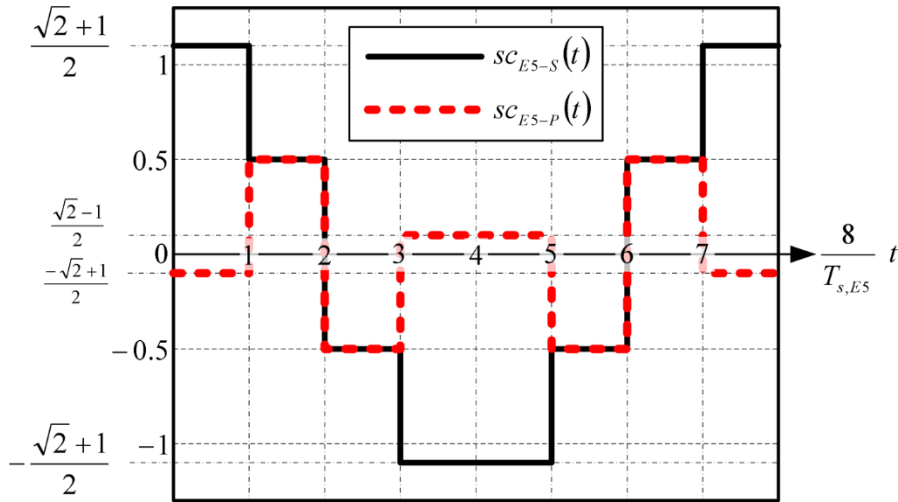
Figure 4: One Period of the Two Sub-carrier Functions Involved in AltBOC Modulation

2.3.1.3 *E5ab-IQ Equivalent Modulation Type*

Equivalently, the AltBOC complex baseband signal $s_{E5}(t)$ can be described as an 8-PSK signal according to Eq. 6 The corresponding phase states are illustrated in Figure 5.

$$s_{E5}(t) = exp\left(j\frac{\pi}{4}\,k(t)\right), \text{with} \ \ k(t) \in \{\,1,2,3,4,5,6,7,8\,\}$$

Eq. 6
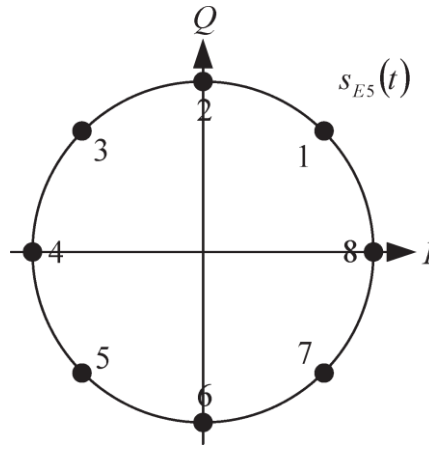
Figure 5: 8-PSK Phase-State Diagram of E5 AltBOC Signal

The relation of the 8 phase states to the 16 different possible states of the quadruple $e_{E5a-I}(t)$, $e_{E5a-Q}(t)$, $e_{E5b-I}(t)$, and $e_{E5b-Q}(t)$ depends also on time. Therefore, time is partitioned first in sub-carrier intervals $T_{s,E5}$ and further sub-divided in 8 equal sub-periods. The index i_{Ts} of the actual sub-period is given by Eq. 7 and determines which relation between input quadruple and phase states has to be used.

$$i_{T_s} = \text{integer part} \left[\frac{8}{T_{s,E5}} \left(t \text{ modulo } T_{s,E5} \right) \right] \text{ with } i_{T_s} \in \{ 0, 1, 2, 3, 4, 5, 6, 7 \} \qquad \text{Eq. 7}$$

The dependency of phase-states from input-quadruples and time is given in Table 7.

Table 7: Look-up Table for AltBOC Phase States

		Input Quadruples															
eE5a-I		-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
eE5b-I		-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1
eE5a-Q		-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1
eE5b-Q		-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1
$t' = t$ modulo $T_{s,E5}$		k according to $s_{E5}(t) = \exp(j\, k\, \pi\, /\, 4)$															
i_{T_s}	t'																
0	$[\,0, T_{s,E5}/8\,[$	5	4	4	3	6	3	1	2	6	5	7	2	7	8	8	1
1	$[\,T_{s,E5}/8, 2\,T_{s,E5}/8\,[$	5	4	8	3	2	3	1	2	6	5	7	6	7	4	8	1
2	$[\,2\,T_{s,E5}/8, 3\,T_{s,E5}/8\,[$	1	4	8	7	2	3	1	2	6	5	7	6	3	4	8	5
3	$[\,3\,T_{s,E5}/8, 4\,T_{s,E5}/8\,[$	1	8	8	7	2	3	1	6	2	5	7	6	3	4	4	5
4	$[\,4\,T_{s,E5}/8, 5\,T_{s,E5}/8\,[$	1	8	8	7	2	7	5	6	2	1	3	6	3	4	4	5
5	$[\,5\,T_{s,E5}/8, 6\,T_{s,E5}/8\,[$	1	8	4	7	6	7	5	6	2	1	3	2	3	8	4	5
6	$[\,6\,T_{s,E5}/8, 7\,T_{s,E5}/8\,[$	5	8	4	3	6	7	5	6	2	1	3	2	7	8	4	1
7	$[\,7\,T_{s,E5}/8, T_{s,E5}\,[$	5	4	4	3	6	7	5	2	6	1	3	2	7	8	8	1

2.3.1.4 *E5a-QP Signal*

The E5a Quasi-Pilot (E5a-QP) signal component is designed to enable low complexity acquisition capability of Galileo signals.

The E5a-QP signal component is generated according to the following:

- $e_{E5a\text{-}QP}$ (pilot component) from the ranging code $C_{E5a\text{-}QP}$

The respective definition is the following (Eq. 8)

$$e_{E5a-QP}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E5a-QP,|i|_{L_{E5a-QP}}} \text{ rect}_{T_{C,E5a-QP}}(t - i\, T_{C,E5a-QP}) \right] \qquad \text{Eq. 8}$$

The Galileo satellites transmit the E5a-QP signal component with the carrier frequency, modulation and ranging codes chip rate provided in Table 8. The E5a-QP signal component does not carry any user data[1].

Table 8: E5a-QP Carrier Frequency, Modulation and Chip Rate

Component	Carrier Frequency (MHz)	Modulation Type	Ranging Code Chip-Rate $R_{C,E5a\text{-}QP}$ (MChip/s)
E5a-QP	1176.450	BPSK	5.115

2.3.2 E6 Signal

Figure 6 provides a generic view of the E6 signal generation.
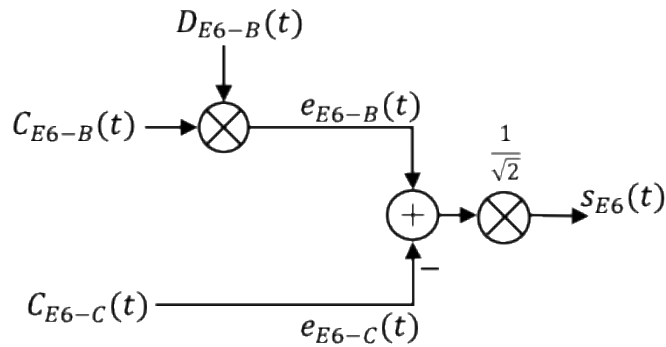
Figure 6: Modulation Scheme for the E6 Signal

The E6 signal B and C components are generated according to the following:

- $e_{E6\text{-}B}$ from the C/NAV navigation data stream $D_{E6\text{-}B}$ modulated with the ranging code $C_{E6\text{-}B}$

---

[1] Further and improved QP signals will be deployed in future (in E5 and in other bands), also including a very short navigation message providing the capability to resolve quickly a remaining receiver time ambiguity (without additional observables). As a result of this service evolution, the E5a-QP will eventually be discontinued, being superseded by the new QP signals. An overview of all QP signals (present and future capabilities) is provided in [RD6]

- $e_{E6\text{-}C}$ (pilot component) from the ranging code $C_{E6\text{-}C}$

Eq. 9 provides their mathematical description.

$$e_{E6-B}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E6-B,|i|_{L_{E6-B}}}\, D_{E6-B,[i]_{DC_{E6-B}}}\, \text{rect}_{T_{C,E6-B}}(t - i\, T_{C,E6-B}) \right]$$

Eq. 9

$$e_{E6-C}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E6-C,|i|_{L_{E6-C}}}\, \text{rect}_{T_{C,E6-C}}(t - i\, T_{C,E6-C}) \right]$$

Ranging code $C_{E6\text{-}C}$ may be encrypted in the future. The Galileo satellites transmit the E6 signal components with the ranging codes chip rates and symbol rates stated in Table 9.

Table 9: E6 Chip Rates and Symbol Rates

Component (Parameter Y)	Ranging Code Chip-Rate $R_{C,E6\text{-}Y}$ (MChip/s)	Symbol-Rate $R_{D,E6\text{-}Y}$ (symbols/s)
B	5.115	1000
C	5.115	No data ('pilot component')

The E6 signal is generated according to Eq. 10, with the binary signal components $e_{E6\text{-}B}(t)$ and $e_{E6\text{-}C}(t)$.

$$s_{E6}(t) = \frac{1}{\sqrt{2}} \left[e_{E6-B}(t) - e_{E6-C}(t) \right]$$

Eq. 10

Note: both pilot and data components are combined on the same carrier component, with a power sharing of 50 percent.

2.3.3 E1 Signal

Figure 7 provides a generic view of the E1 CBOC signal generation.
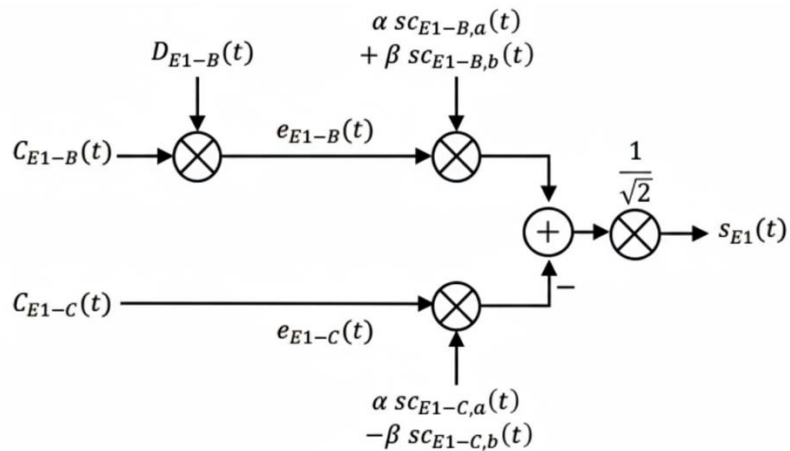
The E1 CBOC signal components are generated as follows:

- e_{E1-B} from the I/NAV navigation data stream D_{E1-B} and the ranging code C_{E1-B}, then modulated with the sub-carriers $sc_{E1-B,a}$ and $sc_{E1-B,b}$

- e_{E1-C} (pilot component) from the ranging code C_{E1-C} including its secondary code, then modulated with the sub-carriers $sc_{E1-C,a}$ and $sc_{E1-C,b}$

Eq. 11 provides the mathematical description of these components.

$$e_{E1-B}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E1-B,|i|_{L_{E1-B}}} D_{E1-B,[i]_{DC_{E1-B}}} \text{rect}_{T_{C,E1-B}}(t - i\, T_{C,E1-B}) \right]$$

Eq. 11

$$e_{E1-C}(t) = \sum_{i=-\infty}^{\infty} \left[C_{E1-C,|i|_{L_{E1-C}}} \text{rect}_{T_{C,E1-C}}(t - i\, T_{C,E1-C}) \right]$$

Galileo satellites transmit ranging signals for the E1 signal with the chip rates and sub- carrier rates defined in the following Table 10.

Table 10: E1 CBOC Chip Rates and Sub-carrier Rates

Component (Parameter Y)	Sub-carrier Type	Sub-carrier Rate		Ranging Code Chip-Rate $R_{C,E1-Y}$ (Mcps)
		$R_{S,E1-Y,a}$ (MHz)	$R_{S,E1-Y,b}$ (MHz)	
B	CBOC, in-phase	1.023	6.138	1.023
C	CBOC, anti-phase	1.023	6.138	1.023

The navigation data message stream, after channel encoding, is transmitted with the symbol rate as stated in Table 11.

Table 11: E1-B/C Symbol Rates

Component (Parameter Y)	Symbol Rate $R_{D,E1-Y}$ (symbols/s)
B	250
C	No data ('pilot component')

The E1-B/C composite signal is then generated according to equation Eq. 12 below, with the binary signal components $e_{E1-B}(t)$ and $e_{E1-C}(t)$. Note that as for E6, both pilot and data components are modulated onto the same carrier component, with a power sharing of 50 percent.

$$s_{E1}(t) = \frac{1}{\sqrt{2}} \left(e_{E1-B}(t) \big(\alpha\, sc_{E1-B,a}(t) + \beta\, sc_{E1-B,b}(t) \big) - e_{E1-C}(t) \big(\alpha\, sc_{E1-C,a}(t) - \beta\, sc_{E1-C,b}(t) \big) \right)$$

$$\text{with} \quad sc_X(t) = \text{sgn}\big(\sin(2\pi\, R_{s,X}\, t)\big) \qquad \text{Eq. 12}$$

The parameters α and β are chosen such that the combined power of the $sc_{E1\text{-}B,b}$ and the $sc_{E1\text{-}C,b}$ sub carrier components equals 1/11 of the total power of $e_{E1\text{-}B}$ plus $e_{E1\text{-}C}$, before application of any bandwidth limitation. This yields:

$$\alpha = \sqrt{\frac{10}{11}} \quad \text{and} \quad \beta = \sqrt{\frac{1}{11}}$$

One period of the sub-carrier function $\alpha\, sc_{E1\text{-}B,a}(t) + \beta\, sc_{E1\text{-}B,b}(t)$ for the E1-B signal component and one period of the sub-carrier function $\alpha\, sc_{E1\text{-}C,a}(t) - \beta\, sc_{E1\text{-}C,b}(t)$ for the E1-C signal component are shown in the following Figure 8
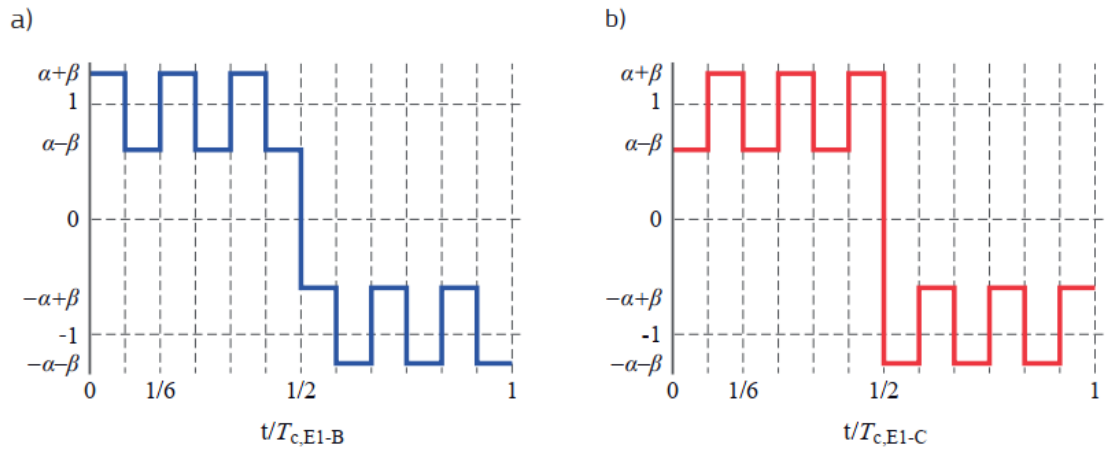
Figure 8: One period of the CBOC sub-carrier for a) the E1-B signal component, and b) the E1-C signal component

2.4 Logic Levels

The correspondence between the logic level code bits used to modulate the signal and the signal level is according to the values stated in Table 12.

Table 12: Logic to Signal Level Assignment

Logic Level	Signal Level
1	-1.0
0	+1.0

2.5 Transmitted Signal Phase Noise

The phase noise spectral density of the un-modulated carrier will allow a second-order phase locked loop with 10 Hz one-sided noise bandwidth to track the carrier to an accuracy of 0.04 radians RMS.

2.6 Transmitted Signals Code/Data Coherency

The edge of each data symbol coincides with the edge of a code chip. Periodic

spreading codes start coincides with the start of a data symbol.

The edge of each secondary code chip coincides with the edge of a primary code chip. Primary code start coincides with the start of a secondary code chip.

2.7 Received Power Levels on Ground

The Galileo satellites provide Galileo E5, E6 and E1 signal strengths that meet the minimum levels of received power on ground as specified in Table 13, for user elevation angles above 5 degrees. The minimum received power on ground is measured at the output of an ideally matched RHCP 0 dBi user receiving antenna.

Assuming the same receiving antenna, the Galileo terrestrial user's received signal power is not expected to exceed the maximum levels specified in Table 13.

Table 13: Minimum and Maximum Received Power Levels on Ground

Signal	Signal Component	Total Received Minimum Power (dBW)	Total Received Maximum Power (dBW)
E5	E5a (total I+Q) (50/50% I/Q power sharing)	-155.25	-150
	E5b (total I+Q) (50/50% I/Q power sharing)	-155.25	-150
	E5a-QP	-160.75	-155.50
E6	E6-B/C (total B+C) (50/50% E6-B/E6-C power sharing)	-155.25	-150
E1	E1-B/C (total B+C) (50/50% E1-B/E1-C power sharing)	-157.25	-152

For the purpose of user receiver design and test, a dynamic range of up to 7 dB above the corresponding minimum power levels should be considered.

2.8 Payload and Component Reception Losses

For each signal component, the correlation loss due to payload distortions will be below 0.6 dB.

For the reference receiver bandwidths defined in section 2.1.3, additional losses due to receiver filtering are to be considered, as shown in Table 14.

Table 14: Additional Losses due to Receiver Filtering

Signal	Loss (dB)
E1	0.1
E6	0.0
E5	0.4
E5a	0.6
E5b	0.6

3. Galileo Spreading Codes Characteristics

3.1 Code Lengths

The ranging codes are built from so-called primary and secondary codes by using a tiered codes construction described in paragraph 3.2. The code lengths to be used for each signal component are stated in Table 15. Note that the E6 ranging codes are not subject of this SIS ICD.

Table 15: Code Lengths

Signal Component	Tiered Code Period (ms)	Code Length (chips)	
		Primary	Secondary
E5a-I	20	10230	20
E5a-Q	100	10230	100
E5b-I	4	10230	4
E5b-Q	100	10230	100
E5a-QP	2 *	330	N/A
E1-B	4	4092	N/A
E1-C	100	4092	25

* The 330-chip code is repeated 31 times within a 2 ms period without any overlay or secondary code. Each code has therefore a period of 2/31 ms.

3.2 Tiered Codes Generation

Long spreading codes are generated by a tiered code construction, whereby a secondary code sequence is used to modify successive repetitions of a primary code, as shown in Figure 9 for a primary code of length N and chip rate f_c, and a secondary code of length N_S and chip rate $f_{cs} = f_c / N$. The duration of N chips is also called a primary code epoch in Figure 9. In logical representation, the secondary code chips are sequentially exclusive-ored with the primary code, always one chip of the secondary code per period of the primary code.
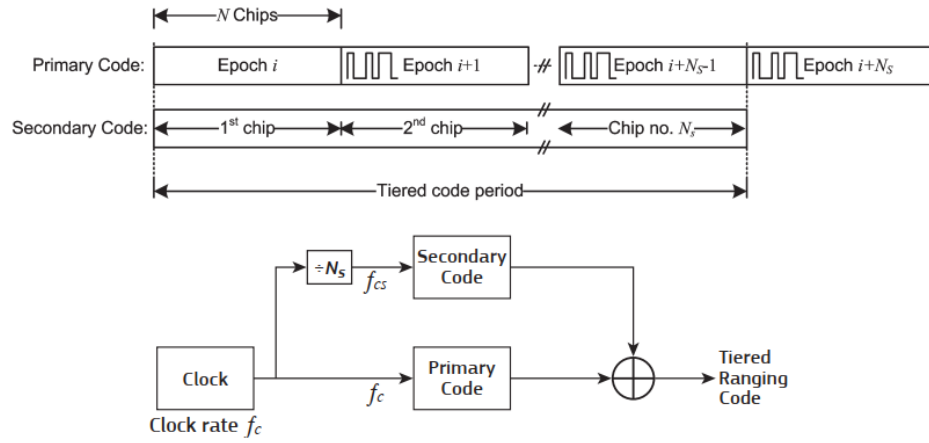
Figure 9: Tiered Codes Generation

3.3 Primary Codes Generation

The primary spreading codes can be either

- Linear feedback shift register-based pseudo-noise sequences, or

- Optimised pseudo-noise sequences

Optimised codes need to be stored in memory and therefore are often called 'memory codes'. Register based codes used in Galileo are generated as combinations of two M-sequences, being truncated to the appropriate length. These codes can be generated either with pairs of LFSR or might be also stored in memory.

Figure 10 shows an example standard implementation of the LFSR method for the generation of truncated and combined M sequences. Two parallel shift registers are used: base register 1 and base register 2. The primary code output sequence is the exclusive OR of base register 1 and 2 output sequences, the shift between these two sequences is zero.

Each shift register i (i = 1 for base register 1 and i = 2 for base register 2) of length R is fed back with a particular set of feedback taps $\{a_{i,j}\}_{j = 1 \ldots R} = [\, a_{i,1}, a_{i,2}, \ldots, a_{i,R} \,]$ and its content is represented by a vector $\{c_{i,j}\}_{j = 1 \ldots R} = [\, c_{i,1}, c_{i,2}, \ldots, c_{i,R} \,]$.

For truncation to primary code length N, the content of the two shift registers is reinitialised (reset) after N cycles with the so-called start-values: $\{s_{i,j}\}_{j = 1 \ldots R} = [\, s_{i,1}, s_{i,2}, \ldots, s_{i,R} \,]$.
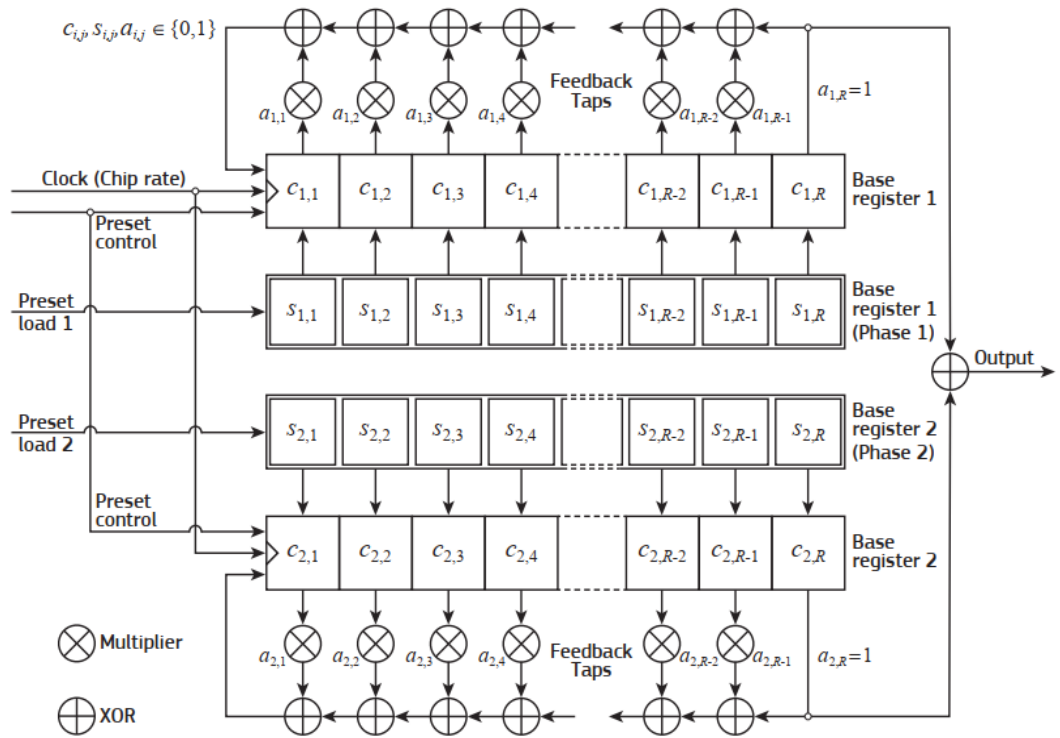
Figure 10: LFSR Based Code Generator for Truncated and Combined M-sequences

3.4 Primary Codes Definition

3.4.1 E5 Primary Codes

The E5a-I, E5a-Q, E5b-I and E5b-Q primary codes are generated via LFSR, using the principle defined in paragraph 3.3, and the parameters defined in Table 16. Note that each set of codes for each signal component comprises 50 members.

Table 16: E5 Primary Codes Specifications

Component	ShiL Register Length (polynomial order)	Feedback Taps (octal)	
		Register 1	Register 2
E5a-I	14	40503	50661
E5a-Q	14	40503	50661
E5b-I	14	64021	51445
E5b-Q	14	64021	43143

The transformation between the octal notation and the vector description $\{a_{i,j}\}$ for the feedback tap positions is defined as follows and is illustrated with an example (Register 1 for E5a-I in Table 16) in Figure 11. After transferring the octal vector notation into binary notation, the bits are counted right to left starting with $j = 0$ from the LSB and ending with $j = R$ at the MSB, where R is the code register length. Then the jth bit applies for the feedback tap $a_{i,j}$ for $j = 1, …, R$, as shown in Figure 10. Note: $a_{i,R}$ is always one and $a_{i,0}$ is not considered in the register feedback tap.
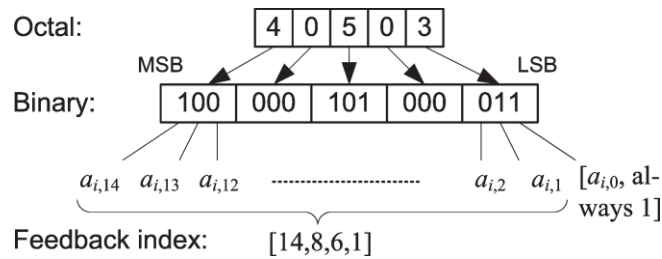
Figure 11: Code Register Feedback Taps Representation (example for E5a-I)

The start values for all base register 1 cells, in logic level notation, are '1' for all codes of E5a-I, E5a-Q, E5b-I and E5b-Q. The start values of base register 2 are provided in the subsequent sections. The transformation between the octal notation and the vector description $\{s_{i,j}\}$ for the register start values is defined as follows and is illustrated with an example in Figure 12 (code number 1 of E5a-I in Table 17). After transferring the octal notation in binary notation, the bits are counted right to left starting with $j=1$ (Note: the different start value compared to the feedback taps definition) from the LSB and ending with $j=R$ at the MSB, where R is the code register length. Then the jth bit applies to the start value $s_{i,j}$ for $j = 1, …, R$, as shown in Figure 10. Note: in this example the MSB is zero in order to complete the 14-bits binary value sequence to fit into a sequence of octal symbols.
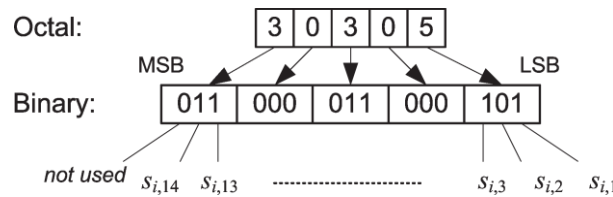
Figure 12: Start Value Representation for Base Register 2 (first code of E5a-I)

3.4.1.1 *Base Register 2 Start Value for E5a-I*

The octal format base register 2 start value with the convention defined in paragraph 3.4.1 is as defined in Table 17 for each primary E5a-I code. In addition, the conventional hexadecimal format of the first 24 code chips of the E5a-I primary codes is given in the table. For example, the first 24 chips of the E5a-I primary code N°1 in Table 17 are 0 0 1 1 1 1 0 0 1 1 1 0 1 0 1 0 1 0 0 1 1 1 0 1, the first binary value corresponding to the first primary code chip in time.

Table 17: Base Register 2 Start Values and First Code Chip for E5a-I

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
1	30305	3CEA9D	26	14401	9BFAC7
2	14234	9D8CF1	27	34727	18A25B
3	27213	45D1C8	28	22627	69A39F
4	20577	7A0133	29	30623	39B27D

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
5	23312	64D423	30	27256	454598
6	33463	23300D	31	01520	F2BC62
7	15614	91CEF2	32	14211	9DDBC6
8	12537	AA82DC	33	31465	332827
9	01527	F2A17D	34	22164	6E2FCA
10	30236	3D84AE	35	33516	22C6D5
11	27344	446D38	36	02737	E881D9
12	07272	C514F2	37	21316	74C4DB
13	36377	0C0184	38	35425	13AB03
14	17046	8767E0	39	35633	119323
15	06434	CB8EFF	40	24655	594886
16	15405	93EBCD	41	14054	9F4D89
17	24252	5D55CE	42	27027	47A3C0
18	11631	B19B7C	43	06604	C9ED53
19	24776	5805FC	44	31455	334994
20	00630	F99EA1	45	34465	1B2A30
21	11560	B23CE5	46	25273	5513F3
22	17272	8515E8	47	20763	7831C1
23	27445	436822	48	31721	30B93A
24	31702	30F77B	49	17312	84D5B4
25	13012	A7D629	50	13277	A5029C

3.4.1.2 *Base Register 2 Start Value for E5a-Q*

The octal format base register 2 start value with the convention defined in paragraph 3.4.1 is as defined in Table 18 for each E5a-Q primary code. The hexadecimal format of the first 24 code chips with the convention defined in paragraph 3.4.1.1 is also given.

Table 18: Base Register 2 start Values and First Code Chip for E5a-Q

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
1	25652	515537	26	20606	79E450
2	05142	D67539	27	11162	B63460
3	24723	58B2E5	28	22252	6D562B
4	31751	305914	29	30533	3A9010
5	27366	442710	30	24614	59CD72

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
6	24660	593CF8	31	07767	C0211A
7	33655	214AD7	32	32705	28EB96
8	27450	435EA6	33	05052	D7554B
9	07626	C1A7D5	34	27553	425126
10	01705	F0E94A	35	03711	E0DAFB
11	12717	A8C239	36	02041	EF79F2
12	32122	2EB63B	37	34775	18085D
13	16075	8F0A46	38	05274	D50CD8
14	16644	896DD4	39	37356	0447B9
15	37556	0245F1	40	16205	8DE877
16	02477	EB0160	41	36270	0D1FA0
17	02265	ED28B3	42	06600	C9FCF7
18	06430	CB9F5B	43	26773	48116D
19	25046	576592	44	17375	840BCC
20	12735	A88811	45	35267	152004
21	04262	DD3649	46	36255	0D4897
22	11230	B59F42	47	12044	AF6D25
23	00037	FF81F6	48	26442	4B7593
24	06137	CE8128	49	21621	71BB1B
25	04312	DCD55C	50	25411	53DA0E

3.4.1.3 *Base Register 2 Start Value for E5b-I*

The octal format base register 2 start value with the conventions defined in paragraph 3.4.1 is as defined in Table 19 for each E5b-I primary code. The hexadecimal format of the first 24 code chips with the conventions defined in paragraph 3.4.1.1 is also given.

Table 19: Base Register 2 Start Values and First Code Chip for E5b-I

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
1	07220	C5BEA1	26	25664	512FA9
2	26047	4F6248	27	21403	73F36B
3	00252	FD5488	28	32253	2D5317
4	17166	86277B	29	02337	EC8390
5	14161	9E39D5	30	30777	380374
6	02540	EA7EDE	31	27122	46B4DE

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
7	01537	F28321	32	22377	6C01D9
8	26023	4FB0C9	33	36175	0E0BB6
9	01725	F0AB64	34	33075	2708C7
10	20637	79833B	35	33151	265B55
11	02364	EC2D91	36	13134	A68E1C
12	27731	409B11	37	07433	C3916E
13	30640	397E16	38	10216	BDC595
14	34174	1E0FCD	39	35466	1327D0
15	06464	CB2F5A	40	02533	EA921F
16	07676	C1079A	41	05351	D45869
17	32231	2D9BC6	42	30121	3EB98A
18	10353	BC5146	43	14010	9FDE16
19	00755	F848B0	44	32576	2A04CA
20	26077	4F01E8	45	30326	3CA56F
21	11644	B16C9B	46	37433	03928A
22	11537	B2827D	47	26022	4FB5B9
23	35115	16C809	48	35770	101EC7
24	20452	7B570F	49	06670	C91D4F
25	34645	1969C0	50	12017	AFC22B

3.4.1.4   *Base Register 2 Start Value for E5b-Q*

The octal format base register 2 start value with the conventions defined in paragraph 3.4.1 is as defined in Table 20 for each E5b-Q primary code. The hexadecimal format of the first 24 code chips with the conventions defined in paragraph 3.4.1.1 is also given.

Table 20: Base Register 2 Start Values and First Code Chip for E5b-Q

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
1	03331	E49AF0	26	20134	7E8CFB
2	06143	CE701F	27	11262	B536C3
3	25322	54B709	28	10706	B8E68C
4	23371	641AB1	29	34143	1E7272
5	00413	FBD0AE	30	11051	B75B69
6	36235	0D8BC9	31	25460	533F65
7	17750	805FA5	32	17665	812B41

Code No	Start Value	Initial Sequence	Code No	Start Value	Initial Sequence
8	04745	D86BA0	33	32354	2C4DE1
9	13005	A7E921	34	21230	759E2C
10	37140	067E55	35	20146	7E6434
11	30155	3E4B58	36	11362	B43640
12	20237	7D82FB	37	37246	05671B
13	03461	E33BC2	38	16344	8C6FE0
14	31662	31372C	39	15034	978D4E
15	27146	46676F	40	25471	5319BF
16	05547	D2613E	41	25646	516499
17	02456	EB443C	42	22157	6E4292
18	30013	3FD0B1	43	04336	DC86A3
19	00322	FCB7CF	44	16356	8C46BE
20	10761	B83815	45	04075	DF0B03
21	26767	48224A	46	02626	E9A5B2
22	36004	0FEE25	47	11706	B0E553
23	30713	38D33B	48	37011	07DBAC
24	07662	C135B9	49	27041	4778E4
25	21610	71DE13	50	31024	37AF4F

3.4.2   E5a-QP Primary Codes

E5a-QP primary codes are a family of 40* memory-stored binary sequences with code length of 330 chips.

E5a-QP primary codes are built from three generative short codes with length 15 chips, 11 chips and 10 chips, shown in Table 21. A hexadecimal representation of the primary codes is provided in Annex C (provided only in the electronic version of this ICD).

The E5a-QP primary codes are obtained as the XOR of three generative codes. Each of these three generative codes are obtained by repeating the 15-, 11- and 10-chip short codes, respectively, until reaching 330 chips. As an example, the first of the three generative codes is obtained by repeating 22 times the 15-chip short code.

Table 21: E5a-QP generative Short Codes

Code No.	15-chip Code	11-chip Code	10-chip Code
1	335A	60A	384
2	146E	1C8	238
3	3876	7AE	4D4
4	499A	688	064

Code No.	15-chip Code	11-chip Code	10-chip Code
5	3548	2C0	588
6	052E	504	070
7	598C	6E2	530
8	2E84	064	658
9	01F2	298	6E4
10	3162	134	478
11	3E16	148	378
12	2722	712	468
13	4E9E	5EC	1BC
14	20CA	046	580
15	78FA	74E	6E0
16	029E	4D0	4C0
17	3D78	106	770
18	4990	5C4	00C
19	75D6	034	760
20	03D6	286	20C
21	456A	114	49C
22	3AE0	48E	658
23	4EBE	2BE	314
24	7DB8	67E	7E4
25	1056	5DE	270
26	0E76	620	300
27	401E	63E	1BC
28	1DF2	73E	478
29	691E	37E	194
30	25EE	328	668
31	4C08	0A6	3F8
32	442C	302	580
33	0272	37C	450
34	42C4	7A6	32C
35	25A2	11A	1D8
36	5598	4DE	190
37	2DD6	508	658
38	1D64	3BA	5C4
39	3E4C	68E	014
40	7EC0	60A	5E8

*   In order to optimise for cross-correlation performance and given the short length of the codes, the family is limited to 40 codes

3.4.3 E1-B and E1-C Primary Codes

The E1-B and E1-C primary codes are pseudo-random memory code sequences according to the hexadecimal representation provided in Annex C (provided only in the electronic version of this ICD). Note that each set of codes for each signal component comprises 50 members.

3.5 Secondary Codes

3.5.1 Definition of Secondary Codes

The secondary codes are fixed sequences as defined in hexadecimal notation in Table 22 and Table 23, following again the convention used in paragraph 3.4.1.1. For secondary codes whose length is not divisible by four (case of $CS25_1$ only), the last (most right- hand) hexadecimal symbol is obtained by filling up the last group of code chips with zeros at the end in time (to the right), to reach a final length of 4 binary symbols. Those two tables provide as well the code identifiers together with the code lengths, the number of hexadecimal symbols and the number of filled zeros.

For example, the $CS25_1$ secondary code in Table 22 corresponds to the binary sequence '0 0 1 1 1 0 0 0 0 0 0 0 1 0 1 0 1 1 0 1 1 0 0 1 0', the first binary value corresponding to the first secondary code chip in time.

Table 22: Secondary Code Sequences (Part 1)

Code Identifier	Code Length	No. of Hexadec. Symbols	Number of Filled up Zeros	Code Sequence
$CS4_1$	4	1	0	E
$CS20_1$	20	5	0	842E9
$CS25_1$	25	7	3	380AD90
$CS100_1$	100	25	0	83F6F69D8F6E15411FB8C9B1C
$CS100_2$	100	25	0	66558BD3CE0C7792E83350525
$CS100_3$	100	25	0	59A025A9C1AF0651B779A8381
$CS100_4$	100	25	0	D3A32640782F7B18E4DF754B7
$CS100_5$	100	25	0	B91FCAD7760C218FA59348A93
$CS100_6$	100	25	0	BAC77E933A779140F094FBF98
$CS100_7$	100	25	0	537785DE280927C6B58BA6776
$CS100_8$	100	25	0	EFCAB4B65F38531ECA22257E2
$CS100_9$	100	25	0	79F8CAE838475EA5584BEFC9B
$CS100_{10}$	100	25	0	CA5170FEA3A810EC606B66494
$CS100_{11}$	100	25	0	1FC32410652A2C49BD845E567
$CS100_{12}$	100	25	0	FE0A9A7AFDAC44E42CB95D261

Code Identifier	Code Length	No. of Hexadec. Symbols	Number of Filled up Zeros	Code Sequence
CS100$_{13}$	100	25	0	B03062DC2B71995D5AD8B7DBE
CS100$_{14}$	100	25	0	F6C398993F598E2DF4235D3D5
CS100$_{15}$	100	25	0	1BB2FB8B5BF24395C2EF3C5A1
CS100$_{16}$	100	25	0	2F920687D238CC7046EF6AFC9
CS100$_{17}$	100	25	0	34163886FC4ED7F2A92EFDBB8
CS100$_{18}$	100	25	0	66A872CE47833FB2DFD5625AD
CS100$_{19}$	100	25	0	99D5A70162C920A4BB9DE1CA8
CS100$_{20}$	100	25	0	81D71BD6E069A7ACCBEDC66CA
CS100$_{21}$	100	25	0	A654524074A9E6780DB9D3EC6
CS100$_{22}$	100	25	0	C3396A101BEDAF623CFC5BB37
CS100$_{23}$	100	25	0	C3D4AB211DF36F2111F2141CD
CS100$_{24}$	100	25	0	3DFF25EAE761739265AF145C1
CS100$_{25}$	100	25	0	994909E0757D70CDE389102B5
CS100$_{26}$	100	25	0	B938535522D119F40C25FDAEC
CS100$_{27}$	100	25	0	C71AB549C0491537026B390B7
CS100$_{28}$	100	25	0	0CDB8C9E7B53F55F5B0A0597B
CS100$_{29}$	100	25	0	61C5FA252F1AF81144766494F
CS100$_{30}$	100	25	0	626027778FD3C6BB4BAA7A59D
CS100$_{31}$	100	25	0	E745412FF53DEBD03F1C9A633
CS100$_{32}$	100	25	0	3592AC083F3175FA724639098
CS100$_{33}$	100	25	0	52284D941C3DCAF2721DDB1FD
CS100$_{34}$	100	25	0	73B3D8F0AD55DF4FE814ED890
CS100$_{35}$	100	25	0	94BF16C83BD7462F6498E0282
CS100$_{36}$	100	25	0	A8C3DE1AC668089B0B45B3579
CS100$_{37}$	100	25	0	E23FFC2DD2C14388AD8D6BEC8
CS100$_{38}$	100	25	0	F2AC871CDF89DDC06B5960D2B
CS100$_{39}$	100	25	0	06191EC1F622A77A526868BA1
CS100$_{40}$	100	25	0	22D6E2A768E5F35FFC8E01796
CS100$_{41}$	100	25	0	25310A06675EB271F2A09EA1D
CS100$_{42}$	100	25	0	9F7993C621D4BEC81A0535703
CS100$_{43}$	100	25	0	D62999EACF1C99083C0B4A417
CS100$_{44}$	100	25	0	F665A7EA441BAA4EA0D01078C
CS100$_{45}$	100	25	0	46F3D3043F24CDEABD6F79543
CS100$_{46}$	100	25	0	E2E3E8254616BD96CEFCA651A

Code Identifier	Code Length	No. of Hexadec. Symbols	Number of Filled up Zeros	Code Sequence
CS100₄₇	100	25	0	E548231A82F9A01A19DB5E1B2
CS100₄₈	100	25	0	265C7F90A16F49EDE2AA706C8
CS100₄₉	100	25	0	364A3A9EB0F0481DA0199D7EA
CS100₅₀	100	25	0	9810A7A898961263A0F749F56

Table 23: Secondary Code Sequences (Part 2)

Code Identifier	Code Length	No. of Hexadec. Symbols	Number of Filled up Zeros	Code Sequence
CS100₅₁	100	25	0	CFF914EE3C6126A49FD5E5C94
CS100₅₂	100	25	0	FC317C9A9BF8C6038B5CADAB3
CS100₅₃	100	25	0	A2EAD74B6F9866E414393F239
CS100₅₄	100	25	0	72F2B1180FA6B802CB84DF997
CS100₅₅	100	25	0	13E3AE93BC52391D09E84A982
CS100₅₆	100	25	0	77C04202B91B22C6D3469768E
CS100₅₇	100	25	0	FEBC592DD7C69AB103D0BB29C
CS100₅₈	100	25	0	0B494077E7C66FB6C51942A77
CS100₅₉	100	25	0	DD0E321837A3D52169B7B577C
CS100₆₀	100	25	0	43DEA90EA6C483E7990C3223F
CS100₆₁	100	25	0	0366AB33F0167B6FA979DAE18
CS100₆₂	100	25	0	99CCBBFAB1242CBE31E1BD52D
CS100₆₃	100	25	0	A3466923CEFDF451EC0FCED22
CS100₆₄	100	25	0	1A5271F22A6F9A8D76E79B7F0
CS100₆₅	100	25	0	3204A6BB91B49D1A2D3857960
CS100₆₆	100	25	0	32F83ADD43B599CBFB8628E5B
CS100₆₇	100	25	0	3871FB0D89DB77553EB613CC1
CS100₆₈	100	25	0	6A3CBDFF2D64D17E02773C645
CS100₆₉	100	25	0	2BCD09889A1D7FC219F2EDE3B
CS100₇₀	100	25	0	3E49467F4D4280B9942CD6F8C
CS100₇₁	100	25	0	658E336DCFD9809F86D54A501
CS100₇₂	100	25	0	ED4284F345170CF77268C8584
CS100₇₃	100	25	0	29ECCE910D832CAF15E3DF5D1
CS100₇₄	100	25	0	456CCF7FE9353D50E87A708FA
CS100₇₅	100	25	0	FB757CC9E18CBC02BF1B84B9A
CS100₇₆	100	25	0	5686229A8D98224BC426BC7FC

Code Identifier	Code Length	No. of Hexadec. Symbols	Number of Filled up Zeros	Code Sequence
CS100₇₇	100	25	0	700A2D325EA14C4B7B7AA8338
CS100₇₈	100	25	0	1210A330B4D3B507D854CBA3F
CS100₇₉	100	25	0	438EE410BD2F7DBCDD85565BA
CS100₈₀	100	25	0	4B9764CC455AE1F61F7DA432B
CS100₈₁	100	25	0	BF1F45FDDA3594ACF3C4CC806
CS100₈₂	100	25	0	DA425440FE8F6E2C11B8EC1A4
CS100₈₃	100	25	0	EE2C8057A7C16999AFA33FED1
CS100₈₄	100	25	0	2C8BD7D8395C61DFA96243491
CS100₈₅	100	25	0	391E4BB6BC43E98150CDDCADA
CS100₈₆	100	25	0	399F72A9EADB42C90C3ECF7F0
CS100₈₇	100	25	0	93031FDEA588F88E83951270C
CS100₈₈	100	25	0	BA8061462D873705E95D5CB37
CS100₈₉	100	25	0	D24188F88544EB121E963FD34
CS100₉₀	100	25	0	D5F6A8BB081D8F383825A4DCA
CS100₉₁	100	25	0	0FA4A205F0D76088D08EAF267
CS100₉₂	100	25	0	272E909FAEBC65215E263E258
CS100₉₃	100	25	0	3370F35A674922828465FC816
CS100₉₄	100	25	0	54EF96116D4A0C8DB0E07101F
CS100₉₅	100	25	0	DE347C7B27FADC48EF1826A2B
CS100₉₆	100	25	0	01B16ECA6FC343AE08C5B8944
CS100₉₇	100	25	0	1854DB743500EE94D8FC768ED
CS100₉₈	100	25	0	28E40C684C87370CD0597FAB4
CS100₉₉	100	25	0	5E42C19717093353BCAAF4033
CS100₁₀₀	100	25	0	64310BAD8EB5B36E38646AF01

3.5.2 Secondary Codes Assignment

The assignment of the secondary codes of paragraph 3.5.1 to the signal components is according to Table 24. For the 4, 20- and 25-bit secondary codes the same code is used for all associated primary codes. For the 100-bit codes, an independent secondary code is assigned for each primary code.

Table 24: Secondary Code Assignment

Component	Secondary Code Assignment
E5a-I	CS20₁

Component	Secondary Code Assignment
E5a-Q	$CS100_{1-50}$
E5b-I	$CS4_1$
E5b-Q	$CS100_{51-100}$
E6-B	N/A
E6-C	$CS100_{1-50}$
E1-B	N/A
E1-C	$CS25_1$

3.6 Code Assignments to Satellites

3.6.1 Primary code assignment to satellites

The E5a-I, E5a-Q, E5b-I, E5b-Q primary codes (defined in Section 3.4.1), the E5a-QP primary codes (defined in Section 3.4.2), and the E1-B, E1-C primary codes (defined in Annex C of the electronic version of this ICD) are allocated to the space vehicle IDs (SVID) as follows:

- To SVID n (with n = 1 to 36) are assigned the corresponding E5a-I, E5a-Q, E5b-I, E5b-Q, E5a-QP, E1-B and E1-C primary code number n.

3.6.2 Secondary code assignment to satellites

The E5a-I, E5a-Q, E5b-I, E5b-Q and E1-C secondary codes (defined in Section 3.5.1) are allocated to the space vehicle IDs (SVID) as follows:

- The following secondary codes are assigned according to SVID n (with n = 1 to 36):
  - secondary code $CS100_n$ for the signal component E5a-Q (i.e. $CS100_1$ to SVID 1)
  - secondary code $CS100_{(n+50)}$ for the signal component E5b-Q (i.e. $CS100_{51}$ to SVID 1)
- The following secondary codes are assigned to all SVIDs (1 to 36):
  - secondary code $CS20_1$ for the signal component E5a-I (same for all SVIDs)
  - secondary code $CS4_1$ for the signal component E5b-I (same for all SVIDs)
  - secondary code $CS25_1$ for the signal component E1-C (same for all SVIDs)

4. Galileo Message Structure

4.1 General Message Format Specification

4.1.1 General Navigation Message Content

The Galileo Signal-In-Space data channels transmit different message types according to the general contents identified in Table 25 below. The F/NAV types of message correspond to the OS and the I/NAV types of message correspond to both OS and CS.

Table 25: Message Allocation and General Data Content

Message Type	Services	Component
F/NAV	OS	E5a-I
I/NAV	OS/CS	E5b-I and E1-B
C/NAV	CS	E6-B

Note: The C/NAV message format is not the subject of this SIS ICD. Refer to [RD5] for further details on the correction data provision through the C/NAV message.

4.1.2 General Navigation Message Structure

The complete navigation message data are transmitted on each data component as a sequence of frames. A frame is composed of several sub-frames, and a sub-frame in turn is composed of several pages. The page is the basic structure for building the navigation message.

For all message types, only the message pages include a 'type' marker to identify the content of each page received by the user. There is no management data transmitted within the navigation message to indicate sub-frame and frame structures, and indeed these higher-level structures should be considered as the typical flow of pages reflecting the current Galileo navigation message design, which may evolve together with future evolutions of Galileo. This evolution may also involve the inclusion of additional new page types beyond the types defined in this version of the Galileo OS SIS ICD. A user receiver is expected to be able to recognise page types and to react properly and in a well-controlled manner to page types unknown to its software as well as to variations in the order of received pages.

4.1.3 Bit and Byte Ordering Criteria

All data values are encoded using the following bit and byte ordering criteria:

- For numbering, the most significant bit/byte is numbered as bit/byte 0

- For bit/byte ordering, the most significant bit/byte is transmitted first

4.1.4 FEC Coding and Interleaving Parameters

4.1.4.1 *FEC Encoding*

The convolutional encoding for all data pages on all signal components is performed according to the parameters given in Table 26.

Table 26: Data Coding Parameters

Code Parameter	Value
Coding Rate	½
Coding Scheme	Convolutional
Constraint Length	7
Generator Polynomials	$G1$=171o $G2$=133o
Encoding Sequence	$G1$ then $G2$

Figure 13 depicts this convolutional coding scheme. Decoding can be implemented using a standard Viterbi decoder.
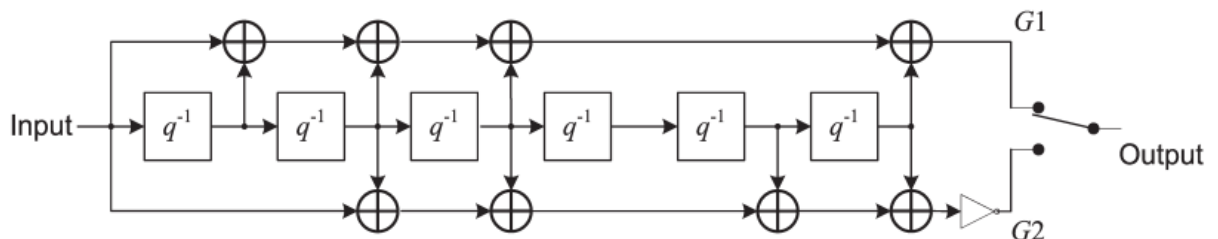
Figure 13: Convolutional Coding Scheme

Note: Figure 13 describes an encoder where the second branch is inverted at the end.

4.1.4.2 *Interleaving*

For each message type, the FEC encoded page is interleaved using a block interleaver with n columns (where data is written) and k rows (where data is read), as shown in Table 27:

Table 27: Interleaving Parameters

Parameters	Message Type	
	F/NAV	I/NAV
Block interleaver size (Symbols)	488	240
Block interleaver dimensions (n columns x k rows)	61 x 8	30 x 8

4.1.4.3 *FEC Coding and Interleaving Numerical Examples*

Numerical examples for the convolutional encoding described in Section 4.1.4.1 and for the subsequent interleaving described in Section 4.1.4.2 are provided in Annex D.

4.1.5 Frame and Page Timing

Time stamps are inserted in the navigation message at regular intervals by the broadcasting satellite to identify absolute Galileo System Time (GST). The exact timing of the page frame boundaries is used to identify fractional GST timing (less than one frame period). This is measured relative to the leading edge of the first chip of the first code sequence of the first page symbol of the page containing the TOW. The transmission timing of the navigation message provided through the TOW is synchronised to each satellite's version of GST.

4.1.6 Reserved and Spare Bits

Reserved and spare bits may be used for evolution, and defined in future updates of this ICD.

4.2 F/NAV Message Description

4.2.1 General Description of the F/NAV Message

The F/NAV message structure is presented in Figure 14, where the duration of each entity is indicated.
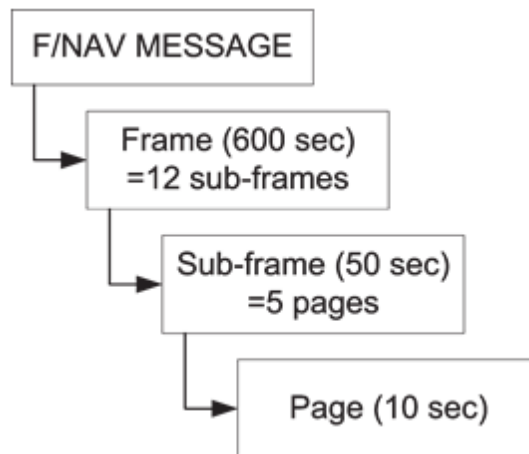
Figure 14: F/NAV Message Structure

4.2.2   F/NAV Page Layout

The page layout for the F/NAV message type is according to Table 28 where the symbols allocation and bits allocation are shown separately. The different fields composing this layout are defined in the sections below.

Table 28: F/NAV Page Layout

Sync.	F/NAV Symbols	Total (symb)
12	488	500

F/NAV Word			Tail	Total (bits)
Page type	Navigation Data	CRC		
6	208	24	6	244

Note: Transmission of a page starts with the first bit of the synchronisation pattern.

4.2.2.1   Synchronisation Pattern

The synchronisation pattern allows the receiver to achieve synchronisation to the page boundary.

Note: The synchronisation pattern is not encoded. The F/NAV synchronisation pattern is: 101101110000

4.2.2.2   Tail Bits

The tail bits field consists of 6 zero-value bits enabling completion of the FEC decoding of each page's information content in the user receiver.

4.2.2.3   F/NAV Word

The useful data are contained in the F/NAV word composed of:

● A page type field (6 bits) enabling to identify the page content as defined in paragraph 4.2.4

- A navigation data field (208 bits) whose structure is presented in paragraph 4.2.4

- A CRC (24 bits) to detect potential bit errors, according to paragraph 5.1.9.4. The CRC is computed on the Page Type and Navigation Data fields.

4.2.3   F/NAV Frame Layout

The F/NAV E5a-I message data packet transmission sequence is according to Table 27 where a whole frame is shown. Note that the odd numbered sub-frames contain the page type 5 and the even numbered sub-frames contain the page type 6. This allows the transmission of the almanacs for three satellites within two successive sub-frames (100 seconds). The parameter k is transparent for the user. It is set by the Galileo system for each of the active satellites, such as to improve almanac transport time by exploiting source diversity.

Table 29: F/NAV Frame Layout

	Page Type	Page Content
Subframe 1	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	5	Almanac for satellite k and almanac for satellite (k+1) part 1
Subframe 2	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	6	Almanac for satellite (k+1) part 2 and almanac for satellite (k+2)
Subframe 3	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	5	Almanac for satellite (k+3) and almanac for satellite (k+4) part 1
Subframe 4	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	6	Almanac for satellite (k+4) part 2 and almanac for satellite (k+5)
Subframe 5	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	5	Almanac for satellite (k+6) and almanac for satellite (k+7) part 1
Subframe 6	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW

	Page Type	Page Content
	6	Almanac for satellite (k+7) part 2 and almanac for satellite (k+8)
Subframe 7	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	5	Almanac for satellite (k+9) and almanac for satellite (k+10) part 1
Subframe 8	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	6	Almanac for satellite (k+10) part 2 and almanac for satellite (k+11)
Subframe 9	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	5	Almanac for satellite (k+12) and almanac for satellite (k+13) part 1
Subframe 10	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	6	Almanac for satellite (k+13) part 2 and almanac for satellite (k+14)
Subframe 11	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	5	Almanac for satellite (k+15) and almanac for satellite (k+16) part 1
Subframe 12	1	SVID, clock correction, SISA, Ionospheric correction, BGD, Signal health status, GST and Data validity status
	2	Ephemeris (1/3) and GST
	3	Ephemeris (2/3) and GST
	4	Ephemeris (3/3), GST-UTC conversion, GST-GPS Conversion and TOW
	6	Almanac for satellite (k+16) part 2 and almanac for satellite (k+17)

4.2.4 F/NAV Page Contents

The following tables specify the contents of the F/NAV pages above allocated (see Chapter 5 for a description of the F/NAV pages contents).

Page Type 1: SVID, Clock correction, SISA, Ionospheric correction, BGD, GST, Signal health and Data validity status

Table 30: Bits Allocation for F/NAV Page Type 1

Type=1	SVID	IOD_{nav}	Clock correction				SISA(E1,E5a)	Ionospheric correction								BGD(E1,E5a)	$E5a_{SHS}$	GST		$E5a_{DVS}$	Spare	CRC	Tail	Total (bits)
								Az			Ionospheric disturbance flag														
			t_{0c}	a_{f0}	a_{f1}	a_{f2}		a_{i0}	a_{i1}	a_{i2}	Region 1	Region 2	Region 3	Region 4	Region 5			WN	TOW					
6	6	10	14	31	21	6	8	11	11	14	1	1	1	1	1	10	2	12	20	1	26	24	6	244

Page Type 2: Ephemeris (1/3) and GST

Table 31: Bits Allocation for F/NAV Page Type 2

Type=2	IOD_{nav}	Ephemeris (1/3)						GST		CRC	Tail	Total (bits)
		M_0	$\dot{\Omega}$	e	$\sqrt{A}$	Ω_0	$\dot{i}$	WN	TOW			
6	10	32	24	32	32	32	14	12	20	24	6	244

Page Type 3: Ephemeris (2/3) and GST

Table 32: Bits Allocation for F/NAV Page Type 3

Type=3	IOD_{nav}	Ephemeris (2/3)								GST		Spare	CRC	Tail	Total (bits)
		i_0	ω	Δn	C_{uc}	C_{us}	C_{rc}	C_{rs}	t_{0e}	WN	TOW				
6	10	32	32	16	16	16	16	16	14	12	20	8	24	6	244

Page Type 4: Ephemeris (3/3), GST-UTC conversion, GST-GPS conversion and TOW.

Table 33: Bits Allocation for F/NAV Page Type 4

Type=4	IOD_{nav}	Ephemeris (3/3)		GST-UTC Conversion								GST-GPS Conversion				TOW	Spare	CRC	Tail	Total (bits)
		C_{ic}	C_{is}	A_0	A_1	Δt_{Ls}	t_{0t}	WN_{0t}	WN_{LSF}	DN	Δt_{LSF}	t_{0G}	A_{0G}	A_{1G}	WN_{0G}					
6	10	16	16	32	24	8	8	8	8	3	8	8	16	12	6	20	5	24	6	244

Page Type 5: Almanac (SVID1 and SVID2(1/2)), Week Number and almanac reference time

Table 34: Bits Allocation for F/NAV Page Type 5

Type=5	IOD_a	WN_a	t_{0a}	SV_{SVID1}											$SV_{SVID2}(1/2)$						CRC	Tail	Total (bits)
				SVID1	$\Delta(\sqrt{A})$	e	ω	δi	Ω_0	$\dot{\Omega}$	M_0	a_{f0}	a_{f1}	$E5a_{SHS}$	SVID2	$\Delta(\sqrt{A})$	e	ω	δi	$\Omega_0(1/2)$			
6	4	2	10	6	13	11	16	11	16	11	16	16	13	2	6	13	11	16	11	4	24	6	244

Page Type 6: Almanac (SVID2(2/2) and SVID3)

Table 35: Bits Allocation for F/NAV Page Type 6

Type=6	IOD_a	$SV_{SVID2}(2/2)$						SV_{SVID3}											Spare	CRC	Tail	Total (bits)
		$\Omega_0(2/2)$	$\dot{\Omega}$	M_0	a_{f0}	a_{f1}	$E5a_{SHS}$	SVID3	$\Delta(\sqrt{A})$	e	ω	δi	Ω_0	$\dot{\Omega}$	M_0	a_{f0}	a_{f1}	$E5a_{SHS}$				
6	4	12	11	16	16	13	2	6	13	11	16	11	16	11	16	16	13	2	3	24	6	244

4.2.5 F/NAV Dummy Page Definition

In case no valid F/NAV data is to be transmitted, the satellite generates and downlinks the dummy pages (Page Type 63) replacing the pages in the nominal sequencing, according to the format in Table 34. CRC is computed on the Page Type and Dummy sequence fields.

Table 36: Bits Allocation for F/NAV Dummy Page

Type=63	Dummy sequence	CRC	Tail	Total (bits)
6	208	24	6	244

4.3 I/NAV Message Description

4.3.1 General Description of the I/NAV Message

The I/NAV message structure is presented in Figure 15, where the duration of each entity is indicated.
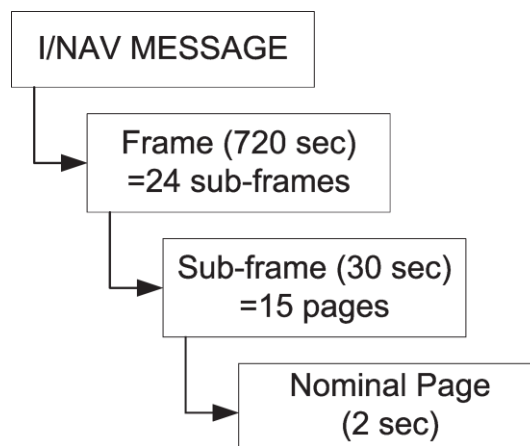

Figure 15: I/NAV Message Structure in the Nominal Mode

The I/NAV message structures for the E5b-I and E1-B signals use the same page layout since the service provided on these frequencies is a dual frequency service, using frequency diversity. Only page sequencing is different, with page swapping between both components in order to allow a fast reception of data by a dual frequency receiver. Nevertheless, the frame is designed to allow receivers to work also with a single frequency.

4.3.2 I/NAV Page Layout

Two types of I/NAV pages are defined:

- Nominal pages having a duration of 2 seconds transmitted sequentially in time in two parts of duration 1 second each on each of the E5b-I and E1-B components according to Table 38. The first part of a page is denoted 'even' and the second one is denoted 'odd'.

- Alert pages having a duration of 1 second transmitted in two parts of duration 1 second each at the same epoch over the E5b-I and E1-B components according to Table 39. Again, the first part of a page is denoted 'even' and the second one

is denoted 'odd'. This transmission is repeated at the next epoch but switching the two parts between the components.

The I/NAV page part (even or odd) layout is defined in Table 37 for both nominal and alert page types. This table shows the symbols allocation and bits allocation separately. The different fields composing this layout are defined in the sections below.

Table 37: I/NAV Page Part Layout

Sync.	I/NAV Page Part (even or odd) Symbols	Total (symb)
10	240	250

I/NAV Page Part (even or odd) Bits	Tail	Total (bits)
114	6	120

Note: Transmission of a page starts with the first bit of the synchronisation pattern.

4.3.2.1 *Synchronisation Pattern*

The synchronisation pattern allows the receiver to achieve synchronisation to the page boundary.

Note: The synchronisation pattern is not encoded. The I/NAV synchronisation pattern is 0101100000

4.3.2.2 *Tail Bits*

The tail bits field consists of 6 zero-value bits enabling completion of the FEC decoding of each page's information content in the user receiver.

4.3.2.3 *I/NAV Page Part*

The structure of the nominal I/NAV even and odd page parts on E5b-I and E1-B are defined in Table 38. A nominal page is composed by the two-page parts (even and odd) transmitted sequentially over the same frequency ("vertical page").

Table 38: I/NAV Nominal Page with Bits Allocation

E5b-I

Even/odd=0	Page Type	Data i (1/2)	Tail	Total (bits)
1	1	112	6	**120**

E1-B

Even/odd=1	Page Type	Data j (2/2)	OSNMA	SAR	Spare	CRC$_j$	SSP	Tail	Total (bits)
1	1	16	40	22	2	24	8	6	**120**

Even/odd=1	Page Type	Data i (2/2)	Reserved 1	CRC$_i$	Reserved 2	Tail	Total (bits)
1	1	16	64	24	8	6	**120**

Even/odd=0	Page Type	Data k (1/2)	Tail	Total (bits)
1	1	112	6	**120**

The parameters for the nominal page have the following meaning and related values:

- Even/Odd field (1 bit) to indicate the part of the page (0=even/1=odd) that is broadcast

- Page Type (1 bit) equal to 0 to indicate the nominal page type

- Data field composed of a nominal word (described in 4.3.5) of 128 bits (comprising 112 bits of data (1/2) and 16 bits of data (2/2))

- OSNMA protocol data (40 bits) on E1-B only: the cryptographic data for Galileo Open Service Navigation Message Authentication and the OSNMA message structure are defined in [RD3]

- SAR data (22 bits) composed of SAR RLM data on E1-B only as defined in 4.3.8

- CRC (24 bits) is computed

    o on Even/Odd fields, Page Type fields, Data fields (1/2 and 2/2) and Reserved 1 field for I/NAV nominal pages on E5b-I;

    o on Even/Odd fields, Page Type fields, Data fields (1/2 and 2/2), OSNMA field, SAR field and Spare field for I/NAV nominal pages on E1B.

In nominal mode the CRC is computed for the Even and Odd parts of a page of the same frequency ("vertical CRC") and is always broadcast on the second part of the "vertical page". More details on the computation of the checksum are provided in Section 5.1.9.4.

Note: The "Reserved 2" field on E5b-I and the SSP field on E1-B are not protected by the CRC.

- SSP (8 bits) containing one of the three secondary synchronisation pattern configurations as defined in 5.1.9.5

- Tail bits (2*6 bits) as defined in 4.3.2.2. These fields are not protected by the CRC.

The structure of the alert I/NAV even and odd page parts on E5b-I and E1-B are defined in Table 39. An alert page is composed by the two-page parts (even and odd) transmitted at the same epoch over E5b-I and E1-B ("horizontal page").

Table 39: I/NAV Alert Page with Bits Allocation

E5b-I						E1-B							
Even/odd=0	Page Type	Reserved 1 (1/2)		Tail	Total (bits)	Even/odd=1	Page Type	Reserved 1 (2/2)	CRC	SSP	Tail	Total (bits)	
1	1	112		6	**120**	1	1	80	24	8	6	**120**	

Even/odd=1	Page Type	Reserved 1 (2/2)	CRC	Reserved 2	Tail	Total (bits)	Even/odd=0	Page Type	Reserved 1 (1/2)	Tail	Total (bits)
1	1	80	24	8	6	**120**	1	1	112	6	**120**

The parameters for the alert page have the following meaning and related values:

- Even/Odd field to indicate the part of the page (0=even/1=odd) that is broadcast

- Page Type (1 bit) equal to 1 to indicate the alert page type

- CRC (24 bits) computed on the Even/Odd fields, Page Type fields and on "Reserved 1" (1/2 and 2/2). In alert mode the CRC is computed for the Even/ Odd pages of both frequencies E5b and E1-B ("horizontal CRC").

  More details on the computation of the checksum are provided in Section 5.1.9.4

- The "Reserved 1" and "Reserved 2" fields will be published in a future update of this ICD. Note that the Reserved 2 field on E5b-I and the SSP field on E1-B are not protected by CRC.

- SSP (8 bits) containing one of the three secondary synchronisation pattern configurations as defined in 5.1.9.5.

- Tail bits (2*6 bits) as defined in 4.3.2.2. These fields are not protected by the CRC.

4.3.3 I/NAV Nominal Sub-Frame Layout

In the nominal mode, the page sequence for I/NAV E5b-I and I/NAV E1-B components in every sub-frame is according to Table 38, where T_0 is synchronised with GST origin modulo 30 seconds.

Table 40: I/NAV Nominal Sub-Frame Structure

T_0 (GST$_0$ sync.) (s)	E5b-I Sub frame ID	E5b-I Page	E5b-I Content				E1-B Content					E1-B Page	E1-B Sub frame ID
0	N	Even	Word 1 (1/2)				Word 16 (2/2)	OSNMA	SAR	CRC	SSP3	Odd	N-1
1	N	Odd	Word 1 (2/2)	Res	CRC	Res	Word 2 (1/2)					Even	N
2	N	Even	Word 3 (1/2)				Word 2 (2/2)	OSNMA	SAR	CRC	SSP1	Odd	N
3	N	Odd	Word 3 (2/2)	Res	CRC	Res	Word 4 (1/2)					Even	N
4	N	Even	Word 5 (1/2)				Word 4 (2/2)	OSNMA	SAR	CRC	SSP2	Odd	N
5	N	Odd	Word 5 (2/2)	Res	CRC	Res	Word 6 (1/2)					Even	N
6	N	Even	Word 7 or 9 (1/2)*				Word 6 (2/2)	OSNMA	SAR	CRC	SSP3	Odd	N
7	N	Odd	Word 7 or 9 (2/2)*	Res	CRC	Res	Word 7 or 9 (1/2)*					Even	N
8	N	Even	Word 8 or 10 (1/2)*				Word 7 or 9 (2/2)*	OSNMA	SAR	CRC	SSP1	Odd	N
9	N	Odd	Word 8 or 10 (2/2)*	Res	CRC	Res	Word 8 or 10 (1/2)*					Even	N
10	N	Even	Word 0 (1/2)				Word 8 or 10 (2/2)*	OSNMA	SAR	CRC	SSP2	Odd	N
11	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 17 or 18 (1/2)**					Even	N
12	N	Even	Word 0 (1/2)				Word 17 or 18 (2/2)**	OSNMA	SAR	CRC	SSP3	Odd	N
13	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 19 or 20 (1/2)**					Even	N
14	N	Even	Word 0 (1/2)				Word 19 or 20 (2/2)**	OSNMA	SAR	CRC	SSP1	Odd	N
15	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 16 (1/2)					Even	N
16	N	Even	Word 0 (1/2)				Word 16 (2/2)	OSNMA	SAR	CRC	SSP2	Odd	N
17	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 0 (1/2)					Even	N

T_0 (GST$_0$ sync.) (s)	E5b-I Sub frame ID	E5b-I Page	E5b-I Content				E1-B Content					E1-B Page	E1-B Sub frame ID
18	N	Even	Word 0 (1/2)				Word 0 (2/2)	OSNMA	SAR	CRC	SSP3	Odd	N
19	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 22 (1/2)					Even	N
20	N	Even	Word 2 (1/2)				Word 22 (2/2)	OSNMA	SAR	CRC	SSP1	Odd	N
21	N	Odd	Word 2 (2/2)	Res	CRC	Res	Word 1 (1/2)					Even	N
22	N	Even	Word 4 (1/2)				Word 1 (2/2)	OSNMA	SAR	CRC	SSP2	Odd	N
23	N	Odd	Word 4 (2/2)	Res	CRC	Res	Word 3 (1/2)					Even	N
24	N	Even	Word 6 (1/2)				Word 3 (2/2)	OSNMA	SAR	CRC	SSP3	Odd	N
25	N	Odd	Word 6 (2/2)	Res	CRC	Res	Word 5 (1/2)					Even	N
26	N	Even	Word 0 (1/2)				Word 5 (2/2)	OSNMA	SAR	CRC	SSP1	Odd	N
27	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 0 (1/2)					Even	N
28	N	Even	Word 0 (1/2)				Word 0 (2/2)	OSNMA	SAR	CRC	SSP2	Odd	N
29	N	Odd	Word 0 (2/2)	Res	CRC	Res	Word 16 (1/2)					Even	N
30	N+1	Even	Word 1 (1/2)				Word 16 (2/2)	OSNMA	SAR	CRC	SSP3	Odd	N

*   The dissemination sequence of Word Types 7, 8, 9 and 10 within a frame is detailed in Table 39.

**   FEC2 RS CED broadcast cycles through all four FEC2 RS CED Words.

***   The scope of the figure is solely to show the sequence of the information within the full sub-frame. At this scope, not all the fields are represented

The sub-frame structure shown in Table 40 is indicative: Deviations from the I/NAV word dissemination sequence as shown may appear, individually per satellite and precautions as per Section 4.1.2 are expected to be foreseen within the user receiver.

The indication of Word Type 0 in Table 40 reflects spare capacities in the I/NAV word dissemination sequence reserved for future use.

4.3.4   I/NAV Nominal Frame Layout

The I/NAV sub-frames containing almanac data are sequenced in a nominal frame according to Table 41.

Table 41: I/NAV Sub-Frame Sequencing

T_0 (s)	Sub-frame ID	E5b	E1B
0	1	Word 7: Almanac SV 1 (1/2)	Word 7: Almanac SV 19 (1/2)
		Word 8: Almanac SV 1 (2/2) + almanac SV 2 (1/2)	Word 8: Almanac SV 19 (2/2) + almanac SV 20 (1/2)
30	2	Word 9: Almanac SV 2 (2/2) + almanac SV 3 (1/2)	Word 9: Almanac SV 20 (2/2) + almanac SV 21 (1/2)
		Word 10: Almanac SV 3 (2/2)	Word 10: Almanac SV 21 (2/2)
60	3	Word 7: Almanac SV 4 (1/2)	Word 7: Almanac SV 22 (1/2)
		Word 8: Almanac SV 4 (2/2) + almanac SV 5 (1/2)	Word 8: Almanac SV 22 (2/2) + almanac SV 23 (1/2)
90	4	Word 9: Almanac SV 5 (2/2) + almanac SV 6 (1/2)	Word 9: Almanac SV 23 (2/2) + almanac SV 24 (1/2)
		Word 10: Almanac SV 6 (2/2)	Word 10: Almanac SV 24 (2/2)
120	5	Word 7: Almanac SV 7 (1/2)	Word 7: Almanac SV 25 (1/2)
		Word 8: Almanac SV 7 (2/2) + almanac SV 8 (1/2)	Word 8: Almanac SV 25 (2/2) + almanac SV 26 (1/2)
150	6	Word 9: Almanac SV 8 (2/2) + almanac SV 9 (1/2)	Word 9: Almanac SV 26 (2/2) + almanac SV 27 (1/2)
		Word 10: Almanac SV 9 (2/2)	Word 10: Almanac SV 27 (2/2)
180	7	Word 7: Almanac SV 10 (1/2)	Word 7: Almanac SV 28 (1/2)
		Word 8: Almanac SV 10 (2/2) + almanac SV 11 (1/2)	Word 8: Almanac SV 28 (2/2) + almanac SV 29 (1/2)
210	8	Word 9: Almanac SV 11 (2/2) + almanac SV 12 (1/2)	Word 9: Almanac SV 29 (2/2) + almanac SV 30 (1/2)
		Word 10: Almanac SV 12 (2/2)	Word 10: Almanac SV 30 (2/2)
240	9	Word 7: Almanac SV 13 (1/2)	Word 7: Almanac SV 31 (1/2)
		Word 8: Almanac SV 13 (2/2) + almanac SV 14 (1/2)	Word 8: Almanac SV 31 (2/2) + almanac SV 32 (1/2)
270	10	Word 9: Almanac SV 14 (2/2) + almanac SV 15 (1/2)	Word 9: Almanac SV 32 (2/2) + almanac SV 33 (1/2)
		Word 10: Almanac SV 15 (2/2)	Word 10: Almanac SV 33 (2/2)
300	11	Word 7: Almanac SV 16 (1/2)	Word 7: Almanac SV 34 (1/2)
		Word 8: Almanac SV 16 (2/2) + almanac SV 17 (1/2)	Word 8: Almanac SV 34 (2/2) + almanac SV 35 (1/2)
330	12	Word 9: Almanac SV 17 (2/2) + almanac SV 18 (1/2)	Word 9: Almanac SV 35 (2/2) + almanac SV 36 (1/2)
		Word 10: Almanac SV 18 (2/2)	Word 10: Almanac SV 36 (2/2)
360	13	Word 7: Almanac SV 19 (1/2)	Word 7: Almanac SV 1 (1/2)
		Word 8: Almanac SV 19 (2/2) + almanac SV 20 (1/2)	Word 8: Almanac SV 1 (2/2) + almanac SV 2 (1/2)
390	14	Word 9: Almanac SV 20 (2/2) + almanac SV 21 (1/2)	Word 9: Almanac SV 2 (2/2) + almanac SV 3 (1/2)
		Word 10: Almanac SV 21 (2/2)	Word 10: Almanac SV 3 (2/2)
420	15	Word 7: Almanac SV 22 (1/2)	Word 7: Almanac SV 4 (1/2)
		Word 8: Almanac SV 22 (2/2) + almanac SV 23 (1/2)	Word 8: Almanac SV 4 (2/2) + almanac SV 5 (1/2)
450	16	Word 9: Almanac SV 23 (2/2) + almanac SV 24 (1/2)	Word 9: Almanac SV 5 (2/2) + almanac SV 6 (1/2)
		Word 10: Almanac SV 24 (2/2)	Word 10: Almanac SV 6 (2/2)
480	17	Word 7: Almanac SV 25 (1/2)	Word 7: Almanac SV 7 (1/2)

T₀ (s)	Sub-frame ID	E5b	E1B
		Word 8: Almanac SV 25 (2/2) + almanac SV 26 (1/2)	Word 8: Almanac SV 7 (2/2) + almanac SV 8 (1/2)
510	18	Word 9: Almanac SV 26 (2/2) + almanac SV 27 (1/2)	Word 9: Almanac SV 8 (2/2) + almanac SV 9 (1/2)
		Word 10: Almanac SV 27 (2/2)	Word 10: Almanac SV 9 (2/2)
540	19	Word 7: Almanac SV 28 (1/2)	Word 7: Almanac SV 10 (1/2)
		Word 8: Almanac SV 28 (2/2) + almanac SV 29 (1/2)	Word 8: Almanac SV 10 (2/2) + almanac SV 11 (1/2)
570	20	Word 9: Almanac SV 29 (2/2) + almanac SV 30 (1/2)	Word 9: Almanac SV 11 (2/2) + almanac SV 12 (1/2)
		Word 10: Almanac SV 30 (2/2)	Word 10: Almanac SV 12 (2/2)
600	21	Word 7: Almanac SV 31 (1/2)	Word 7: Almanac SV 13 (1/2)
		Word 8: Almanac SV 31 (2/2) + almanac SV 32 (1/2)	Word 8: Almanac SV 13 (2/2) + almanac SV 14 (1/2)
630	22	Word 9: Almanac SV 32 (2/2) + almanac SV 33 (1/2)	Word 9: Almanac SV 14 (2/2) + almanac SV 15 (1/2)
		Word 10: Almanac SV 33 (2/2)	Word 10: Almanac SV 15 (2/2)
660	23	Word 7: Almanac SV 34 (1/2)	Word 7: Almanac SV 16 (1/2)
		Word 8: Almanac SV 34 (2/2) + almanac SV 35 (1/2)	Word 8: Almanac SV 16 (2/2) + almanac SV 17 (1/2)
690	24	Word 9: Almanac SV 35 (2/2) + almanac SV 36 (1/2)	Word 9: Almanac SV 17 (2/2) + almanac SV 18 (1/2)
		Word 10: Almanac SV 36 (2/2)	Word 10: Almanac SV 18 (2/2)

4.3.5   I/NAV Word Types

The content of the I/NAV word types is stated in the following tables (see Chapter 5 for a description of the I/NAV word types contents).

Word Type 1: Ephemeris (1/4)

Table 42: Bits Allocation for I/NAV Word Type 1

Type=1	IOD$_{nav}$	Ephemeris (1/4)				Reserved	Total (bits)
		t_{0e}	M_0	e	$\sqrt{A}$		
6	10	14	32	32	32	2	128

Word Type 2: Ephemeris (2/4)

Table 43: Bits Allocation for I/NAV Word Type 2

Type=2	IOD$_{nav}$	Ephemeris (2/4)				Reserved	Total (bits)
		Ω_0	i_0	ω	$\dot{i}$		
6	10	32	32	32	14	2	**128**

Word Type 3: Ephemeris (3/4) and SISA(E1, E5b)

Table 44: Bits Allocation for I/NAV Word Type 3

Type=3	IOD$_{nav}$	Ephemeris (3/4)						SISA(E1, E5b)	Total (bits)
		$\dot{\Omega}$	Δn	C_{UC}	C_{US}	C_{RC}	C_{RS}		
6	10	24	16	16	16	16	16	8	**128**

Word Type 4: SVID, Ephemeris (4/4), and Clock correction parameters

Table 45: Bits Allocation for I/NAV Word Type 4

Type=4	IOD$_{nav}$	SVID	Ephemeris (4/4)		Clock correction				Spare	Total (bits)
			C_{ic}	C_{is}	t_{0c}	a_{f0}	a_{f1}	a_{f2}		
6	10	6	16	16	14	31	21	6	2	**128**

Word Type 5: Ionospheric correction, BGD, signal health and data validity status and GST

Table 46: Bits Allocation for I/NAV Word Type 5

Type=5	Ionospheric correction								BGD(E1,E5a)	BGD(E1,E5b)	E5b$_{SHS}$	E1B$_{SHS}$	E5b$_{DVS}$	E1B$_{DVS}$	GST		Spare	Total (bits)
	Az			Ionospheric disturbance flag											WN	TOW		
	a_{i0}	a_{i1}	a_{i2}	Region 1	Region 2	Region 3	Region 4	Region 5										
6	11	11	14	1	1	1	1	1	10	10	2	2	1	1	12	20	23	**128**

Word Type 6: GST-UTC conversion parameters

Table 47: Bits Allocation for I/NAV Word Type 6

Type=6	GST-UTC conversion parameters								TOW	Spare	Total (bits)
	A_0	A_1	Δt_{LS}	t_{ot}	WN_{0t}	$W_{N_{LSF}}$	DN	Δt_{LSF}			
6	32	24	8	8	8	8	3	8	20	3	128

Word Type 7: Almanac for SVID1 (1/2), almanac reference time and almanac reference week number

Table 48: Bits Allocation for I/NAV Word Type 7

Type=7	IOD_a	WN_a	t_{0a}	SV_{SVID1} (1/2)								Reserved	Total (bits)
				SVID1	$\Delta(\sqrt{A})$	e	ω	δ_i	Ω_0	$\dot{\Omega}$	M_0		
6	4	2	10	6	13	11	16	11	16	11	16	6	128

Word Type 8: Almanac for SVID1 (2/2) and SVID2 (1/2)

Table 49: Bits Allocation for I/NAV Word Type 8

Type=8	IOD_a	SV_{SVID1}(2/2)				SV_{SVID2}(1/2)							Spare	Total (bits)
		af_0	af_1	E5b$_{SHS}$	E1B$_{SHS}$	SVID2	$\Delta(\sqrt{A})$	e	ω	δ_i	Ω_0	$\dot{\Omega}$		
6	4	16	13	2	2	6	13	11	16	11	16	11	1	128

Word Type 9: Almanac for SVID2 (2/2) and SVID3 (1/2)

Table 50: Bits Allocation for I/NAV Word Type 9

Type=9	IOD_a	WN_a	t_{0a}	SV_{SVID2}(2/2)					SV_{SVID3}(1/2)					Total (bits)
				M_0	af_0	af_1	E5b$_{SHS}$	E1B$_{SHS}$	SVID3	$\Delta(\sqrt{A})$	e	ω	δ_i	
6	4	2	10	16	16	13	2	2	6	13	11	16	11	128

Word Type 10: Almanac for SVID3 (2/2) and GST-GPS conversion parameters

Table 51: Bits Allocation for I/NAV Word Type 10

Type=10	IOD_a	SV$_{SVID3}$(2/2)							GST-GPS conversion parameters				Total (bits)
		Ω_0	$\dot{\Omega}$	M_0	a_{f0}	a_{f1}	$E5b_{SHS}$	$E1B_{SHS}$	A_{0G}	A_{1G}	t_{0G}	WN_{0G}	
6	4	16	11	16	16	13	2	2	16	12	8	6	**128**

Word Type 16: Reduced Clock and Ephemeris Data (CED) parameters

Table 52: Bits Allocation for I/NAV Word Type 16

Type=16	Reduced CED parameters								Total (bits)
	ΔA_{red}	$e_{x\,red}$	$e_{y\,red}$	$\Delta i_{0\,red}$	$\Omega_{0\,red}$	$\lambda_{0\,red}$	$a_{f0\,red}$	$a_{f1\,red}$	
6	5	13	13	17	23	23	22	6	**128**

Word types 17, 18, 19, 20: FEC2 Reed-Solomon for Clock and Ephemeris Data (CED)

Table 53: Bits Allocation for I/NAV Word Types 17, 18, 19, and 20

Type= 17, 18, 19, 20	FEC2 Reed-Solomon for CED (1/2)	LSB(IOD$_{nav}$)	FEC2 Reed-Solomon for CED (2/2)	Total (bits)
6	8	2	112	**128**

FEC2 Reed-Solomon (RS) words consist of 15 RS parity octets that can be used

- to recover missing RS octets from the RS information vector

- and/or to correct errors contained in received octets of the RS information vector.

The RS information and parity vectors are described in section 5.1.13.1.

Word Type 0: I/NAV Spare Word

Table 54: Bits Allocation for Spare Word

| Type=0 | Time | Spare | GST | | Total (bits) |
			WN	TOW	
6	2	88	12	20	128

When the field 'Time' is not set to '10', the fields *WN* and *TOW* do not contain valid data.

Word type 22: ARAIM Integrity Support Message (ISM)

Table 55: Bits Allocation for I/NAV Word Types 22

Type=22	GNSS Constellation ID	GNSS Constellation-specific ISM content	ISM CRC	Total (bits)
6	3	87	32	128

The structure of the constellation-specific ISM content in dependence of the GNSS Constellation ID is detailed in section 4.3.7. An additional ISM CRC (32 bits), which is specified in paragraph 5.2.2, ensures critical data integrity. The ISM CRC is computed on the Type field, the GNSS Constellation ID field and the ISM content field.

4.3.6 I/NAV Dummy Message Layout

In case no valid I/NAV data is to be transmitted, the satellite generates and downlinks the dummy message on E5b-I and E1-B components replacing the pages in the nominal sequencing, according to the Dummy page layout defined in Table 56:

Table 56: I/NAV Dummy Page with Bits Allocation

E5b-I				
Even/odd=0	Page Type	Dummy data (1/2)	Tail	Total (bits)
1	1	112	6	120

E1-B						
Even/odd=1	Page Type	Dummy data (2/2)	CRC$_{E1B}$	Spare	Tail	Total (bits)
1	1	80	24	8	6	120

Even/odd=1	Page Type	Dummy data (2/2)	CRC$_{E5b}$	Spare	Tail	Total (bits)
1	1	80	24	8	6	**120**

Even/odd=0	Page Type	Dummy data (1/2)	Tail	Total (bits)
1	1	112	6	**120**

The parameters for the dummy page have the following meaning and related values:

- Even/Odd (1 bit) to indicate the part of the page (0=even/1=odd) that is broadcast

- Page Type (1 bit) equal to 0 to indicate the nominal page type

- Dummy Data (192 bits = 80 bits + 112 bits)

- CRC (24 bits): computed on the Even/odd fields, Type fields and Dummy data fields (1/2 and 2/2) for the Even/Odd page of the same frequency ("vertical CRC"), and the CRC is always broadcast on the second part of the "vertical page"

- Spare (8 bits). This field is not protected by the CRC

- Tail bits (2*6 bits) as defined in 4.3.2.2. These fields are not protected by the CRC.

The dummy data word is formatted according to Table 57, with

- Word Type (6 bits) to indicate the word type dummy message, which is defined as type 63

- The dummy sequence (186 bits) is an arbitrary sequence

Table 57: Dummy Word with Bits Allocation

Type = 63	Dummy Sequence	Total (bits)
6	186	**192**
	Dummy Data (1/2) (112 bits) — Dummy Data (2/2) (80 bits)	

4.3.7 I/NAV ARAIM Integrity Support Message (ISM) Structure

The inner structure of I/NAV Word Type 22 depends on the setting of the GNSS Constellation ID. Currently only ISM for Galileo and ISM in Test are defined.

4.3.7.1 Galileo ISM Word Layout

The content of Galileo Integrity Support Messages, which are identified through the

setting of GNSS Constellation ID to '1', varies for different Service Levels. The Service Level is specified by a three-bits Service Level Identifier (SL ID) as shown in Table 58.

Table 58: Generic Galileo ISM I/NAV Word Layout

Type=22	GNSS Constellation ID = 1 (Galileo)	SL ID	Galileo SL ISM content	ISM CRC	Total (bits)
6	3	3	84	32	**128**

The Galileo ISM Service Level 1 layout is shown in Table 59. Its reception signals that no Galileo Integrity Support Data (ISD) is available. Galileo ISD are a set of parameters that characterize the signal-in-space (SIS) integrity performance.

Table 59: Bits Allocation for Galileo ISM Service Level 1 Word

Type=22	GNSS Constellation ID = 1 (Galileo)	SL ID = 0 (Service Level 1)	Spare	ISM CRC	Total (bits)
6	3	3	84	32	**128**

The Galileo ISM Service Level 3 layout is shown in Table 60.

Table 60: Bits Allocation for Galileo ISM Service Level 3 Word

Type=22	GNSS Constellation ID = 1 (Galileo)	SL ID = 2 (Service Level 3)	WN_{ISM}	t_{0ISM}	Mask – MSB	Mask	P_{const}	P_{sat}	URA	URE	b_{nom}	$T_{validity}$	Spare	ISM CRC	Total (bits)
6	3	3	12	9	1	32	4	4	4	4	4	4	6	32	**128**

4.3.7.2 *Test ISM Word Layout*

The reception of an ISM Test Message signals that no valid ARAIM ISM content is contained in this I/NAV Word Type 22. The ISM content field is reserved for test-specific content if the GNSS Constellation ID is set to '0' as per Table 61.

Type=22	GNSS Constellation ID = 0 (ISM in Test)	Reserved	ISM CRC	Total (bits)
6	3	87	32	128

4.3.8 SAR Field Structure

In the nominal mode the SAR RLM is transmitted only in the E1-B component. The SAR field structure for the E1-B component in nominal mode is formatted according to the values stated in Table 62. When an alert is present, the SAR data will not be transmitted.

Table 62: SAR Field Bit Structure

SAR Data			Total (bits)
Start Bit	Short/Long RLM Identifier	SAR RLM Data	
1	1	20	22

The RLM identifier bit is described in the following Table 63.

Table 63: RLM Identifier Description

RLM Identifier Value	Description
0	Short RLM
1	Long RLM

4.3.8.1 SAR data in Nominal Mode

In nominal mode, 22 bits are allocated to SAR data in one E1-B I/NAV page. The SAR messages are formatted according to the values and structure stated in Table 64 and Table 65, respectively for the short RLM and the long RLM. This structure allows the downlink of a short RLM within 8 seconds and of a long RLM within 16 seconds. The content of the SAR data is provided in paragraph 5.3.

- Short RLM

Table 64: SAR Short RLM

Part (1/4)		SAR RLM data	Part (2/4)		SAR RLM data	Part (3/4)		SAR RLM data	Part (4/4)		SAR RLM data	
Start bit = 1	Short RLM	Beacon ID (1/3)	Start bit = 0	Short RLM	Beacon ID (2/3)	Start bit = 0	Short RLM	Beacon ID (3/3)	Start bit = 0	Short RLM	Message code	Parameters
1	1	20	1	1	20	1	1	20	1	1	4	16
22			22			22			22			

- Long RLM

Part (1/8)		SAR RLM data	Part (2/8)		SAR RLM data	Part (3/8)		SAR RLM data	Part (4/8)		SAR RLM data	
Start bit = 1	Long RLM	Beacon ID (1/3)	Start bit = 0	Long RLM	Beacon ID (2/3)	Start bit = 0	Long RLM	Beacon ID (3/3)	Start bit = 0	Long RLM	Message code	Parameters (1/5)
1	1	20	1	1	20	1	1	20	1	1	4	16
22			22			22			22			

Part (5/8)		SAR RLM data	Part (6/8)		SAR RLM data	Part (7/8)		SAR RLM data	Part (8/8)		SAR RLM data
Start bit = 0	Long RLM	Parameters (2/5)	Start bit = 0	Long RLM	Parameters (3/5)	Start bit = 0	Long RLM	Parameters (4/5)	Start bit = 0	Long RLM	Parameters (5/5)
1	1	20	1	1	20	1	1	20	1	1	20
22			22			22			22		

Table 65: SAR Long RLM

4.3.8.2 *Spare SAR Data*

In case no valid SAR data is to be transmitted, the satellite generates the spare SAR data field according to Table 66.

Table 66: Spare SAR Data

SAR Data		Total (bits)
Start Bit = 1	Spare	
1	21	22

A SAR receiver will use the sequence of start bits (and only these) to identify SAR data parts belonging to SAR RLMs. If the start bit of the current data part is equal to zero, then the data part contains SAR relevant data. If the start bit of the current data part is equal to one, the data part contains SAR relevant data only if the start bit of the next (immediately subsequent) data part is equal to zero.

5. Message Data Contents

This section describes the data items above mentioned. Semantics, formats and other characteristics are provided for all items to be transmitted inside frames.

5.1 Navigation Data

The navigation data contain all the parameters required for the user to compute a complete position, velocity and time (PVT) solution. They are stored on board each satellite with a validity duration and broadcast world-wide by all the satellites of the Galileo constellation.

The 4 types of data needed to perform positioning are:

- Ephemeris parameters, which are needed to indicate the position of the satellite to the user receiver

- Time and clock correction parameters which are needed to compute pseudo-range

- Service parameters which are needed to identify the set of navigation data, satellites, and indicators of the signal health

- Almanac parameters, which are needed to indicate the position of all the satellites in the constellation with a reduced accuracy

5.1.1 Ephemeris

The ephemeris for each Galileo satellite is composed of 16 parameters, which are:

- 6 Keplerian parameters

- 6 harmonic coefficients

- 1 orbit inclination rate parameter

- 1 RAAN rate parameter

- 1 mean motion correction parameter, and

- 1 reference time parameter t_{0e} for the ephemeris data set

The ephemeris for each Galileo satellite is according to the characteristics stated in Table 67.

Table 67: Ephemeris Parameters

Parameter	Definition	Bits	Scale factor	Unit
M_0	Mean anomaly at reference time	32*	2^{-31}	semi-circles**
Δn	Mean motion difference from computed value	16*	2^{-43}	semi-circles/s**
e	Eccentricity	32	2^{-33}	N/A

Parameter	Definition	Bits	Scale factor	Unit
$\sqrt{A}$	Square root of the semi-major axis	32	2^{-19}	meter$^{1/2}$
Ω_0	Longitude of ascending node of orbital plane at weekly epoch***	32*	2^{-31}	semi-circles**
i_0	Inclination angle at reference time	32*	2^{-31}	semi-circles**
ω	Argument of perigee	32*	2^{-31}	semi-circles**
$\dot{\Omega}$	Rate of change of right ascension	24*	2^{-43}	semi-circles/s**
$\dot{i}$	Rate of change of inclination angle	14*	2^{-43}	semi-circles/s**
C_{uc}	Amplitude of the cosine harmonic correction term to the argument of latitude	16*	2^{-29}	radians
C_{us}	Amplitude of the sine harmonic correction term to the argument of latitude	16*	2^{-29}	radians
C_{rc}	Amplitude of the cosine harmonic correction term to the orbit radius	16*	2^{-5}	meters
C_{rs}	Amplitude of the sine harmonic correction term to the orbit radius	16*	2^{-5}	meters
C_{ic}	Amplitude of the cosine harmonic correction term to the angle of inclination	16*	2^{-29}	radians
C_{is}	Amplitude of the sine harmonic correction term to the angle of inclination	16*	2^{-29}	radians
t_{0e}	Ephemeris reference time	14	60	seconds
Total Ephemeris Size		**356**	n/a	n/a

*   Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

**   Note that the 'semi-circle' is not a SI unit but can be converted as:
     1 semi-circle = π rad.

*** More precisely, Ω_0 is the longitude of ascending node of orbital plane at the weekly epoch propagated to the reference time t_{0e} at the rate of change of right ascension.

A single ephemeris is applicable to all signals of a specific satellite. The ephemeris is computed with respect to the apparent CoP common to every frequency.

The user can compute the ECEF coordinates of the SV's antenna phase centre position at GST time t utilising the equations shown in Table 68.

Table 68: User Algorithm for Ephemeris Determination

Constant	Description
π = 3.1415926535898	Ratio of a circle's circumference to its diameter
μ = 3.986004418 × 10^{14} m^3/s^2	Geocentric gravitational constant
ω_E = 7.2921151467 × 10^{-5} rad/s	Mean angular velocity of the Earth
c = 299792458 m/s	Speed of light

Constant	Description
$A = (\sqrt{A}\,)^2$	Semi-major axis
$n_0 = \sqrt{\dfrac{\mu}{A^3}}$	Computed mean motion (rad/s)
$t_k = t - t_{0e}$ *	Time from ephemeris reference epoch
$n = n_0 + \Delta n$	Corrected mean motion
$M = M_0 + n\, t_k$	Mean anomaly
$M = E - e\,\sin(E)$	Kepler's Equation for Eccentric Anomaly E (may be solved by iteration)
$\sin(v) = \dfrac{\sqrt{1-e^2}\,\sin(E)}{1 - e\cos(E)}$ $\cos(v) = \dfrac{\cos(E) - e}{1 - e\cos(E)}$ $v = arctan2(\,\sin(v), \cos(v)\,)$ **	True Anomaly
$\phi = v + \omega$	Argument of Latitude
$\delta u = C_{us}\sin(2\phi) + C_{uc}\cos(2\phi)$	Argument of Latitude Correction
$\delta r = C_{rs}\sin(2\phi) + C_{rc}\cos(2\phi)$	Radius Correction
$\delta i = C_{is}\sin(2\phi) + C_{ic}\cos(2\phi)$	Inclination Correction
$u = \phi + \delta u$	Corrected Argument of Latitude
$r = A(1 - e\cos(E)) + \delta r$	Corrected Radius
$i = i_0 + \delta i + \dot{i}\, t_k$	Corrected Inclination
$x' = r\cos u$ $y' = r\sin u$	Position in orbital plane
$\Omega = \Omega_0 + (\dot{\Omega} - \omega_E)\, t_k - \omega_E\, t_{0e}$	Corrected longitude of ascending node
$x = x'\cos(\Omega) - y'\cos(i)\,\sin(\Omega)$ $y = x'\sin(\Omega) + y'\cos(i)\,\cos(\Omega)$ $z = y'\sin(i)$	GTRF coordinates of the SV antenna phase centre position at time t

* t is Galileo System Time (see e.g.: paragraph 5.1.2). Furthermore, t_k is the actual total time difference between the time t and the epoch time t_{0e} (t_{0a} for the almanacs) and it accounts for beginning or end of week crossovers

** $arctan2(Y, X)$ returns the four-quadrant inverse tangent

5.1.2 Galileo System Time (GST)

The GST is given as 32-bit binary number composed of two parameters as follows:

- The Week Number is an integer counter that gives the sequential week number from the GST start epoch. This parameter is represented with 12

bits, which covers 4096 weeks (about 78 years). Then the counter is reset to zero to cover an additional period modulo 4096.

- The Time of Week is defined as the number of seconds 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.

The GST parameters are transmitted according to the characteristics stated in Table 69.

Table 69: GST Parameters

Parameter	Definition	Bits	Scale factor	Unit
WN	Week Number	12	1	week
TOW	Time of Week	20	1	s
Total Galileo System Time Size		**32**	n/a	n/a

The GST start epoch is defined as 13 seconds before midnight between August 21st and August 22nd,1999, i.e.: GST was equal to 13 seconds on August 22nd, 1999 at 00:00:00 UTC.

As GST is a continuous time scale, and UTC is corrected periodically with an integer number of leap seconds, the Galileo navigation message contains all necessary parameters to convert between GST and UTC.

The epoch denoted in the navigation messages by TOW and WN will be measured relative to the leading edge of the first chip of the first code sequence of the first page symbol. The transmission timing of the navigation message provided through the TOW is synchronised to each satellite's version of Galileo System Time (GST).

5.1.3   Clock Correction Parameters

The clock correction parameters are transmitted according to the values stated in Table 70.

Table 70: Galileo Clock Correction Parameters

Parameter	Definition	Bits	Scale factor	Unit
t_{0c}	Clock correction data reference Time of Week	14	60	s
a_{f0}	SV clock bias correction coefficient	31*	2^{-34}	s
a_{f1}	SV clock drift correction coefficient	21*	2^{-46}	s/s
a_{f2}	SV clock drift rate correction coefficient	6*	2^{-59}	s/s^2
Total Clock Correction Size		**72**	n/a	n/a

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

Each Galileo satellite broadcasts its own clock correction data for all signals through

the relevant signal, according to Table 71:

Table 71: Galileo Clock Correction Data

Message Type	Clock Model X=(f1,f2)	Satellite Time Correction Model Parameters	Services
F/NAV	(E1,E5a)	a_{f0} (E1,E5a) a_{f1} (E1,E5a) a_{f2} (E1,E5a) t_{0C} (E1,E5a)	Dual-Frequency (E1,E5a) Single-frequency E5a
I/NAV	(E1,E5b)	a_{f0} (E1,E5b) a_{f1} (E1,E5b) a_{f2} (E1,E5b) t_{0C} (E1,E5b)	Dual-Frequency (E1,E5b) Single-frequency E5b Single-frequency E1

5.1.4 Satellite Time Correction Algorithm

Each satellite transmits time correction data. The predicted offset of the physical satellite signal TOT relative to the satellite signal TOT in GST can be computed for the dual frequency signal combination using the following formula:

$$TOT_c(X) = TOT_m(X) - \Delta t_{SV}(X)$$

<div align="right">Eq. 13</div>

where:

- $(X) = (f_1, f_2)$ is the dual frequency combination f_1 and f_2 used for the clock model

- $TOT_c(X)$ is the corrected satellite TOT in GST for the signal combination X

- $TOT_m(X)$ is the physical satellite TOT for the signal combination X retrieved through pseudo-range measurements

- $\Delta t_{SV}(X)$ is the satellite time correction for the signal combination X computed by means of the time correction data retrieved from the navigation message

This satellite time correction (in seconds) is modelled through the following second order polynomial:

$$\Delta t_{SV}(X) = a_{f0}(X) + a_{f1}(X) [t - t_{0C}(X)] + a_{f2}(X) [t - t_{0C}(X)]^2 + \Delta t_r$$

<div align="right">Eq. 14</div>

where

- $a_{f0}(X)$, $a_{f1}(X)$, and $a_{f2}(X)$ are defined in 5.1.3

- $t_{0c}(X)$ is the reference time for the clock correction as defined in 5.1.3

- t is the GST time in seconds

- Δt_r, expressed in seconds, is a relativistic correction term, given by:

$$\Delta t_r = F e \sqrt{A} \sin(E)$$

<div align="right">Eq. 15</div>

with the orbital parameters ($e, \sqrt{A}, E$) as described in paragraph 5.1.1, and:

$$F = -2 \sqrt{\mu} / c^2 = -4.442807309 \times 10^{-10} \text{ s/m}^{\frac{1}{2}} \qquad \text{Eq. 16}$$

5.1.5 Broadcast Group Delay

The Broadcast Group Delay $BGD(f_1, f_2)$ broadcast through the Galileo navigation message is defined as follows:

$$BGD(f_1, f_2) = \frac{TR_1 - TR_2}{1 - \left(\frac{f_1}{f_2}\right)^2} \qquad \text{Eq. 17}$$

where:

- f_1 and f_2 denote the carrier frequencies of two Galileo signals

- TR_1 and TR_2 are the group delays of the signals whose carrier frequencies are respectively f_1 and f_2.

A single frequency user receiver processing pseudo-ranges from the frequency f_1 applies the following correction to the SV clock correction Δt_{SV} which is defined in paragraph 5.1.4:

$$\Delta t_{SV}(f_1) = \Delta t_{SV}(f_1, f_2) - BGD(f_1, f_2) \qquad \text{Eq. 18}$$

A single frequency user receiver processing pseudo-ranges from the frequency f_2 applies the following correction to the SV clock correction Δt_{SV} which is defined in paragraph 5.1.4:

$$\Delta t_{SV}(f_2) = \Delta t_{SV}(f_1, f_2) - \left(\frac{f_1}{f_2}\right)^2 BGD(f_1, f_2) \qquad \text{Eq. 19}$$

A dual frequency user receiver processing pseudo-ranges from the two frequencies f_1 and f_2 does not apply any additional correction for group delay. The Broadcast Group Delay is coded according to the values stated in Table 72.

Table 72: BGD Parameters

Parameter	Definition	Bits	Scale factor	Unit
BGD(E1,E5a)	E1-E5a Broadcast Group Delay	10*	2^{-32}	s
BGD(E1,E5b)	E1-E5b Broadcast Group Delay	10*	2^{-32}	s

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

Each Galileo satellite broadcasts its own BGD data for all signals, through the relevant signal according to Table 73.

Table 73: BGD Values Mapping on Messages and Services

Message Type	Type of Satellite Clocks	$BGD(f_1, f_2)$	Services
F/NAV	(E1,E5a)	BGD(E1,E5a)	Single-frequency E5a
I/NAV	(E1,E5b)	BGD(E1,E5b)	Single-frequency E1 Single-frequency E5b

5.1.6 Ionospheric Correction

The ionospheric model parameters provided in Table 74 are foreseen to be used with the ionospheric correction algorithm described in [RD1]. The parameters can also be used with the alternative model described in [RD4].

The ionospheric model parameters include:

- the broadcast coefficients a_{i0}, a_{i1} and a_{i2} used to compute the Effective Ionisation Level Az

- the "Ionospheric Disturbance Flag" (also referred as "storm flag"), given for five different regions

These parameters are transmitted according to the characteristics stated in Table 74.

Table 74: Ionospheric Correction Parameters

Parameter	Definition	Bits	Scale factor	Unit
a_{i0}	Effective Ionisation Level 1st order parameter	11	2^{-2}	sfu**
a_{i1}	Effective Ionisation Level 2nd order parameter	11*	2^{-8}	sfu**/degree
a_{i2}	Effective Ionisation Level 3rd order parameter	14*	2^{-15}	sfu**/degree²
SF$_1$	Ionospheric Disturbance Flag for region 1	1	N/A	dimensionless
SF$_2$	Ionospheric Disturbance Flag for region 2	1	N/A	dimensionless
SF$_3$	Ionospheric Disturbance Flag for region 3	1	N/A	dimensionless
SF$_4$	Ionospheric Disturbance Flag for region 4	1	N/A	dimensionless
SF$_5$	Ionospheric Disturbance Flag for region 5	1	N/A	dimensionless
Total Ionosphere Correction Size		**41**	n/a	n/a

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

** Note that 'sfu' (solar flux unit) is not a SI unit but can be converted as: 1 sfu = 10^{-22} W / (m² × Hz)

The Effective Ionisation Level, Az, is computed from the three ionospheric coefficients broadcast within the navigation message as follows:

$$Az = a_{i0} + a_{i1} \times MODIP + a_{i2} \times (MODIP)^2 \qquad \text{Eq. 20}$$

where (a_{i0}, a_{i1}, a_{i2}) are the three broadcast coefficients described in Table 74 and MODIP is Modified Dip Latitude at the location of the user receiver, expressed in degrees. A table grid of MODIP values versus geographical location is provided in [RD1].

The Ionospheric Disturbance Flags SF_1 to SF_5 are reserved for future use. The five regions mentioned in Table 74 are defined as follows:

- region 1: for the northern region   (60°<MODIP≤90°)
- region 2: for the northern middle region   (30°<MODIP≤60°)
- region 3: for the equatorial region   (-30°≤MODIP≤30°)
- region 4: for the southern middle region   (-60°≤MODIP<-30°)
- region 5: for the southern region   (-90°≤MODIP<-60°)

5.1.7 GST-UTC Conversion Algorithm and Parameters

The UTC time t_{UTC} is computed through 3 different cases depending on the epoch of a possible leap second adjustment (scheduled future or recent past) given by DN, the day at the end of which the leap second becomes effective, and week number WN_{LSF} to which DN is referenced. "Day one" of DN is the first day relative to the end/start of week and the WNLSF value consists of eight bits which are a modulo 256 binary representation of the Galileo week number to which the DN is referenced.

The parameters for GST to UTC conversion are defined in Table 75:

Table 75: Parameters for the GST-UTC Conversion

Parameter	Definition	Bits	Scale factor	Unit
A_0	Constant term of polynomial	32*	2^{-30}	s
A_1	1st order term of polynomial	24*	2^{-50}	s/s
Δt_{LS}	Leap Second count before leap second adjustment	8*	1	s
t_{0t}	UTC data reference Time of Week	8	3600	s
WN_{0t}	UTC data reference Week Number	8	1	week
WN_{LSF}	Week Number of leap second adjustment	8	1	week
DN	Day Number at the end of which a leap second adjustment becomes effective	3**	1	day
Δt_{LSF}	Leap Second count after leap second adjustment	8*	1	s
Total GST-UTC Conversion Size		**99**	n/a	n/a

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

** The value range of DN is from 1 (= Sunday) to 7 (= Saturday).

In all computations the user must account for the truncated nature (roll-over) of the parameters (DN, WN, WN_{0t}, and WN_{LSF}), considering the following properties:

At the time of broadcast of the GST – UTC parameters,

- the absolute value of the difference between untruncated WN and WN_{0t} values does not exceed 127

- when Δt_{LS} and Δt_{LSF} differ, the absolute value of the difference between the untruncated WN and WN_{LSF} values received within the same subframe does not exceed 127.

In addition to the parameters listed in Table 75, the following parameters are used in the GST – UTC conversion algorithm:

- t_E is the GST as estimated by the user through its GST determination algorithm,

- WN is the week number to which t_E is referenced.

Case a

Whenever the leap second adjustment time indicated by WN_{LSF} and DN is not in the past (relative to the user's present time) and the user's present time does not fall in the time span which starts six hours prior to the effective time and ends six hours after the effective time, t_{UTC} is computed according to the following equations:

$$t_{UTC} = (t_E - \Delta t_{UTC}) \ [\text{Modulo } 86400]$$

Eq. 21

$$\text{where:} \quad \Delta t_{UTC} = \Delta t_{LS} + A_0 + A_1(t_E - t_{0t} + 604800(WN - WN_{0t}))$$

Case b

Whenever the user's current time falls within the time span of six hours prior to the leap second adjustment time to six hours after the adjustment time, t_{UTC} is computed according to the following equations (Δt_{UTC} as defined in case a):

$$t_{UTC} = W \ [\text{Modulo } (86400 + \Delta t_{LSF} - \Delta t_{LS})]$$

Eq. 22

$$\text{where: } W = (t_E - \Delta t_{UTC} - 43200)[\text{Modulo } 86400] + 43200$$

Case c

Whenever the leap second adjustment time, as indicated by the WN_{LSF} and DN values, is in the "past" (relative to the user's current time) and the user's present time does not fall in the time span which starts six hours prior to the leap second adjustment time and ends six hours after the adjustment time, t_{UTC} is computed according to the following equation:

$$t_{UTC} = (t_E - \Delta t_{UTC}) \ [\text{Modulo } 86400]$$

Eq. 23

$$\text{where: } \Delta t_{UTC} = \Delta t_{LSF} + A_0 + A_1 (t_E - t_{0t} + 604800(WN - WN_{0t}))$$

5.1.8 GPS to Galileo System Time Conversion and Parameters

The difference between the Galileo and the GPS time scales, expressed in seconds,

is given by the equation below.

$$\Delta t_{Systems} = t_{Galileo} - t_{GPS} = A_{0G} + A_{1G}\left[\, TOW - t_{0G} + 604800 \cdot (WN - WN_{0G})\, \right]$$ Eq. 24

with:

- A_{0G} constant term of the offset $\Delta t_{systems}$

- A_{1G} rate of change of the offset $\Delta t_{systems}$

- t_{0G} reference time for GGTO data

- $t_{Galileo}$ GST time (s)

- t_{GPS} GPS time(s)

- WN GST Week Number

- WN_{0G} Week Number of the GPS/Galileo Time Offset reference

The user must account in the above formula for the truncated nature (roll-over) of the weekly parameters (WN, WN_{0G}), considering that at the time of broadcast of the GGTO parameters, the absolute value of the difference between untruncated WN and WN_{0G} values does not exceed 31.

The GGTO parameters are formatted according to the values in Table 76.

When the GGTO is not available the GGTO parameters disseminated are: A_{0G} (all ones -16 bits), A_{1G} (all ones - 12 bits), t_{0G} (all ones - 8 bits), WN_{0G} (all ones - 6 bits). When a user receives all four parameters set to all ones the GGTO is considered as not valid.

Table 76: Parameters for the GPS Time to GST Offset Computation

Parameter	Definition	Bits	Scale factor	Unit
A_{0G}	Constant term of the polynomial describing the offset $\Delta t_{Systems}$	16*	2^{-35}	s
A_{1G}	Rate of change of the offset $\Delta t_{Systems}$	12*	2^{-51}	s/s
t_{0G}	Reference time for GGTO data	8	3600	s
WN_{0G}	Week Number of GGTO reference	6	1	week
Total GST-GPS Conversion Size		42	n/a	n/a

*   Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

5.1.9   Service Parameters

5.1.9.1   *Satellite ID*

The satellite Identification is coded with 6 bits and has the characteristics given in Table 77.

Table 77: Satellite ID

Parameter	Definition	Bits	Scale Factor	Unit	Values
SVID	Satellite Identification	6	N/A	dimensionless	0…63

Note: SVID = 0 is used in the broadcast almanac data to indicate unused almanac entries. SVID values 1 to 36 are defined in this OS SIS ICD. Higher values are reserved for future use.

5.1.9.2 *Issue Of Data*

The navigation data is disseminated in data batches each one identified by an Issue of Data. In nominal operation the navigation data (ephemeris, satellite clock correction and SISA) have limited validity duration depending on the data type. The identification of each batch by an Issue of Data (IOD) value enables:

- the users to distinguish the data in different batches received from each satellite

- to indicate to the user receiver the validity of the data (which have to be updated using new issue of navigation data)

- the user receiver to compute the full batch of data even if it misses some pages or start receiving the data somewhere during the transmission

Two IODs are defined for (Table 78):

- the ephemeris, satellite clock correction parameters and SISA

- the almanacs

Table 78: IOD Values Mapping on Data Type

Data Type	Bits	Unit
Ephemeris, Clock correction and SISA IOD_{nav}	10	dimensionless
Almanacs IOD_a	4	dimensionless

Each IOD has an associated reference time parameter disseminated within the batch.

Note: the broadcast group delay, ionospheric corrections, GST-UTC and GST-GPS conversion parameters, navigation data validity status and signal health status are not identified by any Issue of Data value.

5.1.9.3 *Navigation Data Validity and Signal Health Status*

The signal health status and data validity status refer to the transmitting satellite. These status flags are used as service performance level notification [e.g.: notification of satellite non-availability, or notification of SIS in Extended Operations Mode (EOM)]. The navigation data validity status transmitted on E5a, E5b and E1, is coded on 1 bit, according to Table 79 and Table 80.

Table 79: Data Validity Satellite Status (transmitted on E5a)

Parameter	Definition	Bits	Scale factor	Unit
E5a$_{DVS}$	E5a Data Validity Status	1	N/A	dimensionless

Table 80: Data Validity Satellite Status (transmitted on E5b and E1-B)

Parameter	Definition	Bits	Scale factor	Unit
E5b$_{DVS}$	E5b Data Validity Status	1	N/A	dimensionless
E1-B$_{DVS}$	E1-B Data Validity Status	1	N/A	dimensionless

The data validity status bit has the values shown in Table 81.

Table 81: Data validity Status Bit Values

Data Validity Status	Definition
0	Navigation data valid
1	Working without guarantee

The E5a signal health status transmitted on E5a-I is coded on 2 bits according to Table 82.

Table 82: Signal Health Status for E5a (transmitted on E5a)

Parameter	Definition	Bits	Scale factor	Unit
E5a$_{SHS}$	E5a Signal Health Status	2	N/A	dimensionless

The E5b and E1-B/C signal health status transmitted on E5b and E1-B are coded on 2 bits according to Table 83.

Table 83: Signal Health Status for E5b and E1-B/C (transmitted on E5b and E1-B)

Parameter	Definition	Bits	Scale factor	Unit
E5b$_{SHS}$	E5b Signal Health Status	2	N/A	dimensionless
E1-B$_{SHS}$	E1-B/C Signal Health Status	2	N/A	dimensionless

The signal status bits have the values shown in Table 84:

Table 84: Signal Health Status Bit Values

Signal Health Status	Definition
0	Signal OK
1	Signal out of service
2	Signal in Extended Operations Mode
3	Signal Component currently in Test

5.1.9.4 *Checksum*

The checksum, which employs a CRC technique, is used to detect the reception of corrupted data. The checksum does not include the frame synchronisation pattern or the tail bit fields since these do not form part of the required message information. For the F/NAV and I/NAV data, a CRC of 24 bits is generated from the generator polynomial $G(X)$ described below:

$$G(X) = (1 + X)\,P(X)$$
<div align="right">Eq. 25</div>

$P(X)$ is a primitive and irreducible polynomial given by the following equation.

$$P(X) = X^{23} + X^{17} + X^{13} + X^{12} + X^{11} + X^{9} + X^{8} + X^{7} + X^{5} + X^{3} + 1$$
<div align="right">Eq. 26</div>

The CRC is composed of a sequence of 24 parity bits p_i; for any i from 1 to 24, p_i is the coefficient of X^{24-i} in $R(X)$ where:

- $R(X)$ is the remainder of the binary polynomial algebra division of the polynomial $m(X)\,X^{24}$ by $G(X)$, and

- $m(X) = m_1 X^{k-1} + \ldots + m_{k-2} X^2 + m_{k-1} X + m_k$ with $m_1, m_2, \ldots, m_k$ the sequence of k-bits information to be protected by the CRC, and m_1 as the MSB.

5.1.9.5 *Secondary Synchronisation Pattern*

The Secondary Synchronisation Pattern (SSP) is a pre-defined data bit sequence of 8 bits located at the end of the I/NAV pages. The SSP can assume three different configurations, named SSP1, SSP2 and SSP3.

Before FEC encoding, the SSP is inserted between the CRC and the tail bits in the I/NAV pages on E1, cycling among the three configurations as shown in Table 38, thus maintaining synchronisation to (GST_0 + 1 s) modulo 6 seconds.

After FEC encoding, the last 16 symbols of E1 I/NAV pages provide three pre-defined sequences with well-defined cross-correlation properties. These are shown in Table 85.

Table 85: Bit and symbol sequences of the three SSP configurations

	SSP1	SSP2	SSP3
Plain SSP configurations	00000100	00101011	00101111
Encoded SSP configurations*	1110100100100101	0110110001001110	1101000000111110

*   Last 16 symbols of the I/NAV E1 pages, after FEC encoding of the 8 plain SSP bits + 6 tail bits.

The Secondary Synchronisation Pattern allows a receiver to correlate a local replica of the encoded pattern configurations with the received data symbols, after de-interleaving. As soon as any occurrence of the three SSP configurations is detected in the incoming symbol stream, the receiver has the knowledge of the GST (modulo 6 seconds) without the need for successful data decoding.

Note: SSP configurations are an evolution of the Galileo navigation message and as such will be gradually deployed to all Galileo satellites, including those already in orbit. During this deployment phase the not-yet upgraded satellites will be downlinking a legacy reserved sequence.

SSP configurations will not be downlinked while I/NAV dummy messages are transmitted on E1-B (see Table 56).

In both cases above, the contents transmitted instead of the SSP configurations are not intended for time synchronisation and have low cross-correlation with the SSP configurations provided in in Table 85.

5.1.10 Almanac

The almanac data is a reduced-precision subset of the clock and ephemeris parameters of the active satellites in orbit. The user receiver utilises the algorithm described in section 5.1.1 to compute the positions of the Galileo satellites. All parameters of Table 68 appearing in the equations, but not included in the content of the almanac, are set to zero for satellite position determination.

The Galileo almanac orbital parameters consist of:

- Semi-major axis
- Eccentricity
- Inclination
- Longitude of the ascending node
- Argument of perigee
- Mean anomaly

The almanac time correction is provided by the coefficients a_{f0} and a_{f1} of a first order polynomial and is evaluated as per section 5.1.4 assuming the clock drift rate is set to zero.

Predicted signal health status is provided as well, which can be used to determine which Galileo satellites should be tracked by the receiver.

The IOD_a disseminated with the almanac data allows detection of almanac batch changes. The almanac reference time t_{0a} and reference week number WN_a apply to the orbital parameters and to the clock correction parameters from the associated almanac batch. The two-bit WN_a provides the two least significant bits of the associated GST week number.

The almanac parameters are transmitted according to the characteristics stated in Table 86.

Table 86: Almanac Parameters

Parameter	Definition	Bits	Scale factor	Unit
SVID	Satellite ID (1 constellation of 36 satellites)	6	1	dimensionless
$\Delta(\sqrt{A})$	Difference between the square root of the semi-major axis and the square root of the nominal semi-major axis ($A_{nominal}$ according to Table 1): $$\Delta(\sqrt{A}) = \left(\sqrt{A} - \sqrt{A_{nominal}}\right)$$	13*	2^{-9}	meters$^{1/2}$
e	Eccentricity	11	2^{-16}	dimensionless
δ_i	Difference between the inclination angle at reference time and the nominal inclination ($i_{nominal}$ according to Table 1): $$\delta i = i_0 - \frac{i_{nominal}}{180°}$$	11*	2^{-14}	semi-circles***
Ω_0	Longitude of ascending node of orbital plane at weekly epoch****	16*	2^{-15}	semi-circles***
$\dot{\Omega}$	Rate of change of right ascension	11*	2^{-33}	semi-circles/s***
ω	Argument of perigee	16*	2^{-15}	semi-circles***
M_0	Satellite mean anomaly at reference time	16*	2^{-15}	semi-circles***
a_{f0}	Satellite clock correction bias "truncated"	16*	2^{-19}	s
a_{f1}	Satellite clock correction linear "truncated"	13*	2^{-38}	s/s
E5a$_{SHS}$**	Satellite E5a signal health status	2	N/A	dimensionless
E5b$_{SHS}$**	Satellite E5b signal health status	2	N/A	dimensionless
E1-B$_{SHS}$**	Satellite E1-B/C signal health status	2	N/A	dimensionless

Parameter	Definition	Bits	Scale factor	Unit
Total Satellite Almanac Size		131 (F/NAV) 133 (I/NAV)		
IOD_a	Almanac Issue Of Data	4	N/A	dimensionless
t_{0a}	Almanac reference time	10	600	s
WN_a	Almanac reference Week Number	2	1	week
Total Almanac References Size		16		

* Parameters so indicated are two's complement, with the sign bit (+or-) occupying the MSB.

** The F/NAV almanac transmitted on the E5a-I component contains the signal health status $E5a_{SHS}$. The I/NAV almanac transmitted on the E5b-I and E1-B components contains both signal health status $E5b_{SHS}$ and $E1\text{-}B_{SHS}$. The two-bit health status is encoded as per Table 84.

*** Note that the 'semi-circle' is not a SI unit but can be converted as: 1 semi-circle = π radian.

**** More precisely, Ω_0 is the longitude of ascending node of orbital plane at the weekly epoch propagated to the reference time t_{0a} at the rate of change of right ascension.

5.1.11 Reduced Clock and Ephemeris Data

The Reduced Clock and Ephemeris Data (Reduced CED) is a compact set of ephemeris and clock minus radial error correction information, transmitted within one single I/NAV word and with a reduced accuracy with respect to the ephemeris of section 5.1.1. Receivers can use these reduced-precision parameters to compute an initial position fix in case a full ephemeris and clock correction set (I/NAV words 1 to 4) has not yet been received.

The Reduced CED for each Galileo satellite is composed of 8 parameters:

- 6 orbital parameters

- 2 clock minus radial error correction coefficients.

The Reduced CED for each Galileo satellite are according to the characteristics stated in Table 87.

Table 87: Reduced Clock and Ephemeris Data parameters

Parameter	Definition	Bits	Scale factor	Unit
ΔA_{red}	Difference between the Reduced CED semi-major axis and the nominal semi-major axis ($A_{nominal}$ according to Table 1): $$\Delta A_{red} = (A_{red} - A_{nominal})$$	5*	2^8	meters
$e_{x\ red}$	Reduced CED eccentricity vector component x ***	13*	2^{-22}	dimensionless
$e_{y\ red}$	Reduced CED eccentricity vector component y ***	13*	2^{-22}	dimensionless

Parameter	Definition	Bits	Scale factor	Unit
$\Delta i_{0\,red}$	Difference between the Reduced CED inclination angle at reference time and the nominal inclination ($i_{nominal}$ according to Table 1): $$\Delta i_{0\,red} = i_{0\,red} - \frac{i_{nominal}}{180°}$$	17*	2^{-22}	semi-circles**
$\Omega_{0\,red}$	Reduced CED longitude of ascending node at weekly epoch	23*	2^{-22}	semi-circles**
$\lambda_{0\,red}$	Reduced CED mean argument of latitude***	23*	2^{-22}	semi-circles**
$a_{f0\,red}$	Reduced CED satellite clock bias correction coefficient	22*	2^{-26}	s
$a_{f1\,red}$	Reduced CED satellite clock drift correction coefficient	6*	2^{-35}	s/s
Total Reduced CED size		**122**		

*   Parameters so indicated are two's complement, with the sign bit (+ or -) occupying the MSB.

**   Note that the 'semi-circle' is not a SI unit but can be converted as: 1 semi-circle = π rad, with π as per Table 68.

***   Definition of orbital elements: $e_x = e \cdot cos(w)$, $e_y = e \cdot sin(w)$, $\lambda_0 = M_0 + w$

The user can compute the ECEF coordinates of the SV's antenna phase centre position and the satellite time minus radial error correction at GST time t utilising the user algorithm for ephemeris determination listed in Table 68 and the satellite time correction algorithm defined in section 5.1.4. Additional computation steps, which are required when working with Reduced CED parameters instead of full-precision CED parameters, are listed in Table 88, Table 89 and Table 90.

Notes:

- The Reduced CED parameters introduced in this section cannot be combined with the full-precision CED parameters of section 5.1.1-5.1.3 when calling the user algorithms for ephemeris determination and/or satellite time correction, since the two sets are not cross-compatible.

- Computation of satellite position and clock correction from Reduced CED must use the parameters from a single Reduced CED word (i.e. parameters or intermediate results derived from different Reduced CED words cannot be combined).

The user can compute the Reduced CED reference time as described in Table 88. A set of Reduced CED parameters is usable for 10 minutes starting from its reference time.

Table 88: Reduced CED parameters Reference Time Computation

Reference Time Computation	Description
$t_{0r} = \text{modulo}\left(30 * \left\lfloor \frac{TOT_{RedCED}}{30} \right\rfloor + 1s\,, 604800\,s\right)^*$	Reduced CED reference time**

* Note: Since both t_{0e} and t_{0c} are reference times of week (GST modulo 604800 seconds), t_{0r} has to be expressed as modulo 604800 seconds value when replacing the reference times t_{0e} and t_{0c}. The Reduced CED reference time is aligned with the E1-B sub-frame boundary (see section 4.3.3.)

** TOT_{RedCED} is the start time of transmission of the Reduced CED word in GST and $\lfloor\cdots\rfloor$ indicates the integer part.

As previously described, in the following Table 89 and Table 90 the additional computation steps required when working with Reduced CED parameters are described for the ephemeris and the clock correction computation, respectively.

Table 89: Introduction of Reduced CED Orbital Parameters into Computation of Satellite Position

Usage of Reduced CED Orbital Parameters	Description
$\sqrt{A} = \sqrt{A_{red}}$	Square root of the semi-major axis
$i_0 = i_{0\,red}$	Inclination angle at reference time *
$e = \sqrt{e_{x\,red}^2 + e_{y\,red}^2}$	Eccentricity
$\omega = arctan2\left(e_{y\,red}, e_{x\,red}\right)$	Argument of perigee *
$M_0 = \lambda_{0\,red} - \omega$	Mean anomaly at reference time *
$\Omega_0 = \Omega_{0\,red}$	Longitude of ascending node of orbital plane at weekly epoch *
$\Delta n = 0$ $\quad$ $\dot{\Omega} = 0$ $\quad$ $\dot{i} = 0$ $\quad$ $C_{uc} = 0 \quad C_{rs} = 0$ $\quad C_{us} = 0 \quad C_{ic} = 0$ $\quad C_{rc} = 0 \quad C_{is} = 0$	Correction terms
$t_{0e} = t_{0r}$	Ephemeris reference time

*   Angular *parameters* are in *radians* for further processing according to Table 68, i.e.: insertion of $i_{0\,red}$, $\lambda_{0\,red}$ and $\Omega_{0\,red}$ in units of radians.

** $arctan2(Y, X)$ returns the four-quadrant inverse tangent

After having applied the steps described in Table 89, GTRF coordinates of the SV antenna phase centre position at time t can be computed utilising the user algorithm for ephemeris determination defined in Table 68.

The combined correction for clock minus radial error is computed using the satellite

time correction algorithm for Δt_{SV} as defined in section 5.1.4 with input parameters from Reduced CED applied as specified in Table 90.

Table 90: Introduction of Reduced CED Clock Correction Coefficients into Computation of Δt_{SV}

Usage of Reduced CED Clock Correction Coefficients	Description
$a_{f0} = a_{f0\,\text{red}}$	SV clock bias correction coefficient
$a_{f1} = a_{f1\,\text{red}}$	SV clock drift correction coefficient
$a_{f2} = 0$	SV clock drift rate correction coefficient
$t_{0c} = t_{0r}$	Clock correction data reference Time of Week

The subsequent PVT computation can use Δt_{SV} calculated from Reduced CED as clock correction, but must then combine this clock correction with the satellite position computation using orbital parameters from the same Reduced CED word. This is important because the Reduced CED clock correction coefficients incorporate a fraction of the radial satellite position, in order to minimise ranging errors due to numerical quantization of Reduced CED parameters.

Note that Δt_{SV} from Reduced CED is optimised for the dual-frequency signal combination (E1/E5b). Single-frequency OS (E1) users may use BGD(E1,E5b) introduced in section 5.1.5 in order to improve the Reduced CED ranging accuracy.

The Galileo satellites transmit Reduced CED only if the E5b and E1-B Data Validity Status and Signal Health Status flags defined in section 5.1.9.3 are set to "0", and if SISA(E1,E5b)≠NAPA as per section 5.1.12.

Note that an absence of Reduced CED in the broadcast may also be due to operational reasons unrelated to the aforementioned SIS flags.

5.1.12 Signal – In – Space Accuracy (SISA)

Signal – In – Space Accuracy (SISA) is a prediction of the minimum standard deviation (1-sigma) of the unbiased Gaussian distribution which overbounds the Signal – In – Space Error (SISE) predictable distribution for all possible user locations within the satellite coverage area. When no accurate prediction is available (SISA = NAPA), this is an indicator of a potential anomalous SIS.

The SISA Index shall be encoded according to the values stated in the following table.

Table 91: SISA Index Values

SISA Index	SISA Value
0 49	0 cm to 49 cm with 1 cm resolution
50 74	50 cm to 0.98 m with 2 cm resolution
75 99	1 m to 1.96 m with 4 cm resolution
100 125	2 m to 6 m with 16 cm resolution
126 254	Spare
255	No Accuracy Prediction Available (NAPA)

The Signal – In – Space Accuracy (SISA) shall be coded according to the values stated in the following table.

Table 92: SISA Parameters

Parameter	Definition	Bits	Scale factor	Units
SISA(E1,E5a)	SISA index for dual frequency E1-E5a	8	N/A	dimensionless
SISA(E1,E5b)	SISA index for dual frequency E1-E5b	8	N/A	dimensionless

5.1.13 Protection of I/NAV Clock and Ephemeris Data by means of Reed-Solomon Outer Forward Error Correction

In order to provide the user with an option for a more robust decoding of I/NAV Clock and Ephemeris Data (CED), an Outer Forward Error Correction (FEC2) based on Reed Solomon (RS) encoding is provided within the E1-B I/NAV message. The FEC2 RS encoding is applied to the data bits of I/NAV word types 1-4.
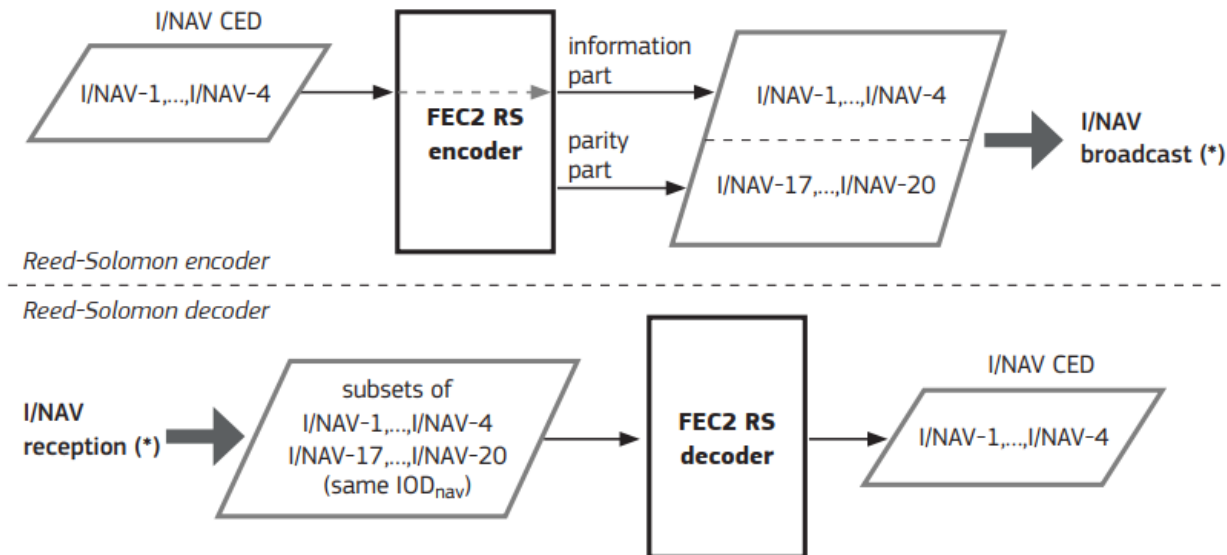

Figure 16: Protection of I/NAV CED by Outer Forward Error Correction (FEC2 RS)

* Like all other I/NAV words, the I/NAV words 1-4 and 17-20 are also subject to convolutional encoding (FEC Viterbi) and interleaving before broadcast (see Chapter 4.1.4). Users must perform de-interleaving and Viterbi decoding after symbol demodulation and before optional application of the FEC2 RS decoding.

The FEC2 RS is a systematic coding scheme, meaning that the CED is provided as unaltered information within I/NAV words 1-4 in every subframe. The FEC2 RS CED parity words are provided in words 17-20 and may differ in subsequent subframes. As depicted in Figure 16, users can either process just the CED words performing the standard Viterbi decoding or, alternatively, process also the FEC2 RS CED parity words in order to benefit from RS erasure and error correction capabilities.

Annex E provides a reference algorithm for the FEC2 RS decoder, which shows how the FEC2 RS CED parity words can be exploited by the user.

The encoding is constructed based upon a Galois Field of order 256, GF(256), using code symbols ('octets') consisting of 8 data or parity bits. The shortened Reed-Solomon code vector (or alternatively, shortened RS code word) comprises 118 octets and is subdivided into RS information vector C_{RS} (58 octets) and RS parity vector γ_{RS} (60 octets).

Annex F provides detailed FEC2 Reed-Solomon encoder parameters, implementation details, and one encoding example.

5.1.13.1 *RS information vector*

The FEC2 RS information vector C_{RS} (58 octets) represented in Figure 17, is constructed from the concatenation of the octet vectors $C_{RS,0}$, $C_{RS,1}$, $C_{RS,2}$ and $C_{RS,3}$, which are derived from I/NAV word types 1 to 4 (all words with the same IODnav).
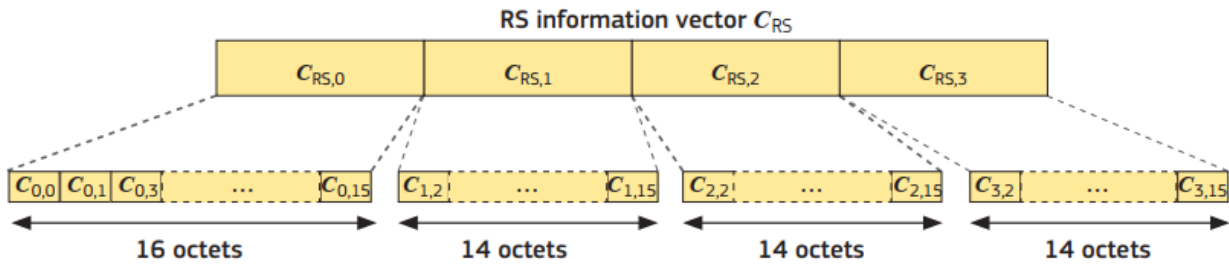

Figure 17: FEC2 RS information vector C_{RS}

The FEC2 RS information vector is built as follows:

a) The octet vector $C_{RS,0} = [C_{0,0} \dots C_{0,15}]$ (16 octets) is derived from I/NAV word type 1 as per Figure 18:
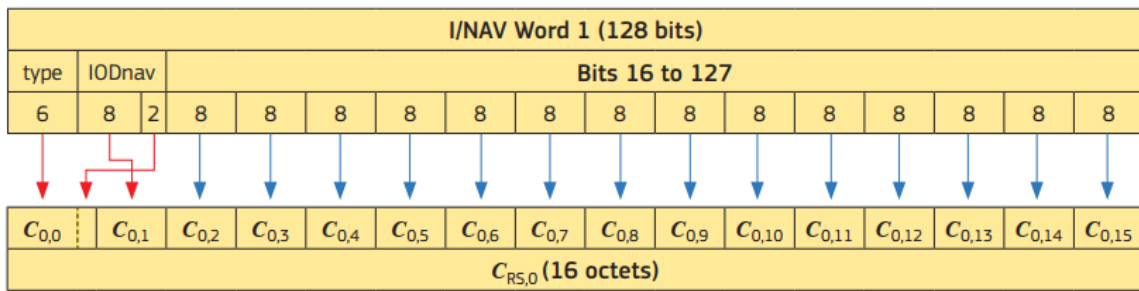
Figure 18: Derivation of the octet vector $C_{RS,0}$

- The octet $C_{0,0}$ consists of a concatenation of the word type field (bit pattern '000001' for word type 1) and of the 2 LSBs of the IODnav derived from word type 1.

- The octet $C_{0,1}$ consists of the 8 MSBs of IODnav derived from word type 1.

- The octets $C_{0,2}$ to $C_{0,15}$ are built by partitioning I/NAV word type 1 bits 16 to 127 into octets while maintaining the order of MSB to LSB.

b) The octet vectors $C_{RS,1} = [C_{1,2} \dots C_{1,15}]$, $C_{RS2} = [C_{2,2} \dots C_{2,15}]$ and $C_{RS,3} = [C_{3,2} \dots C_{3,15}]$

(14 octets each) are derived from I/NAV word types 2, 3 and 4 respectively:

Figure 19: Derivation of the octet vectors $C_{RS,1}$, $C_{RS,2}$ and $C_{RS,3}$

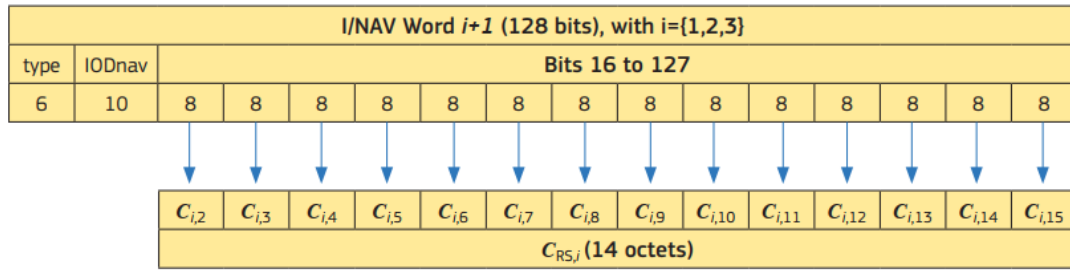- The octets $C_{i,0}$ and $C_{i,1}$ (i = 1,2,3) corresponding to bits 0...15 (word type and IODnav) of I/NAV word types 2...4 are not included in the RS information vector, as this information is already provided through $C_{0,0}$ and $C_{0,1}$.

- The octets $C_{i,2}$ to $C_{i,15}$ are built by partitioning I/NAV word type 2...4 bits 16 to 127 into octets while keeping the order of MSB to LSB.

c) The FEC2 RS information vector C_{RS} is obtained by concatenating the octet vectors $C_{RS,0}$, $C_{RS,1}$, $C_{RS,2}$, and $C_{RS,3}$ as per figure 17.

5.1.13.2 *RS parity vector*

The FEC2 RS parity vector γ_{RS} (60 octets) consists of the concatenation of the octet vectors $\gamma_{RS,0}$, $\gamma_{RS,1}$, $\gamma_{RS,2}$ and $\gamma_{RS,3}$ according to the following figure.
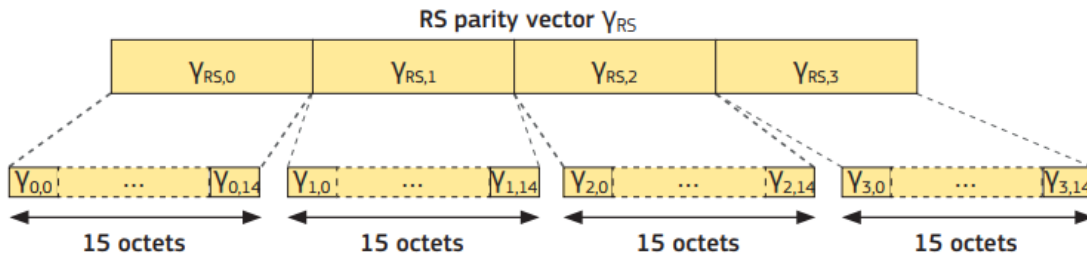
Figure 20: FEC2 RS parity vector γ_{RS}

The octet vectors $\gamma_{RS,0}$, $\gamma_{RS,1}$, $\gamma_{RS,2}$ and $\gamma_{RS,3}$ (15 octets each) are broadcast in I/NAV word types 17, 18, 19 and 20 (FEC2 RS CED words), where

- the field 'type' contains the binary FEC2 Reed-Solomon word type number,

- the field 'L' contains the 2 LSBs of IODnav,

- the remaining bits 6 to 13 and bits 16 to 127 provide the 15 octets $\gamma_{i,0}$ to $\gamma_{i,14}$

2 LSBs of applicable IODnav

I/NAV Word *i*+17 (128 bits), with *i*={0,1,2,3}																
type	$\gamma_{i,0}$	L	Bits 16 to 127													
6	8	2	8	8	8	8	8	8	8	8	8	8	8	8	8	8

$\gamma_{i,0}$	$\gamma_{i,1}$	$\gamma_{i,2}$	$\gamma_{i,3}$	$\gamma_{i,4}$	$\gamma_{i,5}$	$\gamma_{i,6}$	$\gamma_{i,7}$	$\gamma_{i,8}$	$\gamma_{i,9}$	$\gamma_{i,10}$	$\gamma_{i,11}$	$\gamma_{i,12}$	$\gamma_{i,13}$	$\gamma_{i,14}$

$\gamma_{RS,i}$ (15 octets)
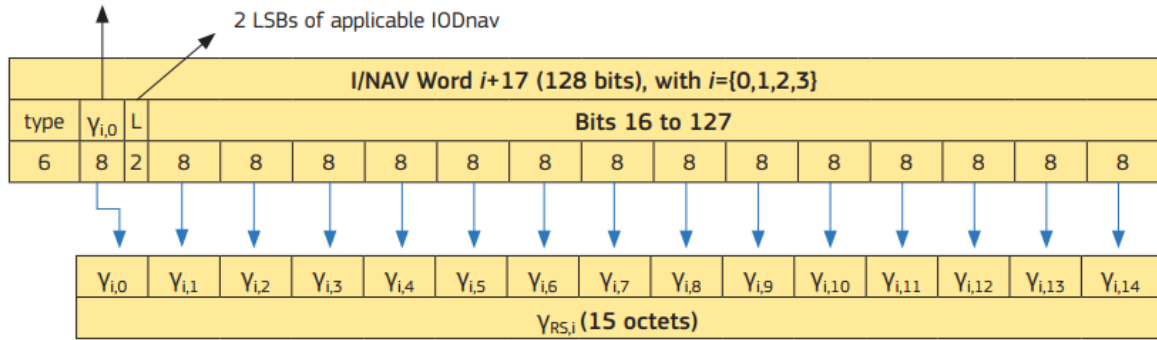
Figure 21: Derivation of the octet vectors $\gamma_{RS,0}$, $\gamma_{RS,1}$, $\gamma_{RS,2}$ and $\gamma_{RS,3}$

Note: The 2 LSBs of IODnav are provided to support detection of changes to IODnav after Viterbi decoding and prior to an RS decoding attempt.

A user may attempt to recover the 58 octets of the shortened RS information vector, containing the I/NAV clock and ephemeris data, with any combination of four or more received words with different types within the range 1 to 4 and 17 to 20. All words must have the same IODnav.

The RS erasure and error correction capability can be used

- to recover missing RS octets from the RS information vector and/or

- to correct errors contained in received octets of the RS information vector.

5.2 ARAIM Integrity Support Data (ISD)

Galileo provides a channel in E1-B for dissemination of Integrity Support Message (ISM) to receivers. Each ARAIM Integrity Support Message encapsulated in I/NAV Word Type 22 contains the following parameters:

- GNSS Constellation ID

- Constellation-specific ISM content, including ISD

- 32-bits ISM CRC

For safety critical purposes, the Galileo ISD needs to be used in combination with a certified ARAIM equipment.

5.2.1   GNSS Constellation ID

Each ARAIM Integrity Support Message contains a GNSS Constellation Identifier.

The GNSS Constellation ID is coded on 3 bits according to Table 93.

Table 93: ARAIM ISM GNSS Constellation ID

Parameter	Definition	Bits	Scale factor	Units
GNSS Constellation ID	Integrity Support Message GNSS Constellation Identifier	3	N/A	dimensionless

The GNSS Constellation ID bits have the values shown in Table 94.

Table 94: GNSS Constellation ID Bit Values

GNSS Constellation ID	Description
0	ISM in Test
1	Galileo
2	Reserved
3	Beidou
4	GPS
5	Spare
6	Spare
7	Spare

5.2.2   ISM CRC

Each ARAIM Integrity Support Message is protected by a checksum of 32 bits in order to ensure critical data integrity. The ISM CRC of 32 bits is generated from the following generator polynomial $G_{ISM}(X)$:

$$G_{ISM}(X) = X^{32} + X^{31} + X^{24} + X^{22} + X^{16} + X^{14} + X^8 + X^7 + X^5 + X^3 + X + 1 \qquad \text{Eq. 27}$$

The ISM CRC is composed of a sequence of 32 parity bits p_i.

For any i from 1 to 32, p_i is the coefficient of X^{32-i} in $R(X)$ where:

- $R(X) = r_1 X^{31} + \cdots + r_{30} X^2 + r_{31} X + r_{32}$ is the remainder of the binary polynomial algebra division of the polynomial $m(X)X^{32}$ by $G_{ISM}(X)$, and

- $m(X) = m_1 X^{k-1} + \cdots + m_{k-2} X^2 + m_{k-1} X + m_k$ with $m_1, m_2, \ldots, m_k$ the sequence of k-bits information to be protected by the ISM CRC, and m_1 as the MSB.

The ISM CRC information field $m(X)$ is formed from all preceding 96-bits of I/NAV Word Type 22 (i.e. Type, GNSS Constellation ID and ISM content bits). Bits are arranged in the order transmitted (see also paragraph 4.1.3): m_1 corresponds to the first transmitted bit of the Type field, and m_k (with $k = 96$) corresponds to the last transmitted bit of the ISM content field. The ISM CRC is ordered such that r_1 is the first bit transmitted, and r_{32} is the last bit transmitted.

A numerical example for the ISM CRC computation is provided in Annex G.

5.2.3 Constellation Specific ISM content including ISD

Each Currently there is exclusively ISM content specified for GNSS Constellation ID = 'GALILEO'. Future evolutions may encompass the provision of ISM content for other GNSS Constellations through GALILEO SIS.

5.2.3.1 *Galileo ISM Parameters*

The content of Galileo ARAIM Integrity Support Messages follows the Service Level Identifier (SL ID).

5.2.3.1.1 Galileo Service Level Identifier

The SL ID is coded on 3 bits according to Table 95.

Table 95: Service Level Identifier

Parameter	Description	Bits	Scale factor	Units
SL ID	Service Level Identifier	3	N/A	dimensionless

The SL ID bits have the values shows in Table 96.

Table 96: SL ID Bit Values

SL ID	Description
0	Service Level 1: no data available
1	Service Level 2: Non-safety of life use
2	Service Level 3: Safety of life use (Horizontal)
3	Service Level 4: Safety of life use (Vertical)
4	Spare
5	Spare
6	Spare
7	Spare

Depending on the Service Level, the contents of WT22 varies as described in the

following sections.

5.2.3.1.2 Integrity Support Data for Galileo ISM with Service Level 1

Galileo ISM with Service Level 1 (SL1) does not provide any ISD.

5.2.3.1.3 Integrity Support Data for Galileo ISM with Service Level 2

Reserved for future non-safety of life applications.

5.2.3.1.4 Integrity Support Data for Galileo ISM with Service Level 3

Table 97 describes the contents of the WT22 Galileo ISM with SL3 including bit lengths, scale factors, and units of these parameters.

Table 97: Galileo Service Level 3 ISM content parameters

Parameter	Definition	Bits	Scale factor	Units
WN_{ISM}	ISM Week Number, which refers to the associated GST week number.	12	1	week
t_{0ISM}	ISM Time of Week, which refers to the associated GST time of week, with a resolution of 0.5 hours.	9	1800	seconds
Mask – MSB	Satellite Mask Most Significant Bit, which serves for shifting the SVID range addressed by the 32-bits Mask field as per Table 98.	1	N/A	dimensionless
Mask	Satellite Mask as specified in Table 98.	32	N/A	dimensionless
P_{const}	Probability of constellation fault, which is provided as index: Index-to-value assignment as per Table 99.	4	N/A	dimensionless
P_{sat}	Probability of satellite fault, which is provided as index: Index-to-value assignment as per Table 100.	4	N/A	dimensionless
URA	User Ranging Accuracy bounding for integrity, which is provided as index: Index-to-value assignment as per Table 101.	4	N/A	m
URE	User Ranging Error bounding for accuracy and continuity, which is provided as index: Index-to-value assignment as per Table 102.	4	N/A	m
b_{nom}	Nominal Bias, which is provided as index: Index-to-value assignment as per Table 103.	4	N/A	m
$T_{validity}$	Validity duration of ISM content, which is provided as index: Index-to-value assignment as per Table 104.	4	N/A	hours

ISM Week Number (WN_{ISM})

Galileo ISM provides the ISM Week Number applicable to the start of the time of

validity for the associated ISD provided in WT22.

The ISM Week Number is an integer counter that gives the sequential week number from the GST start epoch. The parameter is represented with 12 bits, which covers 4096 weeks (about 78 years). Then the counter is reset to zero to cover an additional period modulo 4096.

ISM Time of Week (t_{0ISM})

Galileo ISM provides the ISM Time of Week applicable to the start of the time of validity for the associated ISD provided in WT22.

The ISM Time of Week is defined as the number of seconds that have occurred since the transition from the previous week. The TOW covers an entire week from 0 to 603000 seconds and is reset to zero at the end of each week.

Mask-MSB and Mask

The 1-bit field 'Mask – MSB' and the 32-bits field 'Mask' serve for identifying the Galileo SVIDs to which the succeeding Galileo SL3 ISM parameters apply. The complete SVID range can be shifted by 32 with the help of 'Mask – MSB'. Each bit in the succeeding Mask field addresses one Galileo SVID, as per Table 98, where the applicability of the Galileo SL3 ISM parameters to each SVID is indicated by the Mask bit value as follows:

'0' = Information in the current ISM does not apply to this SVID

'1' = Information in the current ISM does apply to this SVID

Table 98: Galileo SL3 ISM SVID Masking

Mask – MSB (1 bit)	Mask (32 bits)															
bit 1	bit 1	bit 2	bit 3	bit 4	bit 5	bit 6	bit 7	bit 8	bit 9	bit 10	bit 11	bit 12	bit 13	bit 14	bit 15	bit 16
'0'	SVID 1	SVID 2	SVID 3	SVID 4	SVID 5	SVID 6	SVID 7	SVID 8	SVID 9	SVID 10	SVID 11	SVID 12	SVID 13	SVID 14	SVID 15	SVID 16
'1'	SVID 33	SVID 34	SVID 35	SVID 36	SVID 37	SVID 38	SVID 39	SVID 40	SVID 41	SVID 42	SVID 43	SVID 44	SVID 45	SVID 46	SVID 47	SVID 48
bit 1	bit 17	bit 18	bit 19	bit 20	bit 21	bit 22	bit 23	bit 24	bit 25	bit 26	bit 27	bit 28	bit 29	bit 30	bit 31	bit 32
'0'	SVID 17	SVID 18	SVID 19	SVID 20	SVID 21	SVID 22	SVID 23	SVID 24	SVID 25	SVID 26	SVID 27	SVID 28	SVID 29	SVID 30	SVID 31	SVID 32

Mask – MSB (1 bit)	Mask (32 bits)															
'1'	SVID 49	SVID 50	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

The probability of constellation fault (P_{const})

The Galileo Probability of Constellation Fault (P_{const}) is the probability that two or more satellites within a core satellite constellation have faulted signals concurrently due to a common cause. Galileo P_{const} is coded as indicated Table 99.

Table 99: Galileo SL3 ISM P_{const} Index-to-Value Mapping Table

P_{const} Index	Value
0	$1.00 \cdot 10^{-8}$
1	$1.00 \cdot 10^{-7}$
2	$1.00 \cdot 10^{-6}$
3	$3.00 \cdot 10^{-6}$
4	$6.00 \cdot 10^{-6}$
5	$8.00 \cdot 10^{-6}$
6	$1.00 \cdot 10^{-5}$
7	$2.00 \cdot 10^{-5}$
8	$4.00 \cdot 10^{-5}$
9	$6.00 \cdot 10^{-5}$
10	$8.00 \cdot 10^{-5}$
11	$1.00 \cdot 10^{-4}$
12	$1.25 \cdot 10^{-4}$
13	$1.50 \cdot 10^{-4}$
14	$1.75 \cdot 10^{-4}$
15	$2.00 \cdot 10^{-4}$

The probability of satellite fault (P_{sat})

The Galileo Probability of Satellite Fault (P_{sat}) is the probability of a satellite having a faulted signal, where the faulted signal occurs only on one satellite or has independent causes if occurring on more than one satellite. Galileo P_{sat} is coded as indicated in Table 100.

Table 100: Galileo SL3 ISM P_{sat} Index-to-Value Mapping Table

P_{sat} Index	Value
0	$1.0 \cdot 10^{-7}$
1	$3.0 \cdot 10^{-7}$

P_{sat} Index	Value
2	$6.0 \cdot 10^{-7}$
3	$1.0 \cdot 10^{-6}$
4	$2.0 \cdot 10^{-6}$
5	$3.0 \cdot 10^{-6}$
6	$5.0 \cdot 10^{-6}$
7	$7.0 \cdot 10^{-6}$
8	$1.0 \cdot 10^{-5}$
9	$1.2 \cdot 10^{-5}$
10	$1.4 \cdot 10^{-5}$
11	$1.7 \cdot 10^{-5}$
12	$2.0 \cdot 10^{-5}$
13	$2.4 \cdot 10^{-5}$
14	$2.8 \cdot 10^{-5}$
15	$3.0 \cdot 10^{-5}$

Galileo URA

Galileo User Range Accuracy (URA) is the overbounding integrity range error model parameter to be applied for a given satellite signal. Galileo URA is coded as indicated in Table 101.

Table 101: Galileo SL3 ISM URA Index-to-Value Mapping Table

URA Index	Value
0	0.75
1	1.00
2	1.50
3	2.00
4	2.25
5	2.50
6	2.75
7	3.00
8	3.25
9	3.50
10	3.75
11	4.00
12	4.50
13	5.00
14	5.50
15	6.00

Galileo URE

Galileo User Range Error (URE) is the accuracy and continuity range error model parameter to be applied for a given satellite signal. Galileo URE is coded as indicated in Table 102.

Table 102: Galileo SL3 ISM URE Index-to-Value Mapping Table

URE Index	Value
0	0.25
1	0.50
2	0.75
3	1.00
4	1.25
5	1.50
6	1.75
7	2.00
8	2.25
9	2.50
10	2.75
11	3.00
12	3.25
13	3.50
14	3.75
15	4.00

Nominal bias (b_{nom})

Galileo b_{nom} is the overbounding bias term for a given satellite signal. Galileo b_{nom} is coded as indicated in Table 103.

Table 103: Galileo SL3 ISM b_{nom} Index-to-Value Mapping Table

b_{nom} index	Value
0	0.00
1	0.10
2	0.20
3	0.30
4	0.40
5	0.50
6	0.60
7	0.75
8	0.85
9	1.00

b_{nom} index	Value
10	1.20
11	1.40
12	1.60
13	1.80
14	2.00
15	2.40

Validity duration ($T_{validity}$)

The Validity duration parameter determines the validity timeframe of the ISD information provided, beginning from a starting time coded through the ISM Week Number and ISM Time of Week parameters.

The Validity duration is coded as indicated in Table 104.

Table 104: Galileo SL3 ISM $T_{validity}$ Index-to-Value Mapping Table

$T_{validity}$ Index	Value
0	1
1	2
2	3
3	4
4	6
5	8
6	12
7	18
8	24
9	36
10	48
11	72
12	120
13	168
14	720
15	1440

5.2.3.1.5   Integrity Support Data for Galileo ISM with Service Level 4

Reserved for Safety of life applications with vertical guidance.

5.2.3.1.6   Integrity Support Data for Galileo ISM with Service Level 5 to 8

Reserved.

5.3 SAR RLM Data

Each Return Link Message encapsulated in a SAR data page contains the following data:

- Beacon ID (60 bits):

The Beacon ID is identical to the 60 bits (15 Hexadecimal characters) of the standard beacon identification defined in the COSPAS – SARSAT T.001 document [RD2]. It uniquely identifies the beacon to which the RLM is addressed.

- Message code (4 bits):

The Message Code defines the Return Link Service according to Table 105.

Table 105: SAR RLM Message Code Values

RLM	Message Code (4 bits)	Return Link Service
Short-RLM	0 0 0 1	Acknowledgement Service
Short-RLM	1 1 1 1	Test Service
Short-RLM	Other codes	Spare
Long-RLM	All codes to be defined	Spare

- Parameters field (16 bits for the short RLM, 96 bits for the long RLM):

The Parameters field provides the information related to the specific Return Link Service identified by the "Message Code".

The last bit of the Parameters field, i.e. bit 16 of the Short-RLM Parameters field and bit 96 of the Long-RLM Parameters field, is a SAR RLM data parity bit. This parity bit shall ensure that the total number of ones (1) in the fields "Beacon ID", "Message Code" and "Parameters", (including spare bits), is even.

The Parameters field values for Return Link Services based on Short-RLM are defined in Table 106.

Table 106: SAR Short-RLM Data Values

Return Link Service	Beacon Id		Message Code				Short-RLM Parameters Field															
	60		4				16															
	Bit 1**	to Bit 60	Bit 61	Bit 62	Bit 63	Bit 64	Bit 65	Bit 66	Bit 67	Bit 68	Bit 69	Bit 70	Bit 71	Bit 72	Bit 73	Bit 74	Bit 75	Bit 76	Bit 77	Bit 78	Bit 79	Bit 80
Acknowledgement Service - Type 1*	15 Hex Id		0	0	0	1	1	0	Spare													Parity
Test Service	15 Hex Id		1	1	1	1	Reserved															Parity

* Combinations of Message Code [0001] (Acknowledgement Service) with other values of bits 65 – 66 are spare. Refer to COSPAS – SARSAT T.001 document [RD2] for the service description of the acknowledgement Type 1.

** Bit numbers are counted after concatenating the four parts of Short-RLM data described in section 4.3.8 "SAR Field Structure". Bit 1 is received first, Bit 80 is received last.

The Parameters field values for Long-RLM are currently not defined.

Annex A List of Acronyms

AltBOC	Constant envelope modulation scheme for combining two sidebands each consisting itself of two binary signals (in I- and Q-component).
ARNS	Aeronautical Radionavigation Services
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
BGD	Broadcast Group Delay
BOC	Binary Offset Carrier
CBOC	Composite Binary Offset Carrier modulation
CDMA	Code Division Multiple Access
CED	Clock and Ephemeris Data
CoP	Centre of Phase
COSPAS – SARSAT	Cosmicheskaya Systyema Poiska Avariynich Sudov - Search and Rescue Satellite Aided Tracking
CRC	Cyclic Redundancy Check
CS	Commercial Service
DME	Distance Measuring Equipment
DN	Day Number
ECEF	Earth-Centred, Earth-Fixed
EOM	Extended Operations Mode
EGNOS	European Geostationary Navigation Overlay Service
FEC	Forward Error Correction
FEC2	Outer Forward Error Correction
GF	Galois Field
GGTO	Galileo/GPS Time Offset
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GST	Galileo System Time
GTRF	Galileo Terrestrial Reference Frame
H-ARAIM	Horizontal – ARAIM
HAS	High Accuracy Service
I	In-phase signal component
ICD	Interface Control Document
ID	Identifier
IOD	Issue Of Data
ISD	Integrity Support Data
ISM	Integrity Support Message
ITU	International Telecommunication Union
ITU-R	ITU – Radiocommunication Sector
JTIDS	Joint Tactical Information Distribution System
LAN	Longitude of the Ascending Node
LFSR	Linear Feedback Shift Register
LSB	Least Significant Bit
Mcps	Mega chips per second
MHz	Megahertz

MIDS	Multifunctional Information Distribution System
MODIP	MOdified DIP latitude
MSB	Most Significant Bit
MUX	Multiplexer
N/A	Not Applicable
NAPA	No Accuracy Prediction Available
NIB	Non-Interference Basis
NTCM-G	Neustrelitz Total Electron Content Model for Galileo
NRZ	Non-Return-to-Zero
OS	Open Service
OSNMA	Open Service Navigation Message Authentication
PSK	Phase-Shift Keying
PVT	Position, Velocity and Time
Q	Quadrature Signal Component
QPSK	Quadrature Phase-Shift Keying
RAAN	Right Ascension of the Ascending Node
RF	Radio Frequency
RHCP	Right-Hand Circular Polarisation
RLM	Return Link Message
RNSS	Radionavigation-Satellite Services
RS	Reed-Solomon
SAR	Search-and-Rescue Service/Signal
SI	International System of Units (Le Système international d'unités)
SIS	Signal-In-Space
SISA	Signal-In-Space Accuracy
sfu	Solar flux unit
SNF	Satellite Navigation Frame
SL	Service Level
SSP	Secondary Synchronisation Pattern
SV	Space Vehicle
SVID	Space Vehicle IDentifier
TACAN	TACtical Air Navigation (system) equipment
TOT	Time Of Transmission
TOW	Time Of Week
TTF	Time To Fix
URA	User Range Accuracy
URE	User Range Error
UTC	Coordinated Universal Time
WN	Week Number

E5-Signal	The Galileo E5-signal consists of the signals E5a, E5b, E5a-QP (and modulation product signals) and is transmitted in the frequency band 1164 - 1215 MHz allocated to RNSS with a worldwide co-primary status. The E5-signal shares the band with the co-primary Aeronautical Radionavigation Service (ARNS) (ITU-R Radio Regulations). Moreover, it shares the band with other RNSS- signals provided by EGNOS, GPS-L5, GLONASS etc. as well as signals of the ARNS (DME, TACAN). Also found in the band is the JTIDS-MIDS signal which is permitted on a NIB.
E5a-Signal	The Galileo E5a-signal is an inherent element of the E5-signal and consists of a data-component transmitted in the in-phase component and a pilot-component transmitted in the quadrature component. The E5a-signal provides the F/NAV message supporting Galileo Open Service and overlaps (in the spectrum) with the GPS-L5-signal.
E5b-Signal	The Galileo E5b-signal is an inherent element of the E5-signal and consists of a data-component transmitted in the in-phase component and a pilot-component transmitted in the quadrature component. The E5b-signal provides the I/NAV message and supports the Open Service and the Commercial Service.
E6-Signal	The Galileo E6-signal consists of the signal components E6-B and E6-C and is transmitted in the frequency band 1260 - 1300 MHz allocated on a worldwide co-primary basis (ITU-R Radio Regulations), sharing with radar systems of the radio navigation and radiolocation service. The signal components E6-B and E6-C are data-component and pilot-component respectively. The E6-signal provides the C-NAV message and supports Commercial Service.
E1- Signal	The Galileo E1-signal comprises the signal components E1-B and E1-C and is transmitted in the frequency band 1559 - 1591 MHz allocated to RNSS and ARNS on a worldwide co-primary basis (ITU-R Radio Regulations). The signal components E1-B and E1-C are data-component and pilot-component respectively. The E1-signal provides the I/NAV message and supports the Open Service and the Commercial Service.
Navigation Data Stream	Sequence of bits carrying the navigation data information by using a frame structured transmission protocol.
F/NAV Message	Navigation message provided by the E5a signal for Open Service.
I/NAV Message	Navigation message provided by E5b and E1-B signals, supporting the Open Service and the Commercial Service.
C/NAV Message	Commercial navigation message type provided by the E6-B signal supporting Commercial Service.
Data component	A data component is the result of modulating ranging code, sub-carrier (if present) and secondary code with a navigation data stream.
Pilot component	A pilot component (or dataless component) is made of ranging code, sub-carrier (if present) and secondary code only, not modulated by a navigation data stream.
Receiver reference bandwidth	The bandwidth of a hypothetical receiver with ideal (rectangular frequency response) input filters

| Extended Operations Mode | Galileo operational mode characterized by a gradually degrading accuracy with respect to the nominal operating mode. |

C.1. Introduction

This annex provides the primary codes (expressed in hexadecimal format) for the Galileo Open Signal components E5a-I, E5a-Q, E5b-I, E5b-Q, E1-B, E1-C and E5a_QP in sections C.3 to C.9, respectively. The E5 codes are derived from LFSR sequences as described in Section 3.4.1 and provided here for convenience and completeness. The E5a-QP codes are obtained as described in section 3.4.2.

C.2. Hexadecimal Coding Convention

Generally, one hexadecimal symbol (0,..,9, A,..,F) corresponds to four succeeding code-chips. The leftmost code-chip corresponds to the first code-chip in time, and the rightmost code-chip corresponds to the last code-chip in time. The first group is built with the first four code-chips, the second group with the fifth to eighth code-chip etc.

For primary codes whose length is not divisible by four, the last hexadecimal symbol is built from the last group of code-chips, filled up with zeros at the end in time (to the right) to reach a final length of 4 binary symbols. The translation from the chip-stream to hexadecimal symbol stream is illustrated with an example code of length 10 in Table 107.

Table 107: Example for the Translation of Logical (binary) Spreading Code into Hexadecimal Representation
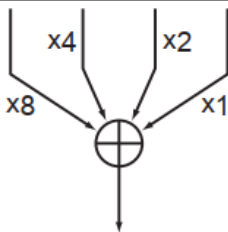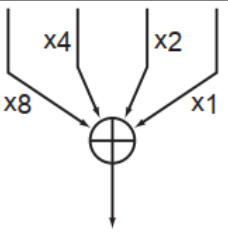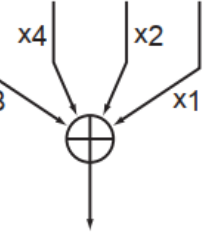
Time (in Chip)	1	2	3	4	5	6	7	8	9	10	11	12
Logic Representation of Chip-Values	1	1	1	0	1	1	0	0	0	1	-	-
Logic Representation Filled up with Zeros at the End	1	1	1	0	1	1	0	0	0	1	0	0
Logic to Decimal Translation												
Decimal Representation	14				12				4			
Hexadecimal Representation	E				C				4			

Table 108: Primary Code-Length and Hexadecimal Representation Characteristics for the Galileo Signal Components

Component	Primary Code Length (chips)	Number of Hexadecimal Symbols	Number of Filled up Zeros	Number of Defined Codes
E5a-I	10230	2558	2	50
E5a-Q	10230	2558	2	50
E5b-I	10230	2558	2	50
E5b-Q	10230	2558	2	50
E5a-QP	330	83	2	40
E1-B	4092	1023	0	50
E1-C	4092	1023	0	50

C.3. to C9. Primary Codes

The primary codes can be accessed/saved from the attachments panel of the pdf file reader.

This appendix provides input and output numerical examples for the convolutional encoding described in Section 4.1.4.1 and for the subsequent interleaving described in Section 4.1.4.2. The same examples can be applied to a decoder and a de-interleaver, by simply using them in the reverse order.

In this annex two examples are provided, namely one for F/NAV and one for I/NAV. The only difference between the two is the size of the block interleaver, as the same convolutional coding is employed for both messages.

D.1. F/NAV FEC Coding and Interleaving Numerical Example

Let the input to the convolutional encoder, M_{input}^{FNAV}, be the following 244-bit binary string:

```
11111111  11110000  11001100  10101010  00000000  00001111  00110011  01010101
11100011  11101100  11011111  10001010  00011100  00010011  00100000  01110101
01010101  01100001  01100010  01100011  10101010  10011110  10011101  10011100
00011100  00100011  00001101  00111001  11011100  11101100  0000
```

Note that the last six bits of the string M_{input}^{FNAV} are 6 zeros, corresponding to the tail bits described in Section 4.2.2.2.

The output of the convolutional encoder (described in Table 26 and Figure 13 within Section 4.1.4.1), $M_{encoded}^{FNAV}$, is the following 488-symbol binary string:

```
10001100  00011010  10101010  01110011  00110001  01011010  01101111  01011001
01111000  10010101  01010101  10001100  11001110  10100101  10010000  10100110
10000100  00000010  00000010  00011011  10011001  11101011  01011100  00011000
10111011  11111101  11111101  11100100  01100110  00010100  10100011  11100111
10100110  01100110  01101011  00010000  00011100  00011101  01010001  10101110
00111001  11101001  10010100  11101111  11100011  11100010  10101110  01010001
11111101  00111101  11110000  10101001  11011000  00110010  00111111  10000100
10010010  10010110  00100100  10101011  01001110
```

The encoded symbols of the string $M_{encoded}^{FNAV}$ are given as input to the F/NAV block interleaver described in Table 27 within Section 4.1.4.2, characterised by 61 columns and 8 rows. The output of the interleaver, $M_{interleaved}^{FNAV}$, is the following 488-symbol binary string:

```
10100000  01011111  10001100  11110011  10000001  01111110  10111001  11010000
10111101  01000000  00110011  11001011  00010010  11101101  01000000  01001110
10100001  01000001  00111110  11111000  01110111  10111101  10001100  10111011
11000100  00110111  11001000  00111101  01000011  11011101  10001110  01111001
10000001  11111110  00000010  11011101  00101101  10100001  11000001  00111110
11000001  00111110  11100110  10011001  01100001  10110101  11011000  00100101
11010010  00101111  10000100  01111000  00011011  01100011  01101100  10000011
10011100  01100100  11011011  00111010  01000010
```

D.2. I/NAV FEC Coding and Interleaving Numerical Example

Let the input to the convolutional encoder, M_{input}^{INAV} ,be the following 120-bit binary string:

11111111 11110000 11001100 10101010 00000000 00001111 00110011 01010101

11100011 11101100 11011111 10001010 00011100 00010011 01000000

Note that the last six bits of the string M_{input}^{INAV} are 6 zeros, corresponding to the tail bits described in Section 4.3.2.2.

The output of the convolutional encoder (described in Table 25 and Figure 13 within Section 4.1.4.1), $M_{encoded}^{INAV}$, is the following 240–symbol binary string:

10001100 00011010 10101010 01110011 00110001 01011010 01101111 01011001
01111000 10010101 01010101 10001100 11001110 10100101 10010000 10100110
10000100 00000010 00000010 00011011 10011001 11101011 01011100 00011000
10111011 11111101 11111101 11100100 01010011 00100010

The encoded symbols of the string $M_{encoded}^{INAV}$ are given as input to the I/NAV block interleaver described in Table 27 within Section 4.1.4.2, characterised by 30 columns and 8 rows. The output of the interleaver, $M_{interleaved}^{INAV}$, is the following 240-symbol binary string:

10100000 01011111 10001100 11110000 01011110 10100000 00011001 11100011
10101000 01010000 01001111 01010111 01111000 10000110 11111010 11100111
10011000 00011111 11100010 00001001 11110110 00001001 11000111 01100000
10010111 01001000 11000110 11011001 00000111 00111010

Reference Algorithm for Exploitation of FEC2 Reed-Solomon Words

In order to recover the I/NAV clock and ephemeris data from unaltered CED words (I/NAV words 1-4) and/or FEC2 RS CED parity words (I/NAV words 17-20), the following simplified example algorithm may be used by the user receiver:
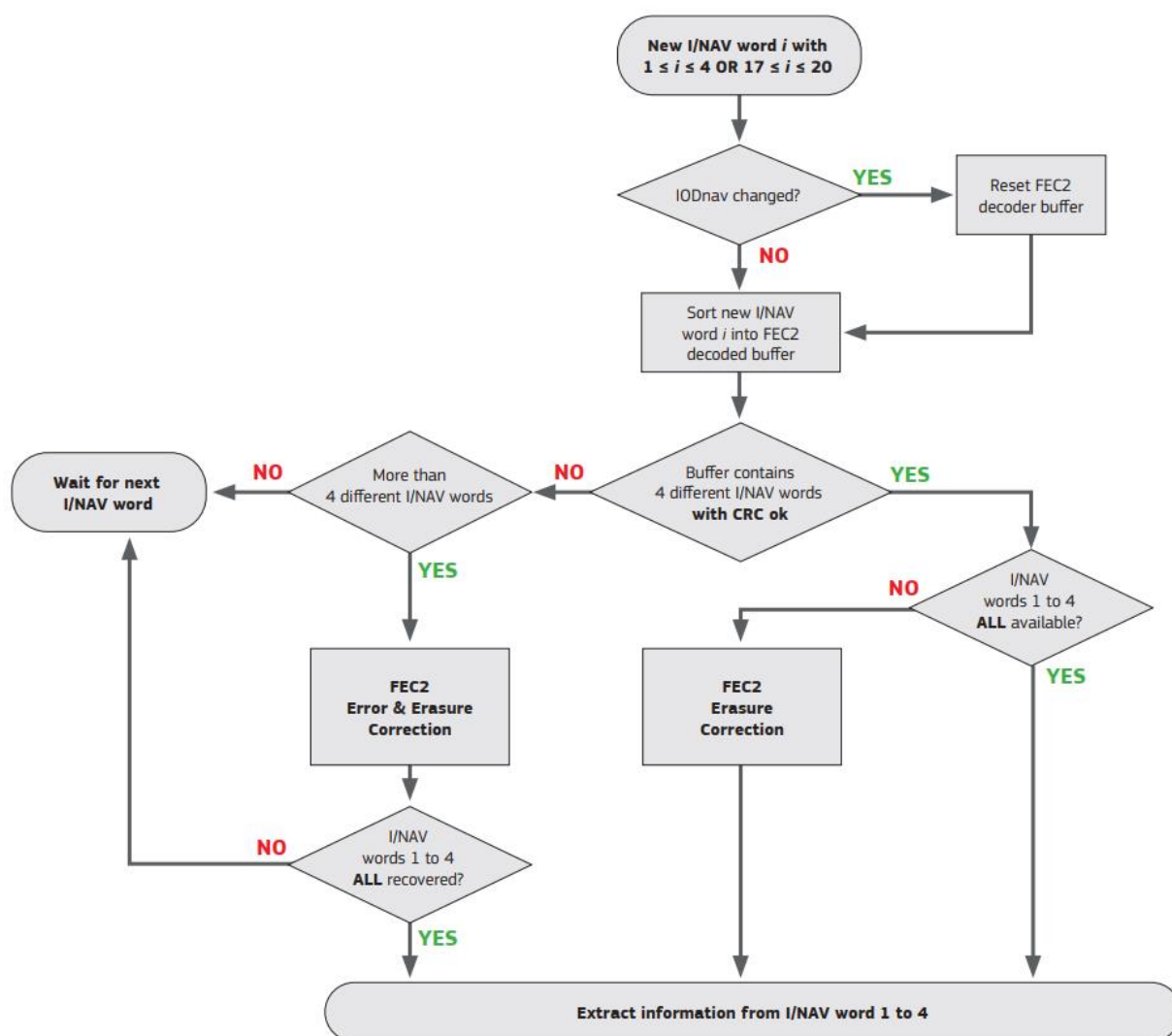

Figure 22: Reference algorithm for exploitation of the FEC2 RS CED words

The octets $C_{0,0}$ and $C_{0,1}$ of the FEC2 RS information vector (see section 5.1.13) contain information that is either pre-defined (i.e. word type value for I/NAV word type 1) or known from repeated transmission in other CED or FEC2 RS CED words (i.e. IODnav value). This known or repeated information can be used to verify correctness of the FEC2 Reed-Solomon erasure and error correction (sanity check).

Specification of the Outer FEC2 Reed-Solomon Encoding of CED in the Galileo E1 I/NAV Message

F.1. Introduction

This annex provides the definition of the Galois field, the generator polynomial and the generator matrix used for FEC2 Reed-Solomon coding of I/NAV clock and ephemeris data (CED), transmitted in the Galileo I/NAV words 17, 18, 19 and 20.

F.2. Galois Field

The FEC2 Reed-Solomon is based on a Galois field of order 256, GF(256), defined by the primitive polynomial

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The resulting Galois field elements in polynomial representation, octet representation (binary and integer), and in α^n representation with primitive element α are provided in the following table:

Table 109: Polynomial, octet and power representation of GF(256) using $p(x)=x^8+x^4+x^3+x^2+1$

Polynomial representation	Octet representation	Octet representation (integer)	Power representation α^n
0	00000000	0	$0 = \alpha^{-\infty}$
1	00000001	1	$1 = a^0$
α	00000010	2	α
a^2	00000100	4	a^2
a^3	00001000	8	a^3
a^4	00010000	16	a^4
a^5	00100000	32	a^5
a^6	01000000	64	a^6
a^7	10000000	128	a^7
$a^4+a^3+a^2+1$	00011101	29	a^8
$a^5+a^4+a^3+a$	00111010	58	a^9
$a^6+a^5+a^4+a^2$	01110100	116	a^{10}
$a^7+a^6+a^5+a^3$	11101000	232	a^{11}
$a^7+a^6+a^3+a^2+1$	11001101	205	a^{12}
a^7+a^2+a+1	10000111	135	a^{13}
$\alpha^4+\alpha+1$	00010011	19	a^{14}

Polynomial representation	Octet representation	Octet representation (integer)	Power representation α^n
$\vdots$	$\vdots$	$\vdots$	$\vdots$
$\alpha^4+\alpha^2+\alpha$	00010110	22	a^{239}
$a^5+a^4+a^2$	00101100	44	a^{240}
$\alpha^6+\alpha^4+\alpha^3$	01011000	88	α^{241}
$a^7+a^5+a^4$	10110000	176	a^{242}
$a^6+a^5+a^4+a^3+a^2+1$	01111101	125	a^{243}
$a^7+a^6+a^5+a^4+a^3+a$	11111010	250	a^{244}
$a^7+a^6+a^5+a^3+1$	11101001	233	a^{245}
$a^7+a^6+a^3+a^2+a+1$	11001111	207	a^{246}
$\alpha^7+\alpha+1$	10000011	131	a^{247}
a^4+a^3+a+1	00011011	27	a^{248}
$a^5+a^4+a^2+a$	00110110	54	a^{249}
$a^6+a^5+a^3+a^2$	01101100	108	a^{250}
$a^7+a^6+a^4+a^3$	11011000	216	a^{251}
$a^7+a^5+a^3+a^2+1$	10101101	173	a^{252}
a^6+a^2+a+1	01000111	71	a^{253}
$a^7+a^3+a^2+a$	10001110	142	a^{254}

F.3. FEC2 Reed-Solomon Generator Polynomial and Generator Matrix

F.3.1 The Shortened Reed-Solomon Code

The Reed-Solomon code used as outer code for Clock and Ephemeris Data in the Galileo E1 I/NAV message is a shortened version of an (n, k, d) linear code, where

- the unshortened code vector length is $n = 2^m - 1 = q - 1 = 255$,

- the unshortened information vector length is $k = 195$

- and the minimum Hamming distance is $d = n - k + 1 = 61$.

A code vector is shortened by setting s symbols of the information vector to the zero element of the underlying GF(256).

The resulting shortened code is (n_s, k_s, d) = (n-s, k-s, d).

The message to be transmitted consists of $k_s = 58$ octets $c_0, c_1, …, c_{57}$.

Since the number of required parity octets is $n_s - k_s = 60$, the shortened code vector

has a length of $n_s = k_s + 60 = 58 + 60 = 118$ and the shortening parameter is determined as $s = n - n_s = 255 - 118 = 137$. The shortened code is $(n_s,\ k_s,\ d) = (118, 58, 61)$.

F.3.2 Generator Polynomial

The foreseen Reed-Solomon code is a narrow sense code over GF(256) with primitive element α. The corresponding generator polynomial in the indeterminate x is:

$$g(x) = \prod_{i=1}^{n_S - k_S} (x - \alpha^i) = \sum_{j=0}^{60} g_j \cdot x^j = \alpha^{45} + \alpha^{92}x + \alpha^{65}x^2 + \cdots + \alpha^{108}x^{59} + x^{60}$$

The resulting coefficients g_j of the polynomial are tabularised below, using integer octet representation:

Table 110: Integer octet representation of the coefficients of the generator polynomial

j	g_j	j	g_j	j	g_j	j	g_j
0	193	15	23	30	66	45	251
1	91	16	36	31	46	46	124
2	190	17	202	32	131	47	18
3	154	18	63	33	42	48	186
4	101	19	20	34	187	49	244
5	58	20	102	35	9	50	166
6	231	21	230	36	122	51	235
7	197	22	131	37	3	52	167
8	152	23	141	38	19	53	108
9	88	24	214	39	118	54	41
10	73	25	45	40	6	55	19
11	62	26	101	41	154	56	76
12	169	27	94	42	14	57	48
13	88	28	62	43	193	58	42
14	188	29	65	44	79	59	208
						60	1

F.3.3 Systematic Encoding Using the Reed-Solomon Generator Polynomial

The zero-padded information vector $\tilde{c}$:

$$\tilde{c}^T = [\ \tilde{c}_0, \tilde{c}_1, \tilde{c}_2, \ldots, \tilde{c}_{194}\ ] = [c_0, c_1, c_2, \ldots, c_{57}, \underbrace{0, \ldots, 0}_{137\ \text{zeros}}\ ]$$

can be represented in polynomial form by:

$$\tilde{c}(x) = \sum_{j-0}^{194} \tilde{c}_j \cdot x^j = \tilde{c}_0 + \tilde{c}_1 \cdot x + \tilde{c}_2 \cdot x^2 + \cdots + \tilde{c}_{194} \cdot x^{194}$$

Where the coefficients $\tilde{c}_{58}$ to $\tilde{c}_{194}$ are set to zero. The coefficients c_0, c_1, ..., c_{57} form the shortened RS information vector $\boldsymbol{c}$:

$$\boldsymbol{c}^T = [\, c_0, c_1, c_2, \ldots, c_{57} \,]$$

The unshortened RS code vector $\tilde{\boldsymbol{\Gamma}}$ is obtained from $\tilde{c}(x)$ and $g(x)$ as:

$$\tilde{\boldsymbol{\Gamma}}(x) = \tilde{\boldsymbol{c}}(x) \cdot x^{n-k} - R_{g(x)} [\, \tilde{\boldsymbol{c}}(x) \cdot x^{n-k} \,]$$
$$= \sum_{j=0}^{254} \tilde{\Gamma}_j \cdot x^j = \tilde{\Gamma}_0 + \tilde{\Gamma}_1 \cdot x + \tilde{\Gamma}_2 \cdot x^2 + \cdots + \tilde{\Gamma}_{254} \cdot x^{254}$$
$$= \gamma_0 + \gamma_1 \cdot x + \cdots + \gamma_{59} \cdot x^{59} + c_0 \cdot x^{60} + c_1 \cdot x^{61} + \cdots + c_{57} \cdot x^{117}$$

where the coefficients $\tilde{\Gamma}_{118}$ to $\tilde{\Gamma}_{254}$ equal zero and are omitted during transmission. The function $R_{g(x)}[f(x)]$ denotes the remainder of the polynomial division $\frac{f(x)}{g(x)}$ and the coefficients γ and c denote parity symbols and information symbols, respectively.

The (shortened) RS code vector $\boldsymbol{\Gamma}$ therefore consists of the non-zero information part and the parity part of $\tilde{\boldsymbol{\Gamma}}$ in exchanged order, i.e.: information part first and parity part second:

$$\boldsymbol{\Gamma}^T = [\, \Gamma_0, \Gamma_1, \ldots, \Gamma_{117} \,] = [\, \tilde{\Gamma}_{60}, \tilde{\Gamma}_{61}, \ldots, \tilde{\Gamma}_{117}, \tilde{\Gamma}_0, \tilde{\Gamma}_1, \ldots, \tilde{\Gamma}_{59} \,] = [\, c_0, c_1, c_2, \ldots, c_{57}, \gamma_0, \gamma_1, \ldots, \gamma_{59} \,]$$

Only the shortened RS code vector is broadcast.

F.3.4 Systematic Encoding Using the RS Generator Matrix

Since RS codes are linear, the encoding can be equivalently expressed as matrix-vector multiplication in the respective Galois field. The following formulation of the encoding directly yields the shortened RS code vector in the required indexing order.

The unshortened RS code vector $\tilde{\boldsymbol{\Gamma}}$ as per section F.3 consists of 255 octets, the first 60 octets being the parity part γ.

The remaining 195 octets are the unshortened information vector $\tilde{c}$, whose first 58 octets then form the shortened RS information vector c (Figure 23a).

Extracting the nonzero part of $\tilde{\boldsymbol{\Gamma}}$, and swapping its components γ and c, then yields the desired form of the shortened RS code vector $\boldsymbol{\Gamma}$ (Figure 23b).
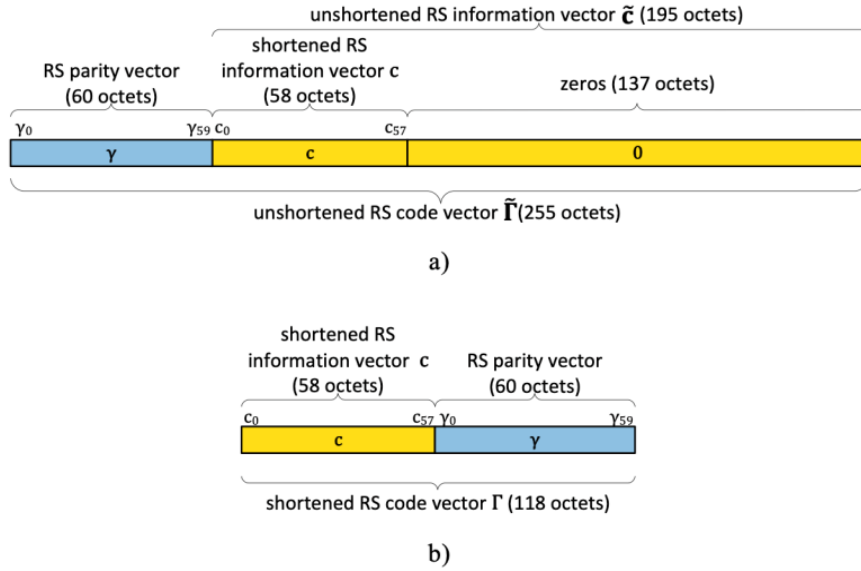
Figure 23: Shortening of the systematic RS code vector
(symbol allocation for polynomial encoding)

The shortened code vector $\mathbf{\Gamma}$ as per figure 23 can be computed through a GF(256) matrix multiplication of the shortened RS information vector c with the systematic generator matrix $\mathbf{G}$:

$$\mathbf{\Gamma} = \mathbf{G} \cdot \mathbf{c}$$

or more explicitly:

$$\mathbf{\Gamma} = \begin{pmatrix} \Gamma_0 \\ \Gamma_1 \\ \dots \\ \Gamma_{117} \end{pmatrix} = \begin{pmatrix} c_0 \\ c_1 \\ \dots \\ c_{57} \\ \gamma_0 \\ \gamma_1 \\ \dots \\ \gamma_{59} \end{pmatrix} = \begin{pmatrix} \boldsymbol{c} \\ \boldsymbol{\gamma} \end{pmatrix} = \mathbf{G} \cdot \mathbf{c} = \begin{pmatrix} \mathbf{I} \\ \mathbf{P} \end{pmatrix} \cdot \begin{pmatrix} c_0 \\ c_1 \\ \dots \\ c_{57} \end{pmatrix}$$

The systematic generator matrix $\mathbf{G}$ consists of 118 rows and 58 columns and can be split into two submatrices $\mathbf{I}$ and $\mathbf{P}$, where $\mathbf{I}$ is the identity matrix of size 58x58 and $\mathbf{P}$ is a dense submatrix of size 60x58 which produces the parity part of the code vector, i.e. the RS parity vector γ:

$$\mathbf{G} = \begin{pmatrix} 1 & 0 & 0 & \dots & 0 \\ 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 1 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & 1 \\ g_{58,0} & g_{58,1} & g_{58,2} & \cdots & g_{58,57} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ g_{117,0} & g_{117,1} & g_{117,2} & \cdots & g_{117,57} \end{pmatrix}$$

The PDF version of this ICD provides the generator matrix $\mathbf{G}$ as a file attachment, as comma separated values in octet representation as per table 90.

F.4. Further Notes on FEC2 Reed Solomon Implementations

F.4.1 Encoding Example

This section provides an example FEC2 Reed Solomon encoding, to support implementers of the above algorithms in the verification of their implementation. The sample information vector (see attached csv file)

$$c^T = [147, 109, 66, 23, …, 162]$$

which contains randomly generated Galois field symbols is encoded via the encoding algorithms described in the previous sections F.3.3 or F.3.4 and yields the shortened RS code vector (see attached csv file):

$$\Gamma^T = [147, 109, 66, 23, …, 162, 238, 77, 12, 72, …, 242]$$

The PDF version of this ICD provides the complete encoding example as file attachments, comma separated values in octet representation.

F.4.2 Implementation Pitfalls

When implementing the RS coding, special care has to be taken concerning the order of the polynomial powers in the respective implementation environment. For example, when using the polynomial representation and an implementation with descending powers, the polynomial coefficients of the information polynomial need to be provided to the encoding function in the reverse order.

Example: if the coded output sequence reads:

$$[147, 109, 66, 23, …, 162, 0, 248, 29, 36, …, 7]$$

instead of the correct coded sequence:

$$[147, 109, 66, 23, …, 162, 238, 77, 12, 72, …, 242]$$

this is an indication that the implementation uses descending powers, i.e. the information vector is interpreted as:

$$[c_{57}, c_{56}, c_{55}, c_{54}, …, c_0]^T$$

instead of:

$$c^T = [c_0, c_1, c_2, …, c_{57}]$$

Therefore, the input sequence needs to be reversed:

$$[c_{57}, c_{56}, c_{55}, c_{54}, …, c_0] = [162, 215, 199, 67, …, 147]$$

Accordingly, the output sequence should then be in the following order:

$$[c_{57}, c_{56}, c_{55}, c_{54}, …, c_0, \gamma_{59}, \gamma_{58}, \gamma_{57}, \gamma_{56}, …, \gamma_0]$$
$$= [162, 215, 199, 67, …, 147, 242, 137, 76, 212, …, 238]$$

Nevertheless, the ordering of the information and parity octets as described and depicted above in Figure 23b) must be restored before further processing and embedding the octets into the (RS) CED words.

This annex provides one numerical example for the 32-bits checksum computation of the ARAIM Integrity Support Message described in Section 5.2.2. Let the input to the ISM CRC computation be an ISM Test Message on I/NAV E1-B (Type = 22, GNSS Constellation ID = 0), where the exemplary "Reserved" ISM content is bit sequence of alternating zeros and ones, starting and ending and with zero:

Table 111: Exemplary ISM Test Message as input to ISM CRC computation

Type = 010110	GNSS Constellation ID = 000	**ISM Test Message Example**	Total (bits)
		Exemplary "Reserved" Sequence = 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 010	
Bits 1…6	Bits 7…9	Bits 10…96	96

The resulting 32-bits sequence for the ISM CRC computed on the input data as per Table 112 is shown hereafter:

Table 112: ISM CRC 32-bits sequence for the exemplary ISM Test Message

ISM CRC = 1011 0010 1111 0100 1101 0110 1010 1111	Total (bits)
Bits 1…32	32

The bit ordering criteria is as specified in Section 4.1.3.

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c) any third party's prior rights to use the OS SIS ICD IPRs and/or to enjoin the activities that benefit from the Authorisation;

d) the dependency of the OS SIS ICD IPRs on third parties' intellectual or industrial property rights;

e) the merchantability or fitness for a particular purpose of the OS SIS ICD IPRs and/or the Products.

To the full extent allowed by law, all warranties, whether expressed or implied, for any use of OS SIS ICD IPRs or related to the Products, including on product liability, are excluded, and the EU shall not be held liable for any claim or damage related thereto, being asserted by the Authorised Person or any third party with respect to the activities of the Authorised Person under the Authorisation.

H.7. Infringements by Third Parties

The EU shall have the discretionary right and faculty to decide whether or not to bring an action for any infringements of the OS SIS ICD IPRs in the case where a third party does not benefit from the Authorisation, even where the EU has been duly informed about such alleged infringement by the Authorised Person. The EU shall have no obligation whatsoever to bring such an action nor to notify any decision thereto to the Authorised Person.

H.8. Action for Infringement Brought by Third Parties

The Authorised Person shall defend itself and at its own expenses, and bear all the consequences, including the payment of damages and attorney fees, against any claim, suit or proceeding made or brought against the Authorised Person and arising from its activities under the Authorisation, including any claim, suit or proceeding for infringement of third parties' rights as a result of the Authorised Person's practice, use or copy of the OS SIS ICD IPRs or commercialisation of Products. The Authorised Person shall notify the EU without undue delay about any such claim, suit or proceeding. The EU may, at its sole discretion, agree to provide the Authorised Person with any assistance which the EU considers to be appropriate, but the EU shall not in any way be obliged to do so. If the EU decides to defend either the Authorised Person or the OS SIS ICD IPRs, the Authorised Person shall collaborate with the EU and provide the EU with all the assistance necessary to such defence.

H.9. Permits

The necessary steps for obtaining all permits and licences required for the activities under the Authorisation, under the laws and regulations in force at the place where said activities of the Authorised Person are provided or to be provided, shall be the exclusive responsibility of the Authorised Person.

H.10. Applicable Law and Dispute Resolution

The Authorisation shall be governed by European Union law, complemented where necessary by the law of Belgium.

Except for the right of the EU and/or the Authorised Person to apply to a court of competent jurisdiction for a temporary restraining order or a preliminary injunction to prevent irreparable harm, any dispute, controversy or claim arising under, out of or relating to the Authorisation and any subsequent amendments thereof, including, without limitation, its validity, binding effect, interpretation, performance, breach or termination shall be submitted to mediation in accordance with the WIPO Mediation Rules. The place of mediation shall be Brussels. The language to be used in the mediation shall be English.

If, and to the extent that, any such dispute, controversy or claim has not been settled pursuant to the mediation within sixty (60) days of the commencement of the mediation, it shall, upon filing of a Request for Arbitration by either the EU or the Authorised Person, be referred to and finally determined by arbitration in accordance with the WIPO Expedited Arbitration Rules. Alternatively, if, before the expiration of said period of sixty (60) days, either the EU or the Authorised Person fails to participate or to continue to participate in the mediation, the dispute, controversy or claim shall, upon the filing of a Request for Arbitration by the participating EU or Authorised Person, be referred to and finally determined by arbitration in accordance with the WIPO Expedited Arbitration Rules. The arbitral tribunal shall consist of three arbitrators. The place of arbitration shall be Brussels. The language used in the arbitration proceedings shall be English.

In any action to enforce the Authorisation, the prevailing entity shall be entitled to recover its reasonable attorney's fees, court costs and related expenses from the other entity.

H.11. Miscellaneous

The provisions of the Authorisation are severable in the sense that the invalidity or unenforceability of any provision of the Authorisation that is not fundamental to its performance shall not affect the validity and/or enforceability of the remaining provisions hereof. Such invalidity or unenforceability of such non-fundamental provision shall not relieve the Authorised Person of its obligations under the remaining provisions of the Authorisation.

This Authorisation fully and exclusively states the scope of the authorisation concerning the OS SIS ICD IPRs that the EU wishes to issue.

The EU reserves the exclusive right to amend the Authorisation upon due public notice.

The fact that the Authorisation is self-executing and that the EU requires no signature of the Authorisation shall not be considered a waiver and shall have no effect on the binding character of the terms, conditions and limitations of the Authorisation upon the practice, use or copy of the OS SIS ICD IPRs by the Authorised Person.

H.12. List of IPRs

The IPRs listed in the following table are an integral part of the Authorisation.

	IPR	Name of IPR	Application Number	Date of filing	Applicant	Owner	Designated Countries
1	Patent	Multi-band antenna for satellite positioning system	PCT/EP2006/064067	10/07/2006	GSA	EU	Australia Canada Norway USA China India Japan Russia
2	Patent	Method for providing assistance data to a mobile station of a satellite positioning system	PCT/EP2006/068177	07/11/2006	GSA	EU	Australia Canada USA S.Korea China India Japan Russia Europe designated countries: (AT, BE, CH, CZ, DE, DK, ES, FI, FR, GR, HU, IE, ITLU, NL, PL, PT, RO, SE, TR, GB)
3	Patent	Chaotic spreading codes and their generation	PCT/EP2007/063080	30/11/2007	GSA	EU	Australia Brazil Canada China India Japan S.Korea Russia USA Europe designated countries: (AT, BE, CH, CZ, DE, DK, ES, FI, FR, GR, HU, IE, IT, LI, LU, MT, NL, PL, PT, RO, SE, TR, GB)
4	Copyright	OS SIS ICD	NA	NA	NA	EU	Worldwide
5	Patent	Spreading codes for a satellite navigation system (concerning memory codes)	PCT/EP2004/014488	17/12/2004	ESA	EU	Brazil
6	Patent	Spreading codes for a satellite navigation system (concerning secondary Codes)	PCT/EP2005/007235	01/07/2005	ESA	EU	Brazil
7	Patent	Method and device for generating a constant envelope navigation signal with four independent codes	PCT/FR2003/003695	12/12/2003	CENTRE NAT ETD SPATIALES (CNES)	Control by the EU under licence from CNES	USA Europe designated countries (AT, BE, CH, DE, ES, FR, GR, IT, LI, SE, TR, GB)

	IPR	Name of IPR	Application Number	Date of filing	Applicant	Owner	Designated Countries
8	Patent	Spread spectrum signal	PCT/EP2006/050179	12/01/2006	CNES	Control by the EU under licence from CNES	Canada China Japan Russia USA India Europe designated countries (AT, BE, CH, CZ, DE, EE, ES, FI, FR, IT, LI, LT, LV, PL, PT, SE, GB)
9	Patent	GNSS radio signal with an improved navigation message	PCT/EP2013/064477	09/07/2013	CNES	Control by the EU under licence from CNES	Japan USA Europe designated countries (BE, CH, DE, FR, IE, LI, LU, GB)
10	Patent	GNSS radio signal for improved synchronisation	PCT/EP2013/064573	10/07/2013	CNES	Control by the EU under licence from CNES	Japan USA Europe designated countries (DE, FR, TR, GB)
11	Patent	Modulation signals for a satellite navigation system	PCT/GB2004/003745	01/09/2004	Secretary of State for Defence of the UK	Control by the EU under licence from the Secretary of State for Defence of the UK	Australia Canada China India Japan New Zealand Russia USA Europe designated countries (BE, DE, DK, ES, FI, FR, IT, NL, SE, GB)
12	Patent	Signals, system, method and apparatus	PCT/GB2007/002293	20/06/07	Secretary of State for Defence of the UK	Control by the EU under licence from the Secretary of State for Defence of the UK	Australia Brazil Canada China Israel India Japan Republic of Korea Malaysia Norway New Zealand Russia Singapore USA Europe designated countries (BE, CZ, DE, DK, ES, FI, FR, HU, IT, NL, PT, SE, SK, GB)

	IPR	Name of IPR	Application Number	Date of filing	Applicant	Owner	Designated Countries
13	Patent Application	Techniques for Transmitting and Receiving GNSS Navigation Messages	16174636.7	15/06/16	Airbus Defence and Space GmbH	Control by the EU under licence from Airbus Defence and Space GmbH	EU (Pending)
14	Patent Application	Techniques for Transmitting and Receiving GNSS Navigation Messages	PCT/EP2017/064120	09/06/17	Airbus Defence and Space GmbH	Control by the EU under licence from Airbus Defence and Space GmbH	USA, China, Japan (Pending)

Annex I   Galileo PRN Codes Assignment

Many radio-navigation systems seek a high level of interoperability with Galileo, including the use of PRN codes from the spreading code families developed for Galileo.

The PRN codes defined in this ICD are reserved exclusively for use by the Galileo satellites. Additional sets of PRN codes have been defined and are available for possible use by cooperating radio-navigation systems. Codes out of the following families are available at this scope:

- E1-B and E1-C

- E6-B and E6-C

- E5a-I, E5a-Q, E5b-I and E5b-Q

A dedicated policy has been defined, detailing the process for getting assigned one or more of those codes. Following such process, a formal request for a PRN code can be initiated by means of an "*Application for PRN Code Assignment*". If the criteria defined in the above-mentioned policy are satisfied, the requested PRN code(s) will be assigned to the applicant for a specific duration and under the conditions described in the above-mentioned policy.

All pertinent documentation, including the assignment policy and the application form, are available under European GNSS Service Centre portal:

https://www.gsc-europa.eu/

At the same URL the full list of PRN codes assigned to external entities is also made available, including a reference to the applicable Interface Control Document.

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