SPECIFICATION FOR SECOND-GENERATION COSPAS-SARSAT 406-MHz DISTRESS BEACONS

C/S T.018
Issue 1 – Revision 1
May 2017

SPECIFICATION FOR SECOND-GENERATION COSPAS-SARSAT 406-MHz DISTRESS BEACONS

History

Issue	Revision	Date	Comments
1	-	December 2016	Approved by CSC-57
1	1	May 2017	Approved by CSC-58

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1.   INTRODUCTION

1.1   Purpose

The purpose of this document is to define the minimum requirements to be used for the development and manufacture of Second Generation 406 MHz Emergency Locator Transmitters (ELTs), Emergency Position-Indicating Radio Beacons (EPIRBs), and Personal Locator Beacons (PLBs). In this document, the term ELT indicates an aviation distress beacon, an EPIRB a maritime distress beacon, and a PLB a distress beacon for personal use.

Specifications that are critical to the Cospas-Sarsat System are defined in detail. Specifications which could be developed by the national authorities are identified in more general terms.

1.2   Scope

This document contains the minimum requirements that apply to Cospas-Sarsat 406 MHz distress beacons. It is divided into the following sections:

a) Section 2 gives the technical requirements applicable to all types of beacons. When met, these requirements will enable the beacons to provide the intended service in terms of location probability and accuracy and will not disturb the system operation.

b) Section 3 deals with the beacon message content. Basic message structure as well as the assignment and meaning of the available data bits are defined in this section.

c) Section 4 defines a set of environmental and operational requirements. These requirements are not intended to be exhaustive and may be complemented by more detailed national or international standards (e.g., RTCA standards for ELTs). However, they represent the minimum environmental and operational performance requirements for a 406 MHz beacon to be compatible with the Cospas-Sarsat System.

d) Appendix 1 provides a list of acronyms used in this document.

e) Appendix 2 provides a sample Bose-Chaudhuri-Hocquenghem error-correcting code calculation.

f) Appendix 3 provides an example of beacon encoded location coding.

g) Appendix 4 provides a map of the BIT assignment numbers.

1.3   Type of Beacon

There are four different types of Cospas-Sarsat 406 MHz beacons; Emergency Locator Transmitters (ELTs), Emergency Position Indicating Radio Beacons (EPIRBs), Personal Locator Beacons (PLBs) and Ship Security Alert System (SSAS) Beacons. This standard does not address requirements for Second Generation SSAS Beacons.

In addition to the four different types of beacon there are up to three Classes of operating temperature range for 406 MHz beacons as follows:

Class 0:	-55°C to +70°C
Class 1:	-40°C to +55°C
Class 2:	-20°C to +55°C

Any type of beacon can be supplied with a Class 0, Class 1 or Class 2 operating temperature range.

Unless otherwise stated herein this specification applies to all types and classes of 406 MHz beacons identified in this section apart from SSAS beacons.

Emergency Locator Transmitters (ELTs)

Are designed for aviation distress purposes and are available as the following types; Automatic Fixed (ELT (AF)), Automatic Portable (ELT (AP)), Survival (ELT (S)), Automatic Deployable (ELT (AD)), and Distress Tracking ELT (ELT (DT)).

Automatic Fixed (ELT (AF))

This type of ELT is intended to be permanently attached to the aircraft before and after a crash and is designed to aid SAR teams in locating a crash site.

Automatic Portable (ELT (AP))

This type of ELT is intended to be rigidly attached to the aircraft before a crash, but readily removable from the aircraft after a crash. It functions as an ELT (AF) during the crash sequence. If the ELT does not employ an integral antenna, the aircraft-mounted antenna may be disconnected and an auxiliary antenna connected in its place. This type of ELT is intended to aid SAR teams in locating the crash site or survivor(s).

Survival (ELT (S))

This type of ELT is intended to survive the crash forces, and then to be generally manually activated by survivors. There are two sub classes of ELT(S) Class A which is buoyant and designed to operate when floating in water and Class B which is non buoyant and may be manually or automatically activated. This type of ELT is intended to aid SAR teams in locating survivor(s).

Automatic Deployable (ELT(AD))

This type of ELT is intended to be rigidly attached to the aircraft before a crash and automatically deployed after the crash sensor has determined that a crash has occurred. This type of ELT shall float in water and is intended to aid SAR teams in locating the crash site.

Distress Tracking (ELT (DT))

This is a specific type of ELT designed to be activated prior to a crash and to function in compliance with the ICAO GADSS[*] requirements for the Location of an Aeroplane in Distress, aimed at establishing, to a reasonable extent, the location of an accident site within a 6 NM radius. It may be

---

[*] See ICAO Convention on International Civil Aviation Annex 6, Part 1.

activated automatically upon detection of a distress condition while in flight or it may also be activated manually.

Emergency Position Indicating Radio Beacons (EPIRBs)

Are designed for maritime distress purposes and are available as Float free and Non Float Free types of EPIRB.

Float Free EPIRB

This type of EPIRB is intended to float free of the vessel on which it is fitted if the vessel sinks, in which case it will automatically activate, it can also be manually activated.

Non Float Free EPIRB

This type of EPIRB is intended to be manually released from its mounting bracket and then either manually activated or dropped in the water so that it will then activate automatically. Some national administrations permit the use of manually activated EPIRBs only without the automatic activation in water feature.

Personal Locator Beacons (PLBs)

Are designed for use by persons in distress who may be on land, in the air or at sea.

1.4   Optional Features

Beacons may contain optional features that are defined in this specification.

Encoded location capability is optional, however in the case of ELT (DT) devices intended for in-flight automatic activation the inclusion of a GNSS capability is mandatory.

All types of beacons may also be provided with the Return Link Service capability.

All types of beacons may be provided with one or more additional radio-locating transmitters for Homing and On-scene Locating purposes.

1.5   Additional Features

Beacons may contain additional functionality that may change the transmitted 406 MHz satellite signal or affect other beacon parameters such as operating lifetime. For example, a beacon may contain a flashing strobe light that while it probably has no effect on the transmitted signal, would reduce the battery life.

Any additional functionality that is not defined in this specification shall not adversely degrade the performance of the beacon to the extent that it no longer complies with this specification.

- END OF SECTION 1 -

2.   TECHNICAL REQUIREMENTS

2.1   Beacon Functional Elements

This section defines requirements for the functional elements of spread-spectrum 406 MHz distress beacons.

2.1.1   Transmitter Notional Functional Block Diagram

This section contains a notional functional diagram which describes the features which are described in greater detail by later sections of this document.

Figure 2-1 illustrates a notional Direct Sequence Spread Spectrum - Offset QPSK (DSSS-OQPSK) high level transmitter functional block diagram which may be used to better understand one possible implementation of the beacon signal design. In this figure:

- $D(t)$ is the linear bit stream for each beacon burst running at 300 bits/second.

- $D(t)$ is split into parallel bit streams $Ib(t)$ and $Qb(t)$ made up of odd and even bits from $D(t)$ running at 150 bps each

- A Linear Feedback Shift Register (LFSR) function produces the two different chipping segments $Ci(t)$ and $Cq(t)$ using the common generator polynomial $G(X)$. Each chipping segment runs at 38,400 chips/second. Each of $Ci(t)$ and $Cq(t)$ is produced by the LFSR function using the specified unique I or Q channel LFSR initialization, and is reproduced identically for each beacon burst for a given beacon mode of operation.

- $Ib(t)$ and $Qb(t)$ are separately mixed with their respective different chipping segments. The resultant on each channel can change state every chip period.

- The resultant of the mixing on the Q component is then delayed by ½ chip period.

- Both I and Q channels may then be low pass filtered (if necessary) and modulated onto cosine and sine sinusoids.

- The two modulated sinusoids are then summed.

- The summation resultant is amplified, band pass filtered (if necessary), and then transmitted as the outgoing beacon burst signal $S(t)$.

Because the I and Q resultants are offset by ½ chip period from each other, when summed, the resulting signal $S(t)$ is bounded to a maximum phase shift of 90 degrees to help minimize amplitude envelope variation.
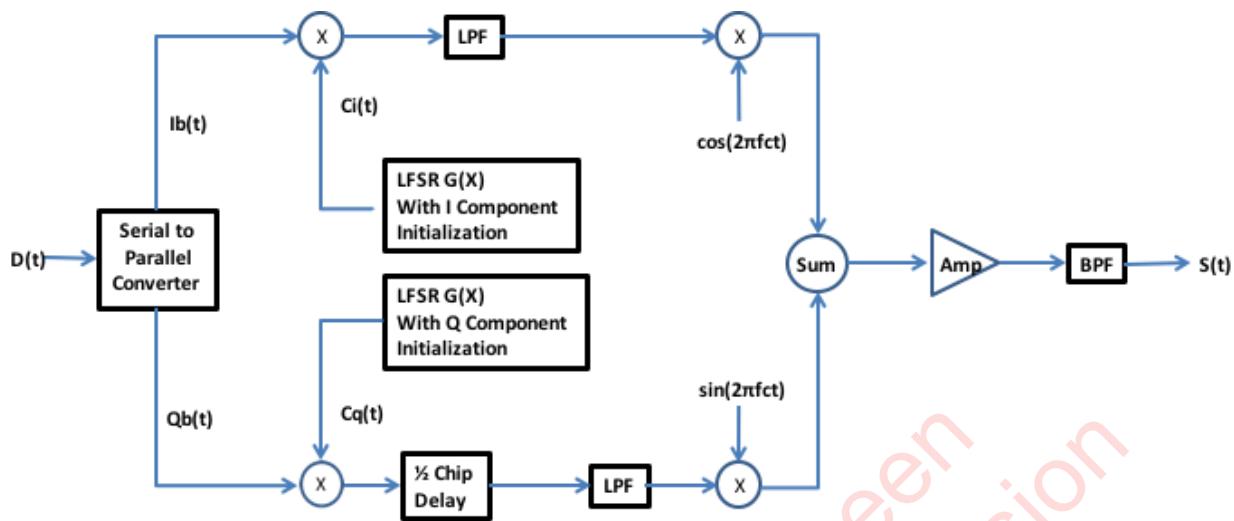
D(t) = digital message bit stream (300 bps)
Ib(t) = I component (odd) bit stream (150 bps)
Qb(t) = Q component (even) bit stream (150 bps)
LFSR = Linear Feedback Shift Register Function
G(x) = generator polynomial
Ci(t) = I component chipping stream generated by LFSR using I channel initialization (38,400 cps)
Cq(t) = Q component chipping stream generated by LFSR using Q channel initialization (38,400 cps)
fc = carrier frequency
LPF = low pass filter (if needed)
BPF = band pass filter (if needed)
S(t) = transmitted signal

Figure 2-1: Notional DSSS-OQPKS Transmitter Functional Block Diagram

2.2 Digital Message Generator

The digital message generator will key the modulator and transmitter so that the message defined in section 3 is transmitted. This section describes the structure of the proposed signal.

2.2.1 Repetition Period

From beacon activation a total of 6 initial transmissions shall be made separated by fixed $5s \pm 0.1s$ intervals. The first transmission shall commence within 3 seconds of beacon activation.

The beacon shall then transmit 59 bursts at nominally 30 second intervals. The repetition period between the start of two successive transmissions shall be randomised around the stated nominal value, so that intervals between successive transmissions are randomly distributed over ± 5 seconds.

Transmissions shall then occur at nominally 120 second intervals. The repetition period between the start of two successive transmissions shall be randomised around the stated nominal value, so that intervals between successive transmissions are randomly distributed over ± 5 seconds.

After the first 30 seconds ELT (DT) transmissions shall continue at intervals of 28.5 seconds until the end of the ELT (DT) operating lifetime. The repetition period between the start of two successive transmissions shall be randomised around the stated nominal value, so that intervals between successive transmissions are randomly distributed over ± 1.5 seconds.

The transmission schedule is summarised in the table below.

Table 2.1: Transmission Schedule

IAMSAR Stage	Time from Activation	Transmission Repetition Interval	Randomization
Initial	0 to 30 Seconds	5 Seconds	0
Action / Planning	30 seconds to 30 minutes	30 Seconds	± 5 seconds
	30 minutes +	120 Seconds	± 5 seconds
ELT (DT)	30 seconds +	28.5 Seconds	± 1.5 seconds

2.2.2 Total Transmission Time

The total transmission time of each burst, measured at the 90 percent power points, shall be 1000 ms ± 1 ms.

2.2.3 Direct Sequence Spread Spectrum

The digital message shall be spread using two truncated segments of a common PRN (Pseudo-Random Noise) maximum length sequence (m-sequence) producing symbols known as "chips". These sequence segments shall be deterministic and must be known by the receiver.

The two truncated spreading PRN segments shall:

a) be applied separately to the full duration of each beacon burst transmission with one segment applied to the in-phase (I) component and the other applied to the quadrature (Q) component of the signal;

b) be generated by a method equivalent to a Linear Feedback Shift Register (LFSR) using the same generator polynomial $G(x) = X23 + X18 + 1$ (see Figure 2-2);

c) be generated in matched pairs using the separate LFSR initialization values for the I and Q components defined in Table 2.2 for each beacon mode;

d) be truncated to the first 38,400 chips of the m-sequence generated using the prescribed initialization values for each of the I and Q components with a 1/2 chip period delay imposed on the Q component relative to the I component (refer to section 2.3.3);

e) be applied to both I and Q components for the full one second duration of each beacon burst transmission including preamble, information bits, and error correction bits, to give a chipping rate of 38,400 chips/second for each component (see 2.3.1.2 for further details); and

f) be identical for each beacon burst transmission for any given burst mode.

Note that this spreading scheme method in fact allows for multiple possible non-overlapping matched I and Q component chipping segment pairs, with each segment in each pair truncated to 38,400 chips. The number of possible segments, 218, is determined by dividing the full m-sequence length for the

generator polynomial, by the truncated segment length, $((2^{23})-1)/38,400 = 218$ segments. Non-overlapping pairs of segments can be selected from this set of 218 segments.
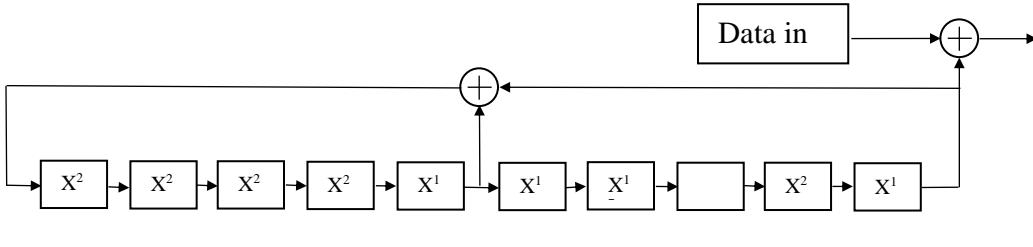
Linear Feedback Shift Register for $x^{23} + x^{18} +1$:
   (1) $x^1 \oplus$ data output
   (2) $x^1 \oplus x^{18}$ -> temp
   (3) Shift x^n -> x^{n-1} $\forall$ n
   (4) temp -> x^{23}

Figure 2-2: Linear Feedback Shift Register

The beacon shall be able to utilize multiple LFSR initialization values for PRN sequence segment generation. Multiple beacon modes such as normal mode and test mode shall be defined by using the same PRN sequence generator polynomial with different LFSR initialization value pairs. Table 2.2 provides the generator polynomial initialization LFSR values for I and Q components for beacon normal mode operation and for beacon self-test mode operation. It also provides the first 60 chips in the order of generation from the LFSR. The 60 chip binary sequence has been displayed in hexadecimal format as demonstrated in the example below the table.

Table 2.2: PRN Sequence Initialization Values

Beacon Mode	Register initialization	First 60 chips
Normal (I component)	(MSB) 000 0000 0000 0000 0000 0001 (LSB)	(1st) 80000108421284A (60th)
Normal (Q component)	(MSB) 001 1010 1100 0001 1111 1100 (LSB)	(1st) 3F8358BAD030F23 (60th)
Self-Test (I component)	(MSB) 101 0010 1100 1001 1111 0000 (LSB)	(1st) 0F934A4D4CF3028 (60th)
Self-Test (Q component)	(MSB) 011 1100 1110 1001 0010 1000 (LSB)	(1st) 14973DC716CDE12 (60th)

Example of representing the chip sequence in hex: 14973 = (1st) 0001 0100 1001 0111 0011 (20th)

The correspondence between the logic level of the chips used to modulate the signal and the signal level is given in Table 2.3:

Table 2.3: Logic to Signal Level Assignment

Logic Level	Signal Level
1	-1.0
0	+1.0

2.2.4 Preamble

The initial 166.7 ms of the transmitted signal shall consist of the combination of the first 6400 chips of the two PRN code segments (each segment 38,400 chips long for the entire burst) used to spread the I and Q message components as illustrated in Figure 2-3. There will be no useful information encoded on either the I or Q components during the preamble. I and Q component information bits shall all be set to '0' during the preamble.

2.2.5 Digital Message

The remaining 833.3 ms of the transmitted signal shall contain a 250-bit message at a bit rate of 300 bps ±1%.

2.2.6 Message Content

The content of the 250 bit message is defined in section 3.

The 250 bit message is composed of two parts:

a) the useful message: 202 bits containing the information transmitted by the beacon.

b) the error correction bits: 48 bits BCH(250,202) containing bits used for error correction at reception.

Preamble	Useful message	Correcting bits
166.7 ms	673.3 ms	160 ms

1s
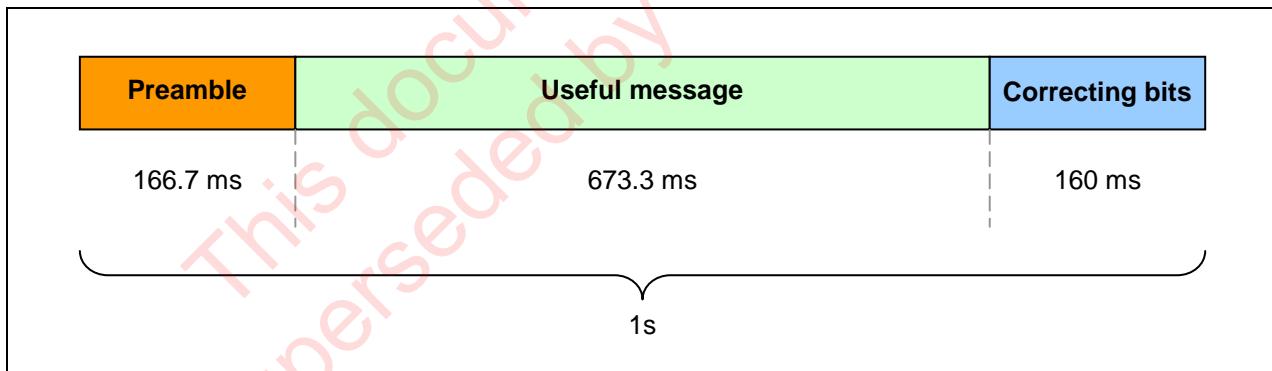
Figure 2-3: Burst general structure

2.2.7 In-Phase (I) and Quadrature-Phase (Q) Components

The odd bits of the 250 bit message are used to generate the in-phase (I) component of the message, while the even bits are used to generate the quadrature-phase (Q) component of the message. The bit rate for each channel shall be 150 bits/sec ±1%.

Each component starts with a 6400 chip preamble described in section 2.2.4 and is spread with the PRN code segment described in section 2.2.3 as shown in Figure 2-4.

The preamble and any bits allocated as '0' are represented by the PRN sequence, and bits allocated as '1' are sent as the PRN sequence inverted for the duration of the bit as shown in Table 2.4. This is the method of modulating data onto the PRN sequence.
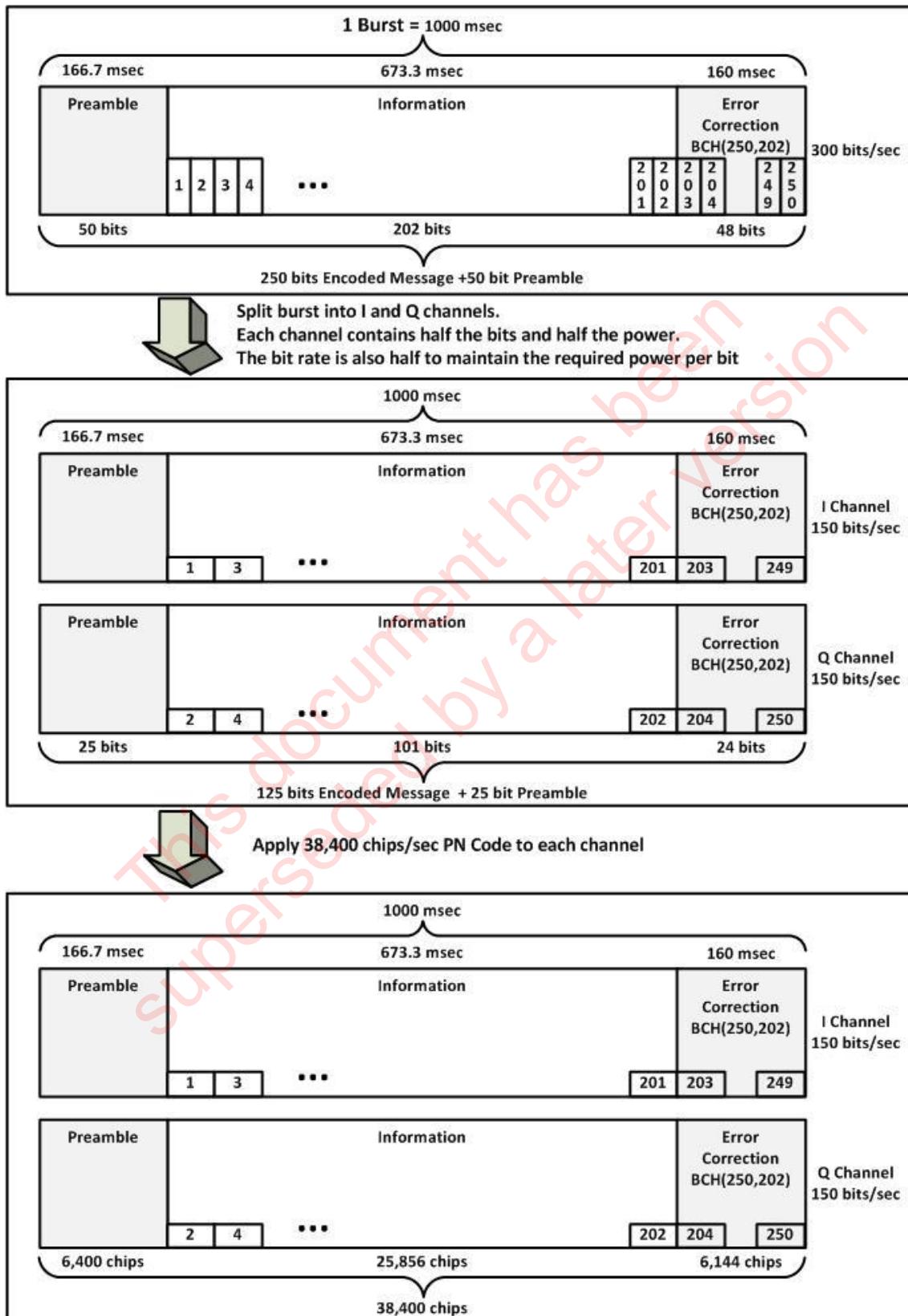
Figure 2-4: I and Q Component Message Structure*

---

* The 50 bits included in the preamble contain no data and are set to "0"

Table 2.4: Bit to PRN Sequence Assignment

Bit	PRN Sequence
1	Inverted
0	Normal

2.3 Modulator and 406 MHz Transmitter

2.3.1 Transmitted Frequency

The following sections define the frequency stability requirements for the Carrier Frequency and the Chip Rate. The specifications for the carrier frequency and the chip rate may be decoupled by using separate oscillators.

2.3.1.1 Carrier Frequency Offset/Drift over aging, thermal, shock and vibration

a) Long Term Stability Requirement

The carrier frequency tolerance shall be 406.05 MHz ±1200 Hz over 5 years or the manufacturers' declared beacon maintenance period[*], whichever is greater; and

b) Short Term Stability Requirement

This requirement applies throughout the operating temperature range and during situations of temperature shock.

The carrier frequency shall be 406.05 MHz with a maximum frequency stability of 7.4E-9 for averaging times at 166.7 msec, which equates to an Allan Deviation value of 1.2 ppb.

2.3.1.2 Chip Rate Accuracy and Variation

The average chip rate shall be 38 400 ± 0.6 chips/s.

The variation of the chip rate shall be ± 0.6 chips/s².

These values shall be met both when measuring over the preamble and on the entire burst.

---

[*] The beacon maintenance should include validation of the frequency stability of the beacon.

2.3.2   Spurious Emissions

The in-band spurious emissions shall not exceed the levels specified by the signal mask in Figure 2-5, when measured in a 100 Hz resolution bandwidth.
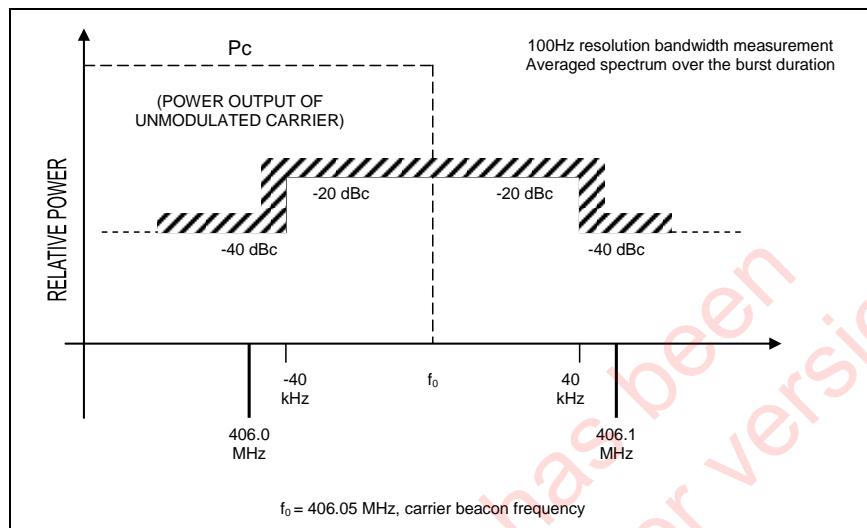
Figure 2-5: Spurious emission mask

Furthermore**,** out of band emissions must be limited to less than 1% of the total transmitted power[*].

2.3.3   Modulation

The RF modulation is Offset Quadrature Phase Shift Keying (OQPSK). The PRN sequences for the in-phase (I) and quadrature (Q) components of the signal are defined in section 2.2.3. The chips of the I and Q components shall have an average offset of half a chip period ± 1% of the chip period over the entire burst with I leading Q by one-half a chip period. In the constellation diagram shown below, it can be seen that this will limit the phase-change to no more than 90° at a time. The peak to peak amplitude of the I and Q components shall be on average within 15% of each other over the entire burst. The Error Vector Magnitude (EVM) of the constellation points away from ideal shall be less than 15 % when measured over any 150 millisecond portion of the entire burst.

The figure below illustrates the OQPSK modulation mid-burst including the one-half chip delay on the Q channel. In this figure, T represents the chip period.

---

[*] The 1% out of band emission is extracted from the recommendation ITU-R SM.1541-4, article 1.153
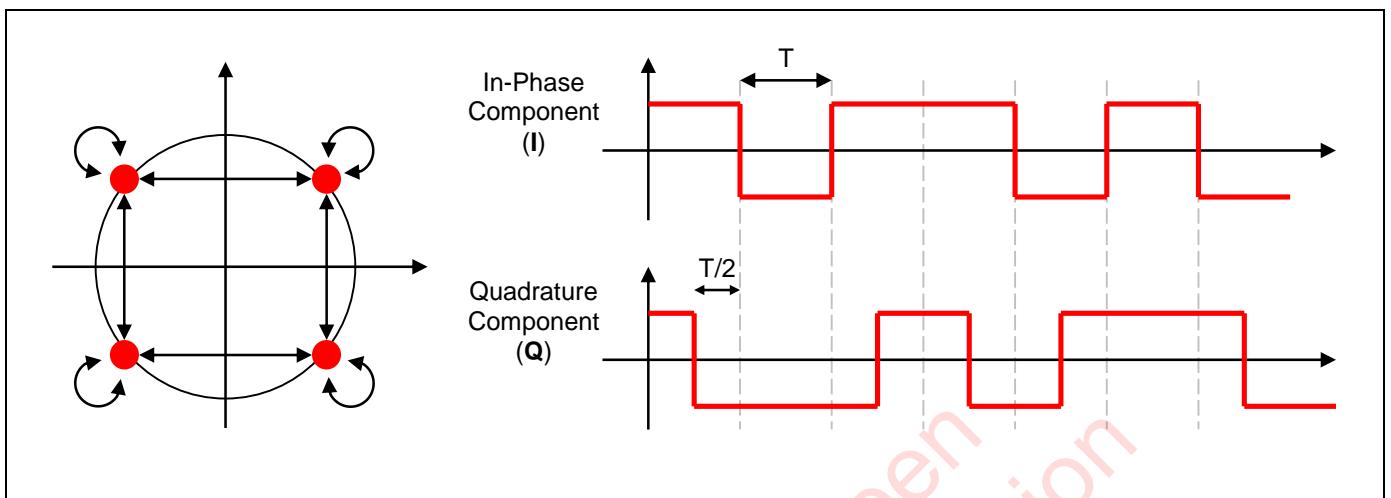
Figure 2-6: OQPSK modulation illustration

2.3.4   Voltage Standing-Wave Ratio

The modulator and 406 MHz transmitter shall be able to meet all requirements within this standard at any VSWR between 1:1 and 3:1, and shall not be damaged by any load from open circuit to short circuit.

2.3.5   Maximum Continuous Transmission

The distress beacon shall be designed to limit any inadvertent continuous 406 MHz transmission to a maximum of 45 seconds.

2.4   Transmitter Power Output

2.4.1   Transmitter Rise Time

The transmitter RF output power shall not exceed -10 dBm prior to 25 ms before the commencement of, or 25 ms after the end of, any 406 MHz burst. Power output rise time shall be less than 0.5 ms measured between the 10% and 90% power points. Pre-amble content shall be transmitted during the power rise time.

2.4.2   Effective Isotropic Radiated Power (EIRP)

Power output is defined in terms of EIRP, not power into a 50-ohm load. Required EIRP varies with elevation angle according to the table below. Greater than 65% of measured EIRP values shall meet the limits shown. In addition 90% of the measured EIRP values shall meet the limits shown at elevation angles below 55 degrees, except for ELT(DT)s, or ELTs used in combination with automatic deployable flight recorders.

Table 2.5: Required EIRP

Elevation (°)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Max dBm	45	45	45	45	45	45	45	45	45	44	44	44	44	44	44	44
Min dBm	34	34	34	34	34	34	34	34	34	34	34	33	33	33	33	33

The horizontal (azimuth) antenna pattern should be substantially omnidirectional and shall remain within the minimum and maximum values of EIRP provided in the above table.

Power output shall be maintained within the above limits throughout the minimum operating lifetime of the beacon at any temperature throughout the operating temperature range. Changes in beacon output power due to for example temperature and operation over the beacons minimum lifetime when operating into a 50-ohm test load shall be taken into account during determination of compliance with the minimum and maximum EIRP limits.

2.4.3   Antenna Characteristics

Antenna polarization shall be either circular (RHCP) or linear. Antenna pattern should be hemispherical and should include coverage at high elevation angles, subject to the EIRP limits given in section 2.4.2 (effective isotropic radiated power). An ideal antenna pattern is shown below for illustration purposes.
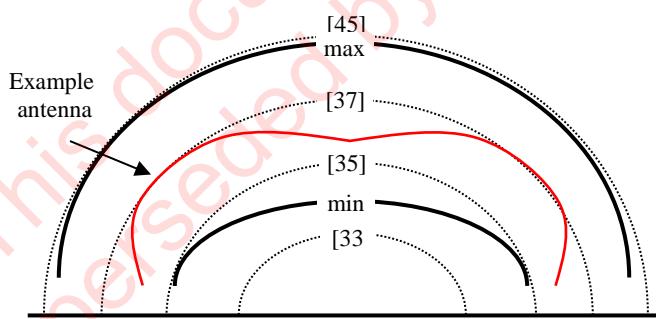
Figure 2-7: Ideal Antenna Pattern

Remote antennas or detachable antennas shall always be approved with a beacon.

The following different types of antenna may be specified for use with a 406 MHz beacon:

External Antenna
An antenna that is external to the casing of the beacon and that is permanently attached to the beacon and that cannot be removed by the user.

Detachable Antenna
An antenna that is external to the casing of the beacon and that is attached directly to the beacon by such means as an RF connector without any intermediate cable which can be removed and replaced by the user.

Detachable antennas when measured directly at the antenna feed point shall achieve a VSWR not greater than 1.5:1 referred to 50Ω.

Internal Antenna
An antenna that is contained within the case of the beacon where the user has no access to the antenna.

Remote Antenna
An antenna that is external to the casing of the beacon and which is remote from the beacon, being attached to it by means of an RF cable. The antenna and the RF cable may be permanently attached to the beacon (in this case the type and length of the antenna cable is fixed and is as supplied by the beacon manufacturer) or one or both parts (antenna or cable) may be varied by the user or the installer (in this case the type and length of the antenna cable may vary).

In either case, remote antennas, when measured directly at the antenna feed point, shall achieve a VSWR not greater than 1.5:1 referred to 50Ω.

Remote Antenna without an Integrated Cable

In this configuration (e.g. an ELT installed in an aircraft) there may be more than one type of approved antenna and the length and type of cable between the antenna and beacon may vary.

The characteristic impedance and minimum and maximum loss of the antenna feed cable shall be specified by the beacon manufacturer. The combined beacon, antenna and cable shall meet the EIRP requirements in section 2.4.2 (effective isotropic radiated power) when operating with the minimum and maximum stated cable loss between the antenna and the beacon.

Remote Antenna with an Integrated Cable

In this configuration (e.g. a military PLB with a body worn antenna) the antenna and cable combination is fixed and supplied by the beacon manufacturer (although there maybe more than one approved combination for different applications) and the length and type of cable between the antenna and beacon cannot be changed.

This combination utilising a specific manufacturer supplied integrated antenna cable shall be tested with that cable.

All antennas and cabling arrangements to be approved with a beacon shall be specified by the manufacturer and shall meet all the requirements of section 2.4.

2.5   406 MHz Homing Transmitter

The distress beacon may transmit a 406 MHz Homing signal as defined in this section[*]. However ELT (DT)s are not required to provide a 406-MHz homing signal.

---

[*] A CW unmodulated 406-MHz homing and on-scene locating signal is under development with details to be provided in a future update to T.018 and will be centered at 406.050 MHz, ± 2 kHz, at a power level, repetition rate, and pulse width to be determined.

- END OF SECTION 2 -

3. DIGITAL MESSAGE CONTENT

3.1 Basic Structure

The digital message which is transmitted by the 406 MHz beacon consists of:

  a) 202 information bits; and

  b) 48 bits for BCH(250,202) error correction.

The 202 information bits are further divided into:
- 154 bits within the main data field (transmitted in every burst),
- 48 bits within a rotating data field (may be 1 of 16 different content types).

Message content structure is shown in Figure 3-1 below. Data transmission starts with bit 1, the left-hand (most significant) bit of the 154 bit main field.

202 information bits										48 error correction bits				
154 bit main field														
Main Message			Spare			48 bit rotating field					48 bit BCH field			
1	…	137	138	…	154	155	156	....	201	202	203	204	....	249	250

Figure 3-1: Message content bits

3.2 Beacon Message Content – Main Field

The main field provides for the minimum requirements of document C/S G.008 using sub-fields as shown in Table 3.1 below.

Unless stated otherwise all sub-fields are separately binary encoded, with the Least Significant Bit to the right (i.e. the highest numbered bit in that particular message field).

Table 3.1: Minimum Requirement main field in the beacon message (transmitted in every burst)

C/S G.008 reqmt Para.	Description	Number of bits	Bit numbers in message	Content
3.7.1a	TAC Number + Serial Number	30	1-30 (MSB=1)	20 bits TAC # (0 to 1,048,575), followed by a 10 bits serial # (0 to 1023)

C/S G.008 reqmt Para.	Description	Number of bits	Bit numbers in message	Content
3.7.1a	Country code	10	31-40 (MSB= 31)	A three-digit decimal country code number (0 to 999). Country codes are based on the International Telecommunication Union (ITU) Maritime Identification Digit (MID) country code available on the ITU website (www.itu.int/cgi-bin/htsh/glad/cga_mids.sh).
3.7.1d	Status of homing device	1	41	On beacon activation a '1' indicates that the beacon is equipped with at least one homing signal and a '0' indicates that the beacon is not equipped with any homing signals or that they have been deliberately disabled. Once the homing signal(s) in the beacon have been activated a '1' indicates that at least one homing device is functional and transmitting. A '0' indicates that no homing device is functional or it has been deliberately disabled
3.7.1e	Self-Test function	1	42	A '0' indicates Normal Beacon operation (transmitting a distress). A '1' indicates a Self-Test Transmission
N/A	Test Protocol	1	43	A '0' indicates normal beacon operation. A '1' indicates a Test Protocol message.
3.7.1g	Encoded GNSS location		(MSB= 45, 52, 68, 75)	Location is provided to 3.4 m resolution max in the following order:
		1	44	N/S flag (N=0, S=1)
		7	45-51	Degrees (0 to 90) in 1 degree increments
		15	52-66	Decimal parts of a degree (0.5 to 0.00003) (Default value of bits = 0 1111111 000001111100000
		1	67	E/W flag (E=0, W=1)
		8	68-75	Degrees (0 to 180) in 1 degree increments
		15	76-90	Decimal parts of a degree (0.5 to 0.00003) (Default value of bits = 0 11111111 111110000011111)
3.7.1h	Vessel ID	3	91-93	A three digit binary field identifier is first transmitted to identify the following message content: 000 - No aircraft or maritime identity (in which case the following 44 binary bits shall all be 0) 001 – Maritime MMSI 010- Radio call sign 011 – Aircraft Registration Marking (Tail Number) 100 – Aircraft aviation 24 Bit Address 101 – Aircraft operator and serial number 110 and 111 Spare This is followed by the vessel or aircraft identity, the following coding schemes are permitted: 1 - Maritime Mobile Service Identity

C/S G.008 reqmt Para.	Description	Number of bits	Bit numbers in message	Content
	Vessel ID (continued)	30	94-123	A unique ship station identity in the format $M_1I_2D_3X_4X_5X_6X_7X_8X_9$ where MID indicates the flag state of the vessel and XXXXXX is the unique vessel number in accordance with ITU-R M.585-6 encoded as a 9 digit number in binary format. If no MSI is available then insert the default decimal number 000111111
		14	124-137	Followed if applicable by the Maritime Mobile Service Identity for the EPIRB-AIS system in the format $9_17_24_3X_4X_5Y_6Y_7Y_8Y_9$ in accordance with ITU-R M.585-6 where only the last 4 digits ($Y_6Y_7Y_8Y_9$) are encoded here as a number in binary format, If there is no EPIRB-AIS device, then insert the default binary number 10101010101010 (10922)
		44	94-137	2 - Radio call sign Is encoded using the modified-Baudot code shown in Table 3.1a. This code enables 7 characters to be encoded using 42 bits (6x7=42). The two highest bits (43 and 44) are spare and shall be coded as 00. This data will be left justified with a modified-Baudot space (100100) being used where no character exists. If no Radio call sign is available then insert a series of 7 spaces (100100)
		44	94-137	3 - Aircraft Registration Marking Is encoded using the modified-Baudot code shown in Table 3.1 a. This code enables 7 characters to be encoded using 42 bits (6x7=42). The two highest bits (43 and 44) are spare and shall be coded as 00. This data will be right justified with a modified-Baudot space (100100) being used where no character exists. If no Aircraft Registration Mark is available then insert a series of 7 spaces (100100)
		44	94-137	4 – Aviation 24 Bit Address Shall be encoded as a 24 Bit Binary Number, followed by 20 spare bits all of which are coded as 0
		44	94-137	5 - Aircraft operator and serial number A 3-letter aircraft operator designator from the list of "Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services" published by the International Civil Aviation Organization (ICAO) as document 8585. The 3 letters are encoded using the modified-Baudot code shown in Table 3.2 (3x6 = 18 Bits).

C/S G.008 reqmt Para.	Description	Number of bits	Bit numbers in message	Content
	Vessel ID (continued)			Followed by a serial number (in the range of 1 up to 4095) as designated by the aircraft operator, encoded in binary, with the least significant bit on the right (12 Bits). The remaining 14 Bits are spare and shall follow the above 30 Bits and be encoded all as 1's.
	Spare bits	17	138-154	These bits are all set to binary 1. For a cancellation message, these bits are all set to 0.
	TOTAL BITS IN EACH BURST	154		To be transmitted in each burst

NOTES

All position information is encoded as degrees and decimal parts of a degree, or as fractions of these units to be as close as possible to the actual position.

Latitude and longitude data are rounded off (i.e. not truncated) to the available resolution.

All rounding shall follow normal rounding conventions, for example with a resolution of 4, 0.000 to 1.999 shall be rounded down to 0 and 2.000 to 3.999 shall be rounded up to 4.

Table 3.2 Modified Baudot Code

Letter	Code* MSB　　LSB	Letter	Code MSB　　LSB	Letter	Code MSB　　LSB
A	111000	N	100110	( )[†]	100100
B	110011	O	100011	(-)[‡]	011000
C	101110	P	101101	/	010111
D	110010	Q	111101	0	001101
E	110000	R	101010	1	011101
F	110010	S	110100	2	011001
G	101011	T	100001	3	010000
H	100101	U	111100	4	001010
I	101100	V	101111	5	000001
J	111010	W	111001	6	010101
K	111110	X	110111	7	011100
L	101001	Y	110101	8	001100
M	100111	Z	110001	9	000011

---

* MSB: most significant bit,
  LSB: least significant bit

[†] Space

[‡] Hyphen

3.3   Beacon Message Content – Rotating Fields

The objective requirements of document C/S G.008 are provided in rotating fields as detailed below. During every transmission burst the beacon shall transmit 1 of the 16 types of rotating field content. The type of field content selected for transmission shall be in accordance with the rotating field scheduling requirements – see section 3.4. The 16 types of rotating field content are listed below.

0. C/S G.008 Objective Requirements (except national use and spares)
1. ELT(DT) In-flight Emergency (to allow more accurate time parameters)
2. RLS (for RLS messages)
3. National Use (to allow national administrations to define for their use)
4. Spare (for future use)
5. Spare (for future use)
6. Spare (for future use)
7. Spare (for future use)
8. Spare (for future use)
9. Spare (for future use)
10. Spare (for future use)
11. Spare (for future use)
12. Spare (for future use)
13. Spare (for future use)
14. Spare (for future use)
15. Cancellation Message

Detailed content of rotating fields #0 through #3, and #15 are shown in the tables below.

Unless stated otherwise all sub-fields of every rotating field are separately binary encoded, with the Least Significant Bit to the right (i.e., the highest numbered bit in that particular message field).

Table 3.3: C/S G.008 Objective Requirements Rotating Field (#0)

C/S G.008 Section	Sub-field Description	Number of bits	Bit numbers in message	Content
	Rotating field Identifier	4	155-158 in message (1-4 in rotating field)	0000 – G.008 Objective Requirements
4.3.1a	Elapsed Time since activation	6	159-164 in message (5-10 in rotating field)	0 to 63 hours in one hour steps (actual time since activation shall be truncated, not rounded e.g. between 1 hour and 2 hours after activation shall be encoded as 1 hour). If the beacon is turned off and on again (even quickly) this field shall be reset to zero.
4.3.1b	Time from last encoded location	11	165-175 in message (11-21 in rotating field)	0 to 2047 minutes (34 hours and 7 minutes) in one minute steps (actual time since last location shall be truncated, not rounded e.g. between 34 minutes and 35 minutes after activation shall be encoded as 34 minutes). Every time that a new / updated encoded location is obtained this field shall be reset to zero. Time is calculated from when the location was obtained not when it was transmitted. If the time is greater than 2047 minutes, the value shall be set to 2047.
4.3.1c	Altitude of Encoded location	10	176-185 in message (22-31 in rotating field)	-400 metres to 15952 metres in steps of 16 metres (where -400m is encoded as all zeros and sea level would be encoded as 0000011001). Heights shall be rounded to the nearest 16 metre step not truncated. If altitude is not available (e.g. there is no location data or only a 2D fix is available) then this field shall be encoded as all 1's
4.3.1d	Dilution of Precision	8	186-193 in message (32-39 in rotating field)	The value of HDOP of the encoded location shall be reported (first 4 bits) followed by the value of VDOP on the following basis: 0000 = DOP <= 1 0001 = DOP > 1 and <= 2 0010 = DOP > 2 and <= 3 0011 = DOP > 3 and <= 4 0100 = DOP > 4 and <= 5 0101 = DOP > 5 and <= 6 0110 = DOP > 6 and <= 7 0111 = DOP > 7 and <= 8 1000 = DOP > 8 and <= 10 1001 = DOP > 10 and <= 12 1010 = DOP > 12 and <= 15 1011 = DOP > 15 and <= 20 1100 = DOP > 20 and <= 30 1101 = DOP > 30 and <= 50 1110 = DOP > 50 1111 = DOP Not Available

C/S G.008 Section	Sub-field Description	Number of bits	Bit numbers in message	Content
4.3.1f	Automated/Manual Activation notification	2	194-195 in message (40-41 in rotating field)	Report the activation method of the beacon as follows: 00 Manual Activation by user 01 Automatic Activation by the beacon 10 Automatic Activation by external means 11 Spare
4.3.1g	Remaining battery capacity	3	196-198 in message (42-44 in rotating field)	The remaining battery capacity in the beacon compared to its initial capacity shall be reported as follows: 000 <= 5% remaining 001 > 5% and <= 10% remaining 010 > 10% and <= 25% remaining 011 > 25% and <= 50% remaining 100 > 50% and <= 75% remaining 101 > 75% and <= 100% remaining 110 Reserved for future use 111 Battery Capacity Not Available
Not in C/S G.008	GNSS status	2	199-200 in message (45-46 in rotating field)	This field reports the status of the GNSS receiver used to provide the encoded location as follows: 00 No Fix 01 2D location only 10 3D location 11 Reserved for future use
	Spare	2	201-202 in message (47-48 in rotating field)	00
TOTAL	Bits in Rotating Field	48		

Table 3.4: ELT(DT) In-Flight Emergency Rotating Field (#1)

C/S G.008 section	Sub-field Description	# Bits	Bit numbers in message	Content
	Rotating field Identifier	4	155-158 in message (1-4 in rotating field)	0001 In Flight Emergency
4.3.1b	Time of last encoded location	17	159-175 in message (5-21 in rotating field)	Time to nearest second (17 bits) Time 'sssss' where '00001' indicates a time of 00:00:01 UTC and '86399' indicates a time of 23:59:59 UTC). If UTC time is not available or the time is more than 24 hours old then this field shall be encoded as all ones.
	Altitude of Encoded Location	10	176-185 in message (22-31 in rotating field)	-400 m to 15952 meters in steps of 16 meters (where -400 m is encoded as all zeros and sea level as 0000011001). Altitude with respect to the WGS84 reference frame shall be rounded to the nearest 16-meter step, not truncated. If altitude is not available, e.g., there is no location data or only a 2D fix is available, then this field shall be encoded as all ones.
	Triggering event	4	186-189 in message (32-35 in rotating field)	0001 - Manual activation by the crew 0100 – G-switch/Deformation Activation 1000 - Automatic Activation from Avionics or Triggering System* All other bit combinations spare
	GNSS Status	2	190-191 in message (36-37 in rotating field)	This field reports the status of the GNSS receiver used to provide the encoded location as follows: 00 Not Fix 01 2D location only 10 3D location 11 Spare
	Remaining battery capacity	2	192-193 in message (38-39 in rotating field)	The remaining battery capacity in the beacon compared to its initial capacity shall be reported as follows: 00 ≤ 9 hours autonomy remaining 01 > 9 hours and ≤ 18 hours autonomy remaining 10 > 18 hours remaining 11 Battery capacity not available
	Spare	9	194-202 in message (40-48 in rotating field)	All 0's
	TOTAL	**48**		

* Trigger in compliance with EUROCAE document ED-237.

Table 3.5: RLS Rotating Field (#2)

C/S G.008 section	Sub-field Description	# Bits	Bit numbers in message	Content
	Rotating field identifier	4	155-158 in message (1-4 in rotating field)	**bit 1-4** "0010"
	Beacon Type	2	159-160 in message (5-6 in rotating field)	**bit 5-6** "00" ELT, "01" EPIRB, "10" PLB, and "11" RLS Test Protocol
	Beacon RLS Capability	6	161-166 in message (7-12 in rotating field)	**bit 7** - Capability to process automatically generated Acknowledgement RLM Type-1. "1": Acknowledgement Type-1 (automatic acknowledgement) accepted by this beacon, "0": Acknowledgement Type-1 not requested and not accepted by this beacon; **bit 8** - Capability to process manually generated RLM (e.g. Acknowledgment Type-2). "1": Manually generated RLM (such as Acknowledgement Type-2) accepted by this beacon, "0": Manually generated RLM (such as Acknowledgement Type-2) not requested and not accepted by this beacon. **bit 9-12** – Reserved for future use.
	RLS Provider Identification	3	167-169 in message (13-15 in rotating field)	**Bit 13-15** "001": GALILEO Return Link Service Provider "010": GLONASS Return Link Service Provider Other combinations: Spares (for other possible RLS providers)

	Beacon Feedback (acknowledgement of RLM reception)	22	170-191 in message (16-37 in rotating field)	If RLS Provider Identification = 001 (bit 13-15)
				bit 16 – RLM Short/Long message identifier
				"0": Short RLM,
				"1": Long RLM.
				
				bit 17 – Reserved
				
				bit 18-37 – RLM
				if (bit 16 = 0 and bit 17=0)
				Copy of bits 61-80 of the short RLM in the Open Service Signal in Space (section 5.2 of OS SIS ICD[*])
				
				if (bit 16 = 0 and bit 17=1)
				To be defined

---

[*] European GNSS (Galileo) Open Service Signal In Space Interface Control Document (OS SIS ICD v1.2), November 2015.

C/S G.008 section	Sub-field Description	# Bits	Bit numbers in message	Content
				if bit 16 = 1 To be defined. If RLS Provider Identification is not 001 Reserved.
	Unassigned	11	192-202 in message (38-48 in rotating field)	All 0's
	TOTAL	**48**		

Table 3.6: National Use Rotating Field (#3)

C/S G.008 section	Sub-field Description	# Bits	Bit numbers in message	Content
	Rotating field identifier	4	155-158 in message (1-4 in rotating field)	0011
4.3.1.i	National use	44	159-202 in message (5-48 in rotating field)	As defined by national administrations Default content all 0's
	TOTAL	**48**		

Table 3.7: Spare Rotating Fields (for future use) (#4 - #14)

C/S G.008 section	Sub-field Description	# Bits	Bit numbers in message	Content
	Rotating field identifier	4	155-158 in message (1-4 in rotating field)	0100 to 1111 inclusive
4.3.1.h	Spares	44	159-202 in message (5-48 in rotating field)	Default content all 0's.
	TOTAL	**48**		

Table 3.8: Cancellation Message Rotating Field (#15)

C/S G.008 section	Sub-field Description	# Bits	Bit numbers in message	Content
	Rotating field Identifier	4	155-158 in message (1-4 in rotating field)	1111
	Fixed	42	159-200 in message (5-46 in rotating field)	Set to all 1's.
	Method of deactivation	2	201-202 in message (47-48 in rotating field)	00 Spare 10 Manual De-Activation by user 01 Automatic De-Activation by external means 11 Spare
	TOTAL	**48**		

3.4   Rotating field – Transmission scheduling

Default: By default field type #0 (C/S G.008 Objective Requirements) shall be sent unless dictated otherwise.

Cancellation Message: Field type #15 shall be sent for cancellation messages, unless dictated otherwise.

ELT(DT) In-flight emergency: Field type #1 shall be sent for ELT(DT)s, unless dictated otherwise.

RLS: For beacons equipped with RLS functionality (except for ELT(DT)s), transmissions shall be alternated between Field type #0 and Field type #2 starting with Field type #2, unless dictated otherwise.

National use: Administrations shall define their own rotation schedule for field type #3. Such schedules shall include regular transmission of field type #0.

3.5   Beacon Message Content – Error Correcting Field

A sample of the BCH Error-correcting Code Calculation is provided in Appendix 2.

3.6   Beacon Coding and Hex ID

Beacon coding methods are defined in section 3.1 of this specification. Specific operational requirements that impact beacon coding, such as the self-test mode and the encoding of position data, are defined in section 4 of this specification.

The 23 hexadecimal characters that uniquely identify each 406 MHz beacon are called the beacon 23 Hex ID. This is never transmitted by the beacon as such, rather it is generated locally by the SAR ground segment hardware and generated during beacon manufacture in order to apply identity labels to the beacon by extracting the bits shown below from the beacon data.

The 23 Hex ID is composed as follows:

Table 3.9: Hex ID Contents

23 Hex ID Bit	No Bits	Reference to Bits in Message	Data Content
1	1	n/a	Fixed Binary '1'
2 to 11	10	31-40	C/S Country Code
12	1	n/a	Fixed Binary '1'
13	1	n/a	Fixed Binary '0'
14	1	n/a	Fixed Binary '1'
15 to 34	20	1-20	C/S TAC No
35 to 44	10	21-30	Beacon Serial Number
45 to 47	3	91-93	Aircraft / Vessel ID Type
48 to 91	44	94-137	Aircraft / Vessel ID
92	1	n/a	Spare Bit – Fixed Binary '1'
Total	**92**		**23 Hex**

Notes

1) Fixing bits 1, 12, 13 and 14 of the 23 Hex ID to '1101' ensures that the 23 Hex ID cannot duplicate a First Generation Beacon 15 Hex ID.

2) The first 60 bits of the 23 Hex ID comprising the C/S Country Code, C/S TAC Number, Beacon Serial Number, Fixed Bits 1, 12, 13 and 14 and the first part of the Aircraft / Vessel ID together form a unique subset of the 23 Hex ID which form an SGB 15 Hex ID which is required for certain services, such as the Return Link Service. That is a unique SGB 15 Hex ID which may be obtained by simply truncating the 23 Hex ID and ignoring the last 8 Hex characters.

- END OF SECTION 3 -

4. ENVIRONMENTAL AND OPERATIONAL REQUIREMENTS

4.1 General

As explained in section 1.2, the environmental and operational requirements defined in this section are not intended to be exhaustive. They are minimum requirements, which may be complemented by national or international standards.

4.2 Thermal Environment

4.2.1 Operating Temperature Range

Three standard classes of operating temperature range are defined, inside which all of the requirements within this specification shall be met:

Class 0: -55°C to +70°C
Class 1: -40°C to +55°C
Class 2: -20°C to +55°C

4.2.2 Temperature Gradient

All of the requirements within this specification, shall be met when the beacon is subjected to the temperature gradient shown in Figure 4.1.

4.2.3 Thermal Shock

All of the requirements within this specification shall be met, for measurements beginning 3 seconds after simultaneously activating the beacon and applying a rapid thermal shock of 50 °C within the specified operating temperature range of the beacon within 1 minute. Subsequently, all requirements shall continue to be met for a minimum period of two hours.
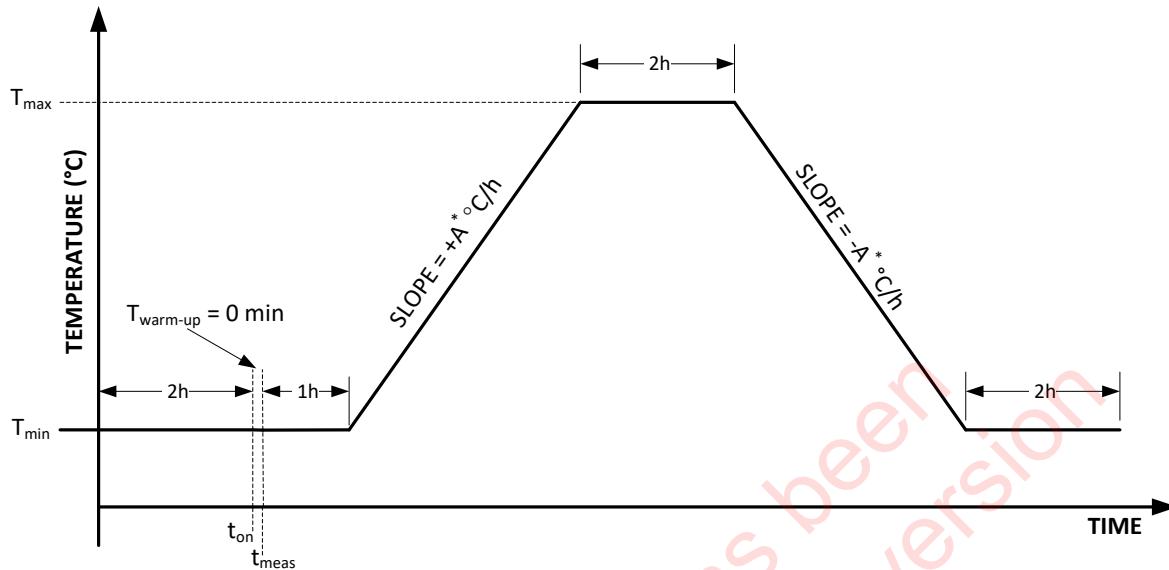
NOTES:

T_{max} = + 70°C (Class 0 beacon)
T_{max} = + 55°C (Class 1 & 2 beacons)

T_{min} = - 55°C (Class 0 beacon)
T_{min} = - 40°C (Class 1 beacon)
T_{min} = - 20°C (Class 2 beacon)

t_{on} = beacon turn-on time after 2 hour "cold soak"
t_{meas} = start time of frequency stability measurement (t_{on} + 0 min)

A^* = 7°C/hour for Class 0
A^* = 5°C/hour for Class 1 and Class 2

Figure 4-1: Temperature Gradient

4.3   Mechanical Environment

Beacons should be submitted to vibration and shock tests consistent with their intended use. These requirements should be defined by national authorities, preferably using internationally-recognized standards such as RTCA/DO-204 for ELTs.

4.4   Other Environmental Requirements

Other environmental requirements such as humidity tests, altitude tests, over/under pressure tests, waterproofness tests, sand and dust tests, fluids susceptibility tests, etc., may be defined by national authorities, preferably using internationally-recognized standards.

4.5   Operational Requirements

4.5.1   Duration of Continuous Operation

The minimum duration of continuous operation shall be at least 24 hours[*] at any temperature throughout the specified operating temperature range.

4.5.1.1   Battery Replacement Interval

The beacon battery replacement interval shall be declared by the beacon manufacturer. At the end of the battery replacement interval the beacon shall continue to meet the required duration of continuous operation as defined in 4.5.1 after accounting for all losses in battery capacity over the declared battery replacement interval at ambient temperatures plus a safety factor of 65% applied to all losses.

4.5.2   Other Operational Requirements

Other operational requirements such as installation and maintenance methods, remote monitoring, activation methods on planes or boats, etc. may be defined by national authorities.

4.5.3   Radio-Locating Signal (for Homing and on-Scene Locating)

The distress beacon may transmit a 406 MHz Radio-Locating signal as defined in section 2.5. ELT(DT)s are not required to provide a Radio-Locating signal.

The transmission of the 406 MHz satellite signal shall take precedence over any Radio-Locating Signals. Homing signal types should be momentarily interrupted, delayed, rescheduled, or eliminated according to the relevant standard for each type.

The distress beacon may transmit other radio-locating signals in compliance with appropriate national or international standards. The inclusion of any Radio-Locating Signals within a beacon and the prioritization of these Radio-Locating Signals is the responsibility of the appropriate national or international bodies. The status of the radio-locating transmissions (e.g., operational or non-operational) shall be monitored before each beacon satellite transmission and shall be encoded in the beacon message as indicated in section 3.2.

Any such radio-locating device must satisfy all the national performance standards applicable to radio-locating devices at the selected frequency.

Radio-Locating Signals shall not begin transmissions for at least 30 seconds (in order for the as equipped status to be transmitted) but shall begin transmission within 5 minutes maximum after beacon activation, except (if applicable) AIS signals which shall not be delayed for longer than 1 minute after beacon activation.

---

[*] For installations meeting IMO GMDSS requirements, a minimum operating lifetime of 48 hours (EPIRB) and 168 hours (for Float Free VDR capsules) at any temperature throughout the specified operating temperature range is necessary. The minimum operating lifetime for an ELT (DT) to meet the ICAO GADSS requirement at any temperature throughout the specified operating temperature range shall be 20 hours. This duration is based on the ICAO requirement for the ELT(DT) to transmit for the maximum duration of the flight.

4.5.4   Beacon Self-Test Mode

4.5.4.1   Nominal Beacon Self-Test Mode

All beacons shall include a self-test mode of operation, which shall include a Verification of Registration function as detailed in section 4.5.8.

In the self-test mode beacons shall transmit a digital message encoded in accordance with section 3. The content of the self-test message shall always provide the beacon ID as defined in section 3.6. The transmitted message shall contain an identifier to indicate that the message is a self-test transmission as specified in section 3.2 and shall be spread by a specific sequence defined in section 2.2.3.

The complete self-test transmission shall be limited to one 406 burst at full power and one burst of each radio-locating signal at full power with a maximum duration of 3 sec each. The radiolocating signals shall be transmitted first in order of ascending frequency followed lastly by the 406 MHz satellite signal.

The self-test mode shall be activated by either a separate switch to that used to activate the beacon or cancel transmissions; or a separate switch position of the beacon activation switch.

The duration of the self-test cycle shall not exceed 15 seconds.

The self-test function shall perform an internal check and provide a distinct indication:

   a) that the self-test mode has been initiated within 2 secs of activation;

   b) that RF power is being emitted at 406 MHz and the radio locating frequencies, if applicable; and

   c) that the internal check has passed successfully within 15 secs of activation; or

   d) that any of item a), b) or c) has failed the self-test within 15 secs of activation

The beacon shall be designed to ensure an automatic termination of the self-test mode immediately after completion of the self-test cycle and indication of the self-test results.

For beacons without valid location data, the content of the encoded position data field of the self-test message shall be the default values specified in section 3. Additionally, beacons may optionally also provide for the transmission of a self-test message encoded with a GNSS position.

Location protocol beacons which provide for the transmission of an encoded position in a GNSS self-test message shall:

   a) activate the GNSS self-test mode via a distinct operation from the normal self-test mode, but the GNSS self-test mode may be activated via the same self-test switch(es) or operation provided that it shall require a separate, deliberate action by the user that would limit the likelihood of inadvertent GNSS self-test activation, and shall not result in more than a single self-test burst;

b) provide for that in the case of internal GNSS receivers powered by the primary[*] beacon battery the number of GNSS self-tests shall be limited by the beacon design to prevent inadvertent battery depletion;

c) provide a distinct indication that the GNSS self-test is underway and to register successful completion or failure of the GNSS self-test;

d) provide, for beacons with internal navigation devices powered by the primary beacon battery, a separate distinct indication that the limited number of GNSS self-test opportunities have been attained;

e) ensure that the duration of the GNSS self-test is limited to a maximum time duration set by the manufacturer, noting that:

- in the case where the beacon fails to encode the location into the 406 MHz message within this time limit the GNSS self-test shall cease, the beacon shall indicate a GNSS self-test failure and may transmit a single self-test burst with default location data,

- in the case where the beacon encodes the location into the 406 MHz message within this time limit the GNSS self-test shall cease at that time (or before the time limit is reached), indicate a GNSS self-test pass and transmit a single self-test burst containing the valid location data.

4.5.5 Encoded Position Data[†]

4.5.5.1 General

Beacon position data, obtained from a navigation device internal, integral[‡] or external to the beacon, shall be encoded in the beacon message, if available. Beacons that do not provide encoded position data shall indicate this within the message and shall transmit default location data as defined in section 3. Beacons capable of encoding position data shall comply with all the appropriate parts of section 4.5.5.

Encoded position message content shall be as defined in section 3.

ELT (DT)s shall incorporate an internal navigation device and may incorporate an interface to an external navigation device. The initial position transmitted in the first burst may be obtained from either the internal navigation device or from the external navigation device input. Subsequently all future positions shall only be obtained from the internal navigation device.

Operation or failure of an internal or external navigation device providing position data to the beacon shall not degrade other aspects of beacon performance.

---

[*] The primary battery is the battery which is powering the 406 MHz function.
[†] ELTs carried to satisfy the requirements of ICAO Annex 6, Parts I, II and III shall operate in accordance with ICAO Annex 10.
[‡] An integral navigation device is a part of the beacon system but may be separate to the beacon transmitter and shall comply with the performance requirements of an internal navigation device.

4.5.5.2 Internal Navigation Device

An internal navigation device shall be capable of global operation and should conform to an applicable international standard.

An internal navigation device shall incorporate self-check features to ensure that erroneous position data is not encoded into the beacon message. The self-check features shall prevent position data from being encoded into the beacon message unless minimum performance criteria are met. These criteria could include the proper internal functioning of the device, the presence of a sufficient number of navigation signals, sufficient quality of the signals, and sufficiently low geometric dilution of precision.

Internal navigation device cold start shall be forced at every beacon activation. Cold start refers to the absence of time dependent or position dependent data in memory, which might affect the acquisition of the GNSS position.

With a clear view of the sky the distance between the horizontal position provided by the navigation device, at the time of the position update, and the actual navigation device position shall not exceed 30 m 95% of the time. The distance between the vertical position (altitude) provided by the navigation device, at the time of the position update, and the actual navigation device position shall not exceed 50 m 95% of the time. The encoded position data shall be provided in a format compatible with the International Terrestrial Reference System (ITRS) and its reference frames (ITRF) such as the WGS 84 or GTRF. The difference between the chosen format and the ITRF shall not exceed 10 cm.

The navigation device shall provide an indication of the potential error of each provided position in terms of Horizontal Dilution of Precision (HDOP) and Vertical Dilution of Precision (VDOP) and shall encode the respective DOP values in the message in accordance with section 3.3.

The navigation device shall provide the following additional information for each provided position whether it has no Fix or was operating in 2D or 3D Mode and shall encode this data in the message in accordance with section 3.3. If a valid 3D location (including height) is available then this shall be transmitted, however if a 3D location is not available but a valid 2D location is then this shall be transmitted instead.

First provision of encoded location within a transmitted message shall occur within 2 minutes with a 95% probability, with a clear view of the sky.

The Internal navigation device shall operate continuously during the initial 30 minutes period following beacon activation. During this period the beacon shall acquire fresh position information immediately prior to every transmission burst unless this becomes impractical due to navigation signal constraints.

During the first 30 minutes after beacon activation the location transmitted by the beacon shall always be the latest information provided by the navigation device. This applies even if the quality of the location has become worse. The navigation device shall provide an updated location at least every 1 second and the update immediately prior to the next scheduled transmission burst shall be encoded and transmitted by the beacon within 1 second of receipt.

After the first 30 minutes, the navigation device shall make at least one attempt every 15 minutes to obtain an initial location until an initial location is obtained or 2 hours has passed since beacon activation.

After the first 30 minutes once an initial location is obtained or 2 hours has passed since beacon activation, the navigation device shall attempt location updates following the regime set out below:

- In the first 6 hours the navigation device shall attempt at least one location update every 30 minutes

- Beyond 6 hours a location update shall be attempted at least every 60 minutes for the life of the battery

Whenever the beacon has fresh encoded location data at the start of a burst, this shall be indicated within the message by zeroing the "time from last encoded location" field as required by section 3.3.

If no position is available then the beacon shall transmit either default position data (if it has no position) or the last received position until such time as a fresh position is available. In addition the beacon shall compute the elapsed time since the last position update (or since activation) to an accuracy of 10 seconds and provide this in the transmitted message to a resolution of the nearest minute as required by section 3.3.

Internal navigation devices shall be enabled prior to 406 MHz transmissions. Each location update attempt shall require the navigation device to be operational for a period of at least 90 seconds or until a valid location has been obtained whichever is shortest.

If the internal navigation device fails to provide a location during the two location update attempts immediately previous to the current location update attempt, then the current update attempt shall be extended to a minimum duration of 3 minutes scheduled immediately prior to the next planned location update.

4.5.5.3 Internal Navigation Device ELT(DT)s only

An internal navigation device shall be capable of global operation and should conform to an applicable international standard.

An internal navigation device shall incorporate self-check features to ensure that erroneous position data is not encoded into the beacon message. The self-check features shall prevent position data from being encoded into the beacon message unless minimum performance criteria are met. These criteria could include the proper internal functioning of the device, the presence of a sufficient number of navigation signals, sufficient quality of the signals, and sufficiently low geometric dilution of precision.

The ELT (DT) navigation system shall be cold-started on initial power-up (ELT(DT) in ARMED mode see section 4.5.6.1), but shall not be cold started if the ELT(DT) is subsequently activated or between ELT(DT) transmissions. Cold start refers to the absence of time dependent or position dependent data in memory, which might affect the acquisition of the GNSS position.

With a clear view of the sky the distance between the horizontal position provided by the navigation device, at the time of the position update, and the actual navigation device position shall not exceed 30 m 95% of the time. The distance between the vertical position (altitude) provided by the navigation device, at the time of the position update, and the actual navigation device position shall not exceed 50 m 95% of the time. The encoded position data shall be provided in a format compatible with the International Terrestrial Reference System (ITRS) and its reference frames (ITRF) such as the WGS 84 or GTRF. The difference between the chosen format and the ITRF shall not exceed 10 cm.

The navigation device shall provide the following additional information for each provided position whether it has no Fix or was operating in 2D or 3D Mode and shall encode this data in the message in accordance with section 3.3. If a valid 3D location (including height) is available then this shall be transmitted, however if a 3D location is not available but a valid 2D location is then this shall be transmitted instead.

First provision of encoded location within a transmitted message shall occur within 3 seconds[*] with a 95% probability, with a clear view of the sky.

The Internal navigation device shall operate continuously during the initial 30 minutes period following beacon activation, subsequently each location update attempt prior to every 406 MHz transmission shall require the navigation device to be operational for a period of at least 90 seconds or until a valid location has been obtained whichever is shortest. If the internal navigation device fails to provide a location during the two location update attempts immediately previous to the current location update attempt, then the current update attempt shall be extended to a minimum duration of 3 minutes scheduled immediately prior to the next planned location update.

ELT(DT)s shall attempt to acquire fresh position information prior to every 406 MHz transmission (unless this becomes impractical due to navigation signal constraints) for the entire operating lifetime of the ELT (DT) and shall encode the latest position obtained within less than 1 second prior to each burst into that transmission. If an updated position is not available within 1 second immediately prior to every 406 MHz transmission, then the ELT(DT) shall transmit the latest position that it has, unless this position is more than 24 hours old, in which case it shall revert to transmitting the default position until such time as an updated position is available.

ELT (DT)s shall provide the UTC time of the last encoded location to an accuracy and resolution of 1 second and provide this in the transmitted message as required by section 3.3, Table 3.5. If UTC is not available for an encoded location, or if the time of the last encoded location is over 24 hours old then the ELT(DT) shall transmit default data.

4.5.5.4   External Navigation Device Input

It is recommended that beacons, which are designed to accept data from an external navigation device, be compatible with an applicable international standard, such as the IEC Standard on Digital Interfaces (IEC Publication 61162). The input must be able to provide all relevant position

---

[*] The ELT(DT)'s internal navigation device or even the entire ELT(DT) may be powered by an external source prior to its activation in order to comply with this requirement, but shall be powered solely by the ELT(DT)'s internal power source immediately after activation of the ELT(DT).

data as required by sections 3.2 and 3.3, this includes horizontal position, vertical position (altitude), time of this position to an accuracy of 1 second, HDOP, VDOP and, No Fix or 2D or 3D operating. Examples of suitable Maritime IEC 61162-1 sentences to achieve this objective include GNS and GSA and Aviation ARINC 429 labels to achieve this objective include Label 101, 102, 310, 311 etc. The beacon user manual shall include details of the acceptable interfaces.

In addition to providing horizontal position and altitude the external navigation input shall provide an indication of the potential error of each provided position in terms of Horizontal Dilution of Precision (HDOP) and Vertical Dilution of Precision (VDOP) and shall encode the respective DOP values in the message in accordance with section 3.3.

The external navigation input shall indicate for each provided position whether it has no Fix or was operating in 2D or 3D Mode and the beacon shall encode this data in the message in accordance with section 3.3. If a valid 3D location (including height) is available then this shall be transmitted, however if a 3D location is not available but a valid 2D location is then this shall be transmitted instead.

In static conditions the distance between the horizontal position provided by the external navigation input, at the time of the position update, and the position transmitted by the beacon shall not exceed 30 m 95% of the time. The distance between the vertical position (altitude) provided by the external navigation input, at the time of the position update, and the position transmitted by the beacon shall not exceed 50 m 95% of the time.

First provision of encoded location within a transmitted message shall occur within 3 seconds with a 95% probability, with a clear view of the sky.

During the first 30 minutes after beacon activation the location transmitted by the beacon shall always be the latest information provided by the external navigation input. This applies even if the quality of the location has become worse. The external navigation input shall provide an updated location at least every 1 second and the update immediately prior to the next scheduled transmission burst shall be encoded and transmitted by the beacon within 1 second of receipt.

After the first 30 minutes, the external navigation input shall make at least one attempt every 15 minutes to obtain an initial location until an initial location is obtained or 2 hours has passed since beacon activation.

After the first 30 minutes once an initial location is obtained or 2 hours has passed since beacon activation, the external navigation input shall attempt location updates following the regime set out below:

- In the first 6 hours the external navigation input shall attempt at least one location update every 30 minutes

- Beyond 6 hours a location update shall be attempted at least every 60 minutes for the life of the battery

Whenever the beacon has fresh encoded location data at the start of a burst, this shall be indicated within the message by zeroing the "time from last encoded location" field as required by section 3.3.

If no position is available then the beacon shall transmit either default position data (if it has no position) or the last received position until such time as a fresh position is available. In addition the beacon shall compute the elapsed time since the last position update (or since activation) to an accuracy of 10 seconds and provide this in the transmitted message to a resolution of the nearest minute as required by section 3.3.

4.5.6   Beacon Activation

Beacons shall have a means of manual activation and deactivation and may optionally also include means of automatic activation (for ELT (DT)s see section 4.5.6.1 below).

The beacon shall be designed to prevent inadvertent activation.

Within 1 second after activation, the beacon shall provide a visual indication that it has been activated.

For beacons which can be remotely activated, there shall be an indicator on both the remote activation device and the beacon.

The beacon (except ELT(DT)s) shall track time since activation to an accuracy of 10 minutes and provide this in appropriate transmitted messages to a resolution of the nearest one hour as required by section 3.3.

4.5.6.1   ELT(DT) Modes of Operation

ELT(DT)s shall allow for automatic and manual means of activation. ELT(DT)s shall also have means of deactivation by the same means of activation which shall be followed by a cancellation message sequence.

Consequently:

- If the ELT(DT) has been automatically activated by the triggering system, it shall only be de-activated by the same means.

- If the beacon has been manually activated (i.e., from the cockpit), it shall only be manually de-activated.

- If the beacon has been activated by any combination of activation means, it can only be de-activated once each activation means has been deactivated.

Thus an ELT(DT) shall as a minimum have the following modes of operation:

OFF - The complete ELT(DT) (and any related components) is/are unpowered

ARMED - The ELT(DT) or some parts of it may if required be powered up, such that when it is activated by an automatic triggering system* or manually, it can start transmitting within 3 seconds and meet the requirements in this specification for ELT(DT)s including the provision of encoded location in the first burst. However until the ELT(DT) is activated there are no outputs from the ELT(DT) at all (e.g. no 406 MHz or Homing Signal transmissions)

---

* For example, triggered in compliance with EUROCAE ED-237 or by G-switch / deformation.

ON - The ELT(DT) has been either activated by an automatic triggering system and/or has been manually activated and is transmitting 406 MHz signals in full compliance with the ELT(DT) requirements in this specification.

RESET – The ELT(DT) is deactivated and ceases transmitting distress alerts and instead transmits a sequence of cancellation messages as defined by Section 4.5.7. Upon completion of the cancellation message sequence, the ELT(DT) reverts to the ARMED condition. The ELT(DT) can only be deactivated as defined above.

4.5.7 Beacon Activation Cancellation Function

The beacon shall include a beacon activation cancellation function. This shall be a separate function from the on/off capability of the beacon. The cancellation function shall be protected from inadvertent activation and shall be triggered by two simple and independent actions that provide confidence in intentional cancellation action by the user. ELT (DT)s shall include a means of automatic cancellation from the same source as the aircraft automatic activation.

When the beacon is deactivated the beacon shall transmit 10 identical cancellation messages transmitted at intervals of 10 seconds ±0.5 seconds, after which time the beacon shall cease transmitting. In the case the beacon is activated (e.g., triggered) during the cancellation sequence, the beacon shall terminate the cancellation transmission sequence and reinitiate the alert sequence per section 2.2.1.

When the beacon activation cancellation function is enabled it shall comply with section 3.4, Table 3.1 and Table 3.4.

4.5.8 Verification of Registration

See footnote.[*]

4.5.9 ELT (DT) Triggered In-Flight Operation

The in-flight triggered ELT (DT) operation should be activated by a means outside of the ELT (DT).

ELTs with this capability shall also transmit encoded location data as available in the beacon message as specified in the appropriate parts of section 4.5.5.

4.5.10 RLS Function

If a beacon is equipped with a Return Link Service (RLS) functionality, it shall meet the following additional requirements.

---

[*] C/S G.008 Section 3.13 describes an operational beacon requirement to design the beacon such that the registration status of the beacon is displayed to the beacon user. The registration status shall remain valid for a period of two years and the beacon shall be designed such that the self-test function indicates by default that the beacon is not registered. National Administrations have a variety of registration renewal requirements and methods for registration verification. The lack of a common approach makes it difficult to identify a specific specification to achieve the requirement at this time. It's possible that in the future that a common approach would be identified, but until such time, compliance with this requirement is not met by SGBs in C/S T.018.

4.5.10.1 GNSS Receiver

The RLS beacon shall contain an internal GNSS Receiver capable of receiving and decoding Return Link Messages (RLMs) from a Cospas-Sarsat recognised Return Link Service Provider (RLSP) and of providing these messages to the beacon in an IEC 61162-1 RLM compliant sentence.

The following Return Link Message has been defined by Cospas-Sarsat to date:

- Type-1 An automated response that simply acknowledges receipt of the RLS request.

The definition of the Type-1 RLM message content included as part of the Galileo L1 navigation message is defined in the Galileo Open Service Public Signal in Space ICD Issue 1.3.

4.5.10.2 RLS GNSS Receiver Operation

4.5.10.2.1 Operation Cycle

In addition to the beacons normal GNSS receiver operating cycle as defined in sections 4.5.5.2 and 4.5.5.4 or as defined by the beacon manufacturer if in excess of this requirement, the RLS beacon shall:

a) within 5 seconds of the beacon transmitting its first RLS Rotating Field message maintain the GNSS receiver in an active mode of operation such that it can continuously check for receipt of an RLM message for a minimum period of 30 minutes or until the beacon is deactivated if this occurs first;

b) as soon as possible determine Coordinated Universal Time (UTC) from the GNSS receiver and maintain a clock for the operating lifetime of the beacon to an accuracy of better than one second or until the beacon is deactivated;

c) After the first 30 minutes, utilise UTC time to activate the GNSS receiver at the time given by M_{offset} past each subsequent hour until the beacon is deactivated or the beacon battery has expired:

At M_{offset} minutes, with $0 \leq M_{offset} \leq 59$, past the next natural hour since end of the initial GNSS receiver 30 minute activation period to check for receipt of an RLM for a minimum period of 15 minutes; and

d) If UTC is not available after the first 30 minutes the beacon shall attempt to establish UTC using the timings detailed in sections 4.5.5.2 and 4.5.5.4. If UTC is then established the beacon shall continue as per c) above.

The GNSS receiver in the beacon continues with this operation mode until the expiration of the battery even if a Type 1 RLM has been received.

For instance, if the beacon transmitted an RLS protocol at 03.17h UTC, then the GNSS receiver would remain active until at least 03.47h UTC or until the beacon is deactivated if it is deactivated before that time. It would then re-activate at 04:00+Moffset and remain active until at least 04.00+M_{offset}+15 or until the beacon is deactivated and it would then reactivate again at 05:00+M_{offset} until 05.00+M_{offset}+15. The scheme continues until the battery has expired or the beacon is deactivated.

The RLS beacon may contain an internal GNSS receiver capable of receiving and decoding other type of acknowledgment RLM following the same operation cycle as the one described.

4.5.10.2.2   Derivation of M_{offset}

The value of M_{offset} for each beacon is computed from the beacon 15 Hex ID subset of the 23 Hex ID (see section 3.4). More specifically:

$$M_{offset} = BIN2DEC\ (CRC16(Beacon\ 15\ Hex\ ID\ in\ Binary))\ mod\ 60$$

Where BIN2DEC and CRC16 are functions performing the conversion of binary number to a decimal number and the CRC-16 of a stream of bits with polynomial $x^{16}+x^{15}+x^2+1$ respectively. The CRC-16 is used to obtain a uniform distribution of M_{offset}.

4.5.10.3 RLS Indicator

The beacon shall be provided with an RLS indicator designed to advise the user when a Type 1 RLS message has been received by the RLSP and the beacon has received a Type 1 Return Link Message (RLM). The RLS Indicator shall:

a) be readily visible to the user when the beacon is operated in all its normal operational configurations as declared by the manufacturer;
b) be clearly visible to the user in direct sunlight;
c) provide a distinct unique indication;
d) remain inactive at all times when the beacon message is encoded with any message content other than the RLS Rotating Field;
e) within 5 seconds of the beacon transmitting an initial RLS request, commence indication of an RLS request until either a valid RLM Type 1 message is received, or the beacon is deactivated, or the beacon battery is expired;
f) within 5 seconds of the beacon receiving a valid RLM Type 1 message acknowledgement, commence a distinct indication until either the beacon is deactivated or the beacon battery is expired; and
g) only provide the indication of receipt of an RLS request acknowledgment when the received RLM Type 1 message contains the unique 15 Hex ID subset of the 23 Hex ID programmed into that beacon and the beacon has validated that this matches its own 15 Hex ID subset of its 23 Hex ID.

4.5.10.4 Confirmation of a Return-Link Message Receipt

Upon receipt of an Acknowledgement Type-1 RLM or a Test RLM associated with the beacon 15 HEX ID, the beacon shall, within 1 minute, acknowledge the RLM receipt by changing the coding of its message as defined in the RLS rotating field, as described in section 3.3. Once changed, the RLM beacon feedback field shall no longer be changed until a different RLM message is received or beacon is switched off or the beacon battery is depleted.

4.5.10.5 RLS Beacon Documentation

The operation of the RLS function shall be clearly explained in the User Manual including any limitations of the overall RLS system.

4.5.11   Battery Status Indication

The battery status indication provides the user with an indication prior to beacon activation that the battery may be partially depleted and may not operate for the full specified operating lifetime.

Beacons powered by a rechargeable battery shall automatically provide an indication when the battery requires recharging. Beacons powered by a non-rechargeable battery may provide an indication of battery status during a self-test.

If provided this shall be a separate indication to the self-test pass/fail indication and the battery status indicator shall be activated when the battery in the beacon may not have sufficient energy to support beacon operation for the declared operating lifetime.

4.5.12   Beacon Labelling

All beacons shall have the following information durably marked on the exterior of the beacon:

1)   The beacon 23 Hex ID

2)   The beacon operating temperature range

3)   The minimum duration of continuous operation

4.5.13   Beacon Instruction Manual

An End User instruction manual shall be made available with all beacons, it shall include the information as outlined in the data item description (Annex G of document C/S T.021).

4.5.14   Beacon Data Requirements

The manufacturer shall make available for the purposes of supporting the type approval review the information as outlined in the data item description (Annex G of document C/S T.021).

- END OF SECTION 4 -

APPENDIX 1 [TO BE REVISED]

LIST OF ACRONYMS [NOTE: TO BE FURTHER DEVELOPED]

BCD	binary-coded decimal
BCH	Bose-Chaudhuri-Hocquenghem (code)
BCH-1	first BCH error correcting field
BCH-2	second BCH error correcting field
C/S	Cospas-Sarsat
DSSS	direct-sequence spread-spectrum
ELT	emergency locator transmitter
EPIRB	emergency position indicating radio beacon
F	format flag
GHz	gigahertz
GNSS	Global Navigational Satellite System
Hex	Hexadecimal
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
ITU	International Telecommunication Union
LSB	least significant bit
LUT	local user terminal
MHz	megahertz
MID	maritime identification digits
MMSI	maritime mobile service identity
ms	millisecond
MSB	most significant bit
NB	narrowband
P	protocol flag
PC	protocol code
PDF-1	first protected data field
PDF-2	second protected data field
PLB	personal locator beacon
PRN	pseudo-random noise
RHCP	right hand circular polarization
RMS	root mean square
RTCA	Radio Technical Commission for Aeronautical Services (USA)
SART	search and rescue radar transponder
SS	spread-spectrum
TAC	type approval certificate
VSWR	voltage standing-wave ratio

- END OF APPENDIX 1 -

APPENDIX 2

SAMPLE BOSE-CHAUDHURI-HOCQUENGHEM
ERROR-CORRECTING CODE CALCULATION

Sample 48-Bit BCH Code Calculation

The error-correcting code used in 406 MHz messages is a shortened form of a (255,207) Bose-Chaudhuri-Hocquenghem (BCH) code. The shortened form (250,202) consists of 202 bits of data followed by a 48-bit sextuple error-correcting code. The code is used to detect and correct up to six errors in the entire 250-bit pattern (bits 1 through 250 of the 406 MHz message).

Note: For the purpose of error correction, all calculations shall be performed with the full 255 length code. Therefore, 5 zeros are placed before the 202 data bits to form the 207 bit pattern of the (255,207) BCH code. These padding zeros do not affect the generation of the BCH code as described below.

For the (250,202) BCH code, a generator polynomial g(X) (the same as for (255,207) BCH code) is defined as follows:

$$g(X) = LCM(m_1(X), m_3(X), m_5(X), m_7(X), m_9(X), m_{11}(X))$$

where LCM = Least Common Multiple.

In the above case:

$$m_1(X) = X^8 + X^4 + X^3 + X^2 + 1$$

$$m_3(X) = X^8 + X^6 + X^5 + X^4 + X^2 + X + 1$$

$$m_5(X) = X^8 + X^7 + X^6 + X^5 + X^4 + X + 1$$

$$m_7(X) = X^8 + X^6 + X^5 + X^3 + 1$$

$$m_9(X) = X^8 + X^7 + X^5 + X^4 + X^3 + X^2 + 1$$

$$m_{11}(X) = X^8 + X^7 + X^6 + X^5 + X^2 + X + 1$$

from which

$$
\begin{aligned}
g(X) \quad &= m_1(X), m_3(X), m_5(X), m_7(X), m_9(X), m_{11}(X) \\
&= X^{48} + X^{47} + X^{46} + X^{42} + X^{41} + X^{40} + X^{39} + X^{38} + X^{37} + X^{35} + X^{33} + X^{32} + X^{31} \\
&\quad + X^{26} + X^{24} + X^{23} + X^{22} + X^{20} + X^{19} + X^{18} + X^{17} + X^{16} + X^{13} + X^{12} + X^{11} + X^{10} + X^7 + X^4 + X^2 \\
&\quad + X + 1
\end{aligned}
$$

a determination of g(X) results in the following 49-bit binary number

$$g(X) = 1110001111110101110001011101111001110010010111$$

To generate the BCH code, an information polynomial, m(x) is formed from the 202 data bits as follows:

$$m(X) = b_1 X^{201} + b_2 X^{200} + \cdots + b_{201} X + b_{202}$$

where b_1 - is the first bit (i.e. fixed binary '1' or the first bit of 23-HEX ID), and b_{202} - is the last bit of the message.

m (X) is then extended to 250 bits by filling the least significant bits with 48 "0". The resulting 250-bit binary string is then divided by g(X) and the remainder, r(X), becomes the BCH code (the quotient portion of the result of the module-2 binary division is discarded).

The above process may be clarified by the following example. Suppose, that digital message consists of the following data (decimal notation):

Country code	201
TAC number	230
Serial Number	573
Type of Vessel	6
Vessel ID	0
Status of homing device	1
Self-Test function	1
User cancellation	0

Message also contains encoded GNSS location. This example uses the following values of position data:

Current latitude	48,793153539336956 °N
Current longitude	69,00875866413116 °E
Altitude	430,24 м

Encoded GNSS location in binary notation:

Current latitude	00110000011001110100011
Current longitude	00100010100000010010010

In this example Rotating Field 1 (C/S G.008 Objective Requirements) is used. Suppose, that 1 hour 27 minutes and 24 seconds (1 hour after truncation) had passed since radiobeacon activation, and 6 minutes and 24 seconds had passed since last encoded location (6 minutes after truncation), then the content of rotating field will be the following (binary notation):

Rotating field identifier	0000
Elapsed time since activation	000001
Time from last encoded location	00000000110
Altitude of encoded location	0000110011
Dilution of precision	00000001
Automated/Manual activation notification	00
Remaining battery capacity	101
GNSS status	10

Thus, digital message in hexadecimal and binary notation will be the following:

23 HEX ID	99340039A3DC00000000001 (bits 1-92)	
Message*	99340039A3DC00000000001C60CE8C8A024BFFC0100C198096C (bits 1-202)	
Bits 1-202	1001 1001 0011 0100 0000 0000 0011 1001	
	1010 0011 1101 1100 0000 0000 0000 0000	
	0000 0000 0000 0000 0000 0000 0001 1100	
	0110 0000 1100 1110 1000 1100 1000 1010	
	0000 0010 0100 1011 1111 1111 1100 0000	
	0001 0000 0000 1100 0001 1001 1000 0000	
	1001 0110 11	

* As the length of the message in bits is not divisible by 4, message was supplemented with two binary '0', which gave in hexadecimal notation symbol 'C' at the end of the message.

The division [*] described above is shown in Figure A1, and results in a 49-bit remainder of:

0001110000010111100000000111010001001100000010110

The most significant bit position of the remainder will always be a "0" and is deleted to obtain the 48-bit BCH code.

Thus BCH Error-Correcting Code:

001110000010111100000000111010001001100000010110

REFERENCE

An Introduction to Error Correcting Codes, Shu Lin, Prentice Hall 1970

[*] Modulo 2 division prohibits a "borrow" in the subtraction portion of the long division.
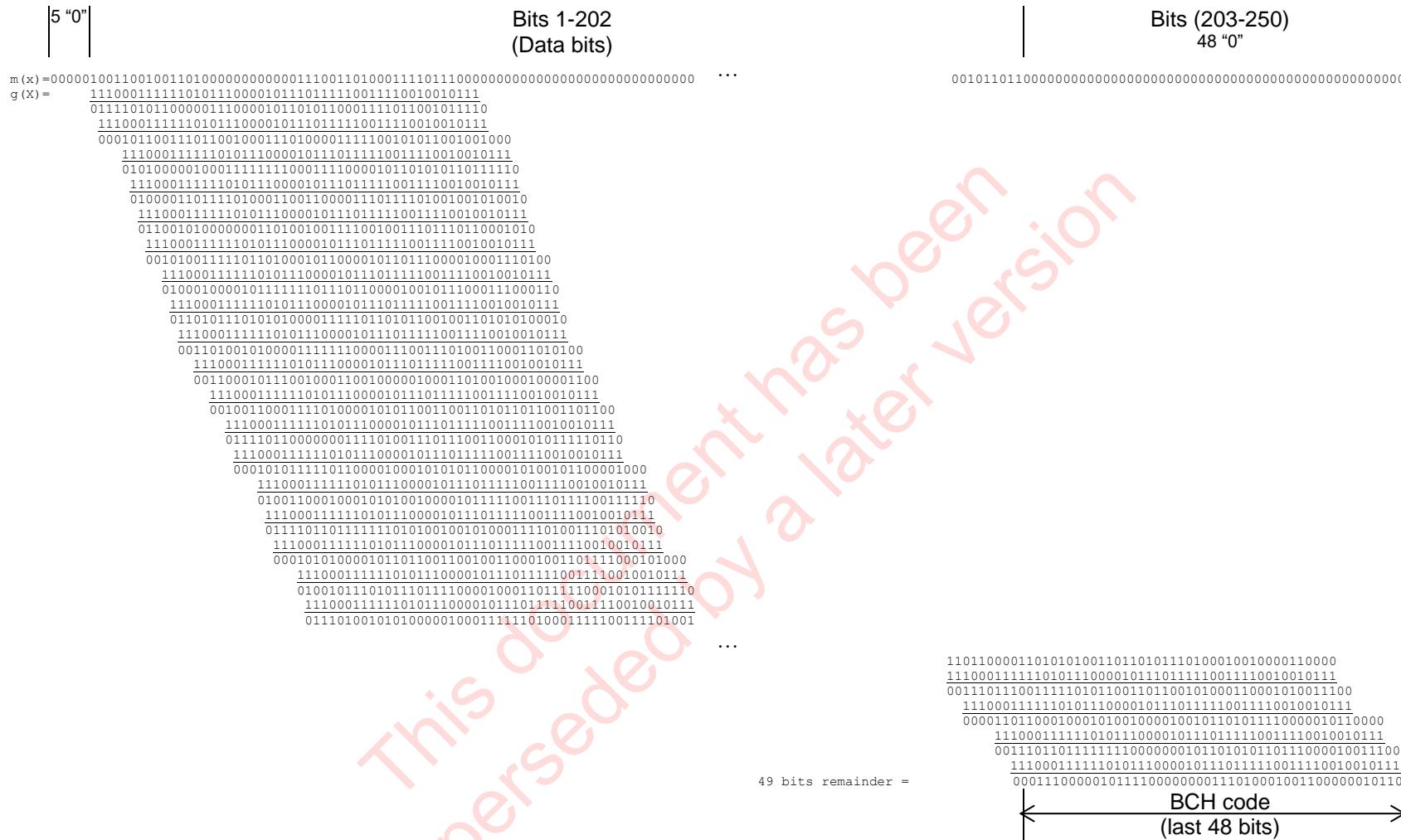
Figure A2-1: Sample 48-Bit BCH Error-Correcting Code Calculation
(for easier viewing the calculation is reduced and divided into 2 parts)

- END OF APPENDIX 2 -

APPENDIX 3

BEACON ENCODED LOCATION CODING

1.1 ENCODED LOCATION PROTOCOL

This section defines the encoded location protocol which can be used with the 406 MHz beacon message formats for encoding beacon position data in the digital message transmitted by a 406 MHz distress beacon.

1.2 Summary

Encode location is represented differently in second generation beacons. In first generation beacons, degrees, minutes and seconds were used. For second generation beacons, degrees and decimal part of the degrees are used. Moreover, there is no coarse and fine offset fields: all information appears in one field. Moreover, there is no separate return link location protocol. Instead, RLS data is contained in one of the rotating fields.

1.3 Default Values in Position Data

The following default values shall be used in all encoded position data fields of the location protocols, when no valid data is available:

a) all bits in the degrees are set to "1", with N/S, E/W flags set to "0"; and

b) the bits in the decimal parts of the degrees are set to the following patterns:
   i. Latitude: 000001111100000 (Note the first five decimal parts of degrees bits are set to "0"s, the middle five bits are set to "1" s and the last 5 bits are set to "0"s)

   ii. Longitude: 111110000011111 (Note the first five decimal parts of degrees bits are set to "1"s, the middle five bits are set to "0" s and the last 5 bits are set to "1"s)

The default pattern shall also be transmitted in the self-test mode. Additionally, if a location protocol beacon includes an optional GNSS self-test and this fails to provide a valid location to encode into the transmitted self-test message, then the beacon may radiate a single self-test message with the above default data. However if a location protocol beacon with optional GNSS self-test obtains a location, then the beacon shall radiate a single self-test message with encoded position.

This default bit pattern is different from first generation beacons. The degree bits are all set to "1"s as in first generation beacons. But it is not easy to set the minutes bit to "0"s and the seconds bits to "1"s as the decimal parts do not fall on integer minute or second boundaries.

1.4   Definition of Location Protocols

The general structure of location protocols is illustrated in table TBD

1.4.1   Encoded Location field

The 47 bits available in the main digital message are defined as follows:

a)   bits 44-66:   latitude data (23 bits), including:

- bit 44:   N/S flag (N=0, S=1)
- bits 45-51:   degrees (0 to 90) in 1 degree increments
- bits 52-66:   decimal parts of degrees

b)   bits 67-90:   longitude data (24 bits), including:

- bit 67:   E/W flag (E=0, W=1)
- bits 68-75:   degrees (0 to 180) in 1 degree increments
- bits 76-90   decimal parts of degrees

1.4.2   Encoded Location Data (1)

All position information is encoded as degrees, and decimal parts of latitude or longitude. Latitude and longitude data are rounded off (i.e., not truncated) to the available resolution. All rounding shall follow normal rounding conventions, for example with a resolution of 4, 0.000 to 1.999 shall be rounded down to 0 and 2.000 to 3.999 shall be rounded up to 4. In each location field the Most Significant Bit (MSB) is the lowest numbered bit in the message which is not a N/S, or E/W flag bit.

The following table illustrates the bit assignments for the degrees portion of the encoded location field.

Latitude Bit assignment	Longitude Bit assignment	Bit value in degrees
N/A	68 (MSB)	128
45 (MSB)	69	64
46	70	32
47	71	16
48	72	8
49	73	4
50	74	2
51	75	1

The following table illustrates the bit assignments for the decimal parts of the degrees portion of the encoded location field. The equivalent in minutes and seconds is also provided. The resolution in meters of each bit of longitude at the equator is also given, with the resolution of each latitude bit 0.169% less than for the longitude bit (at the equator). This reflects the fact that the circumference around the earth at the equator is 40,075.16 Km and 40,008 Km for each meridian.

Latitude bit assignment	Longitude Bit assignment	Bit value of decimal parts in degrees	Bit value of decimal parts in minutes	Bit value of decimal parts in seconds	Resolution in meters (equator)
52	76	0.5	30	1800	55566.67
53	77	0.25	15	900	27783.33
54	78	0.125	7.5	450	13891.67
55	79	0.0625	3.75	225	6945.833
56	80	0.03125	1.875	112.5	3472.917
57	81	0.015625	0.9375	56.25	1736.458
58	82	0.0078125	0.46875	28.125	868.2292
59	83	0.00390625	0.234375	14.0625	434.1146
60	84	0.001953125	0.1171875	7.03125	217.0573
61	85	0.000976563	0.05859375	3.515625	108.5286
62	86	0.000488281	0.029296875	1.7578125	54.26432
63	87	0.000244141	0.014648438	0.87890625	27.13216
64	88	0.00012207	0.007324219	0.439453125	13.56608
65	89	6.10352E-05	0.003662109	0.219726563	6.78304
66	90	3.05176E-05	0.001831055	0.109863281	3.39152

1.5   Instructions for converting Latitudes and Longitudes to a Binary Number

Global Navigation Satellite System receivers (e.g. GPS, Glonass, Galileo etc.) normally output position data using an IEC 61162-1 (NMEA 0183) formatted sentence. This will provide a position in decimal degrees, minutes and parts of a minute as a decimal fraction in a defined format for example "3546.295, N, 14821.291, W". That is 35 degrees and 46.295 minutes North by 148 degrees and 21.291 minutes West. The size of the decimal fraction is not defined In IEC 61162-1, but in order to ensure adequate accuracy initially and during subsequent rounding processes the number of digits after the decimal point should not be less than 3.

In order to transmit this as a part of a Second Generation Beacon message it is necessary to convert the position into a binary number expressed as degrees and a decimal fraction of a degree. The following text provides an example of how this can be achieved.

Referring to C/S T.018 Table 3.1 Encoded GNSS Location we can see that the required message format is as follows:

No of Bits	Content
1	N/S flag (N=0, S=1)
7	Degrees (0 to 90) in 1 degree increments
15	Decimal parts of a degree (0.5 to 0.00003)
1	E/W flag (E=0. W=1)
8	Degrees (0 to 180) in 1 degree increments
15	Decimal parts of a degree (0.5 to 0.00003)

The use of the bits for the N/S or E/W flags and the encoding of Degrees is straightforward and no further explanation is deemed necessary. But converting minutes and a decimal fraction of a minute to decimal parts of a degree and then to binary is less obvious, so an example of this is provided below. Using the example above "3546.295, N" in binary would appear as follows:

N/S	Degrees							Decimal Parts of a Degree													
0/1	64	32	16	8	4	2	1	1/2	1/4	1/8	1/16	1/32	1/64	..	..	..	..	..	..	..	..	..
0	0	1	0	0	0	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	1	1

Initially the minutes and decimal fraction of minutes must be converted into a decimal fraction of a degree, this is achieved by simply dividing the whole number by 60 e.g. 46.295 Minutes divided by 60 equals 0.77158333 Degrees. Again in order to maintain accuracy this number should be rounded to no less than [5] decimal places e.g. [0.77158]. So 35 Degrees and 46.295 Minutes becomes [35.77158] Degrees.

Two procedures for converting decimal parts of a degree to binary are provided below, the first uses the Successive Multiplication Method while the second uses the Integral Number Conversion Method.

Successive Multiplication Method

1) Start with the decimal fraction part and multiply it by 2 (add it to itself)
2) If the result is greater than 1 then the first decimal fraction is a 1, if the result is less than 1 then the first decimal fraction is a 0
3) If the result was greater than 1 then subtract 1 from the result
4) Multiply the remaining number by 2
5) Repeat step 2) to obtain the second decimal fraction and then repeat steps 3) and 4)
6) Repeat step 5) for all the remaining decimal fractions
7) On completing the final step to obtain the fifteenth digit again repeat step 3), if the remainder is 0.5 or greater then increase the computed binary number by one to round to the closest possible number, or if the remaining number is less than 0.5 then use the binary number as computed

The above example is provided below:

1) 0.77158 x 2 = 1.54316 thus the first digit is a 1
2) 1.54316 – 1 = 0.54316
3) 0.54316 x 2 = 1.08632 thus the second digit is a 1
4) 1.08632 – 1 = 0.08632
5) 0.08632 x 2 = 0.1728 thus the third digit is a 0
6) 0.17264 x 2 = 0.34528 thus the fourth digit is a 0
7) 0.34528 x 2 = 0.69056 thus the fifth digit is a 0
8) 0.69056 x 2 = 1.38112 thus the sixth digit is a 1
9) 1.38112 – 1 = 0.38112
10) 0.38112 x 2 = 0.76224 thus the seventh digit is a 0
11) Keep going as above

12) 0.78336 x 2 = 1.56672 thus the fourteenth digit is a 1
13) 1.56672 – 1 = 0.56672
14) 0.56672 x 2 = 1.13344 thus the last digit is a 1
15) 1.13344 – 1 = 0.13344
16) If the remaining number is 0.5 or greater then increase the computed binary number above by one to round to the closest possible number, or if the remaining number is less than 0.5 then use the binary number computed above
17) In this example, one computed 110001011000011, applying the rounding rule above means that in this instance the actual binary number to use is the same

Integral Number Conversion Method
1) Start with the decimal fraction part and multiply it by 2^{15} (2 to the power of 15)
2) Round the result to the nearest whole number
3) Convert this number to binary
4) The result is the binary fraction of the decimal fraction

The above example is provided below:
1) $0.77158 \times 2^{15} = 25283.13344$
2) Rounding gives us 25283
3) Converting 25283 to binary gives 110001011000011

- END OF APPENDIX 3 -

APPENDIX 4

BIT ASSIGNMENT NUMBERS

Bits 1 to 43 of 202 Information bits

Bits 1 to 43 of 154 bit Main Field

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43
TAC Number (20 bits) (Part of 23 HEX ID)	Serial Number (10 bits) (Part of 23 HEX ID)	Country Code (10 bits) (Part of 23 HEX ID)	Homing / Self Test / Cancellation
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	35 36 37 38 39 40 41 42 43 44	3 4 5 6 7 8 9 10 11	

23 HEX ID bit numbers

Bits 44 to 90 of 202 Information bits

Bits 44 to 90 of 154 bit Main Field

44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
Encoded Location (47 bits)

Bits 91 to 137 of 202 Information bits

Bits 91 to 137 of 154 bit Main Field

91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137
Vessel ID (47 bits) (Part of 23 HEX ID)
45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91

23 HEX ID bit numbers

Bits 138 to 202 of 202 Information bits

Bits 138 to 154 of 154 bit Main Field	Rotating Field 0 (48 bits)							
138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154	155	156 157 158 159 160 161 162 163 164	165 166 167 168 169 170 171 172 173 174 175	176 177 178 179 180 181 182 183 184 185	186 187 188 189 190 191 192 193	194 195	196 197 198	199 200	201 202
Spares (17 bits)	Rotating Field Identifier	Elapsed Time (6 bits)	Time from Last Encoded Location (11 bits)	Encoded Location Altitude (10 bits)	Encoded location HDOP (8 bits)	Activation (2 bits)	Remaining Battery (2 bits)	GNSS Status (2 bits)	Spare (2 bits)
Rotating field bit number	1 2 3 4	5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20 21	22 23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40	41 42	43 44	45 46	47 48

Error Correction Code

48 bits

203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250
BCH (250, 202)

NOTE: When displaying a message as 63 hex characters, two zeroes are appended to the end of the message (bits 251 and 252)

- END OF APPENDIX 4 -