RCB-F9T

High accuracy timing board

Integration manual

Abstract

This document describes the features and application of RCB-F9T, a multi-band GNSS timing board offering nanosecond-level timing accuracy.

Document information

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Contents

1 Integration manual overview

This document is an important source of information on all aspects of RCB-F9T system, software and hardware design. The purpose of this document is to provide guidelines for a successful integration of the receiver with the customer's end product.

2 System description

2.1 Overview

The RCB-F9T timing board enables multi-band GNSS timing in a compact form factor using the ZED-F9T, the u-blox F9 high accuracy timing module. The ZED-F9T module provides nanosecond-level timing accuracy in both standalone and differential timing modes.

In addition to the ZED-F9T module, the RCB-F9T timing board contains an SMB antenna connector and 5 V power supply circuitry for an external active multi-band GNSS antenna. The 8-pin, 2.0 mm pitch pin-header provides powering of the board, UART communications, and two independently configurable time pulse signals.

2.1.1 Differential timing

The u-blox RCB-F9T high accuracy timing board takes local timing accuracy to the next level with its differential timing mode.

In differential timing mode correction data is exchanged with other neighboring RCB-F9T timing receivers via a communication network. In differential timing mode the RCB-F9T can operate either as a reference base station, or as a differential timing receiver station.

When RCB-F9T acts as a reference base timing station, it sends RTCM 3.3 differential corrections to differential timing receivers.

When RCB-F9T acts as a differential timing receiver, it receives differential corrections RTCM 3.3 messages and aligns its time pulse to the reference base station.

2.2 Architecture

The RCB-F9T timing board provides all the necessary RF and baseband processing to enable multi-band GNSS timing. The block diagram below (Figure 1) shows the key functionality implemented in the RCB-F9T.

2.2.1 Block diagram
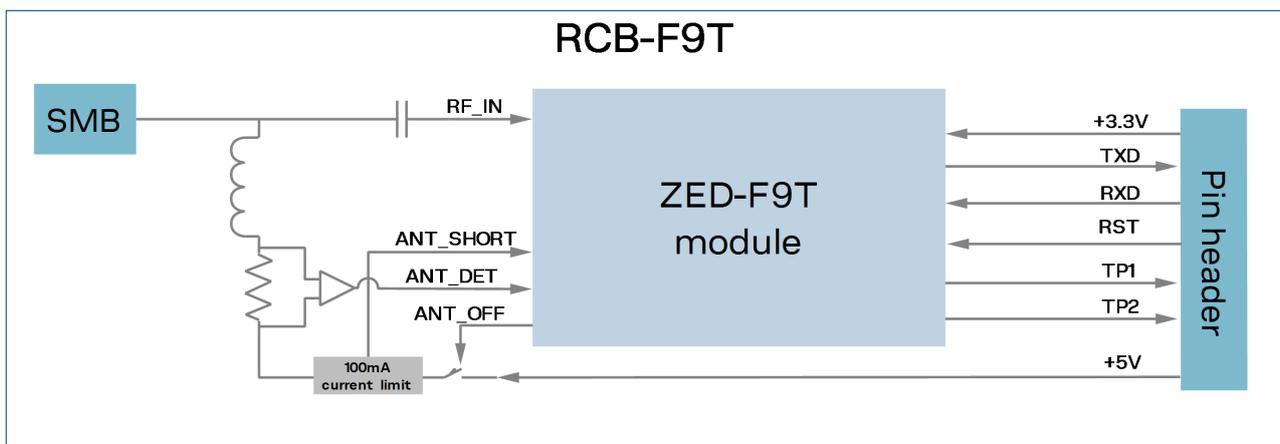
Figure 1: RCB-F9T block diagram

☞ An active antenna is mandatory with the RCB-F9T.

3 Receiver functionality

This chapter describes the RCB-F9T operational features and their configuration.

3.1 Receiver configuration

RCB-F9T is fully configurable with UBX configuration interface keys. The configuration database in the receiver's RAM holds the current configuration, which is used by the receiver at run-time. It is constructed on startup of the receiver from several sources of configuration. The configuration interface and the available keys are described fully in the applicable Interface description [2].

⚠ **CAUTION** The configuration interface has changed from earlier u-blox positioning receivers. Legacy messages have been deprecated and will not be supported in future firmware releases. Users are advised to adopt the configuration interface described in this document. See legacy UBX-CFG message fields reference section in the applicable Interface description [2].

Configuration interface settings are held in a database consisting of separate configuration items. An item is made up of a pair consisting of a key ID and a value. Related items are grouped together and identified under a common group name: CFG-GROUP-*; a convention used in u-center and within this document. Within u-center, a configuration group is identified as "Group name" and the configuration item is identified as the "item name" under the "Generation 9 Configuration View" - "Advanced Configuration" view.

The UBX messages available to change or poll the configurations are UBX-CFG-VALSET, UBX-CFG-VALGET, and UBX-CFG-VALDEL. For more information about these messages and the configuration keys, see the configuration interface section in the applicable Interface description [2].

3.1.1 Changing the receiver configuration

All configuration messages, including legacy UBX-CFG messages, will result in a UBX-ACK-ACK or UBX-ACK-NAK response. If several configuration messages are sent without waiting for this response then the receiver may pause processing of input messages until processing of a previous configuration message has been completed. When this happens a warning message "wait for cfg ACK" will be sent to the host.

3.1.2 Default GNSS configuration

The RCB-F9T default GNSS configuration is set as follows:

RCB-F9T-0:

- GPS: L1C/A, L2C
- GLONASS: L1OF, L2OF
- Galileo: E1B/C, E5b
- BeiDou: B1I, B2I
- QZSS: L1C/A, L2C

RCB-F9T-1:

- GPS: L1C/A
- GLONASS: L1OF
- Galileo: E1B/C, E5a
- BeiDou: B1I, B2a
- QZSS: L1C/A, L5

The NavIC L5 signal is supported by the RCB-F9T-1, but not enabled in the default GNSS configuration. SBAS is also supported but not enabled by default as it is not recommended for timing applications.

For more information about the default configuration, see the applicable Interface description [2].

3.1.3 Default interface settings

Interface	Settings
UART Output	115200 baud, 8 bits, no parity bit, 1 stop bit. NMEA **GGA, GLL, GSA, GSV, RMC, VTG, TXT** (and no UBX) messages are output by default.
UART Input	115200 baud, 8 bits, no parity bit, 1 stop bit. UBX, NMEA and RTCM 3.3 messages are enabled by default.

Table 1: Default configurations

☞ Refer to the applicable Interface description [2] for information about further settings.

By default the RCB-F9T outputs NMEA messages that include satellite data for all GNSS bands being received. This results in a higher-than-before NMEA load output for each navigation period. Make sure the UART baud rate being used is sufficient for the selected navigation rate and the number of GNSS signals being received.

3.1.4 Basic receiver configuration

This section summarizes the basic receiver configuration most commonly used.

3.1.4.1 Communication interface configuration

Several configuration groups allow operation mode configuration of the various communication interfaces. These include parameters for the data framing, transfer rate and enabled input/output protocols. The configuration groups available for each interface are:

Interface	Configuration groups
UART1	CFG-UART1-*, CFG-UART1INPROT-*, CFG-UART1OUTPROT-*

Table 2: Interface configurations

3.1.4.2 Message output configuration

The rate of the supported output messages is configurable.

If the rate configuration value is zero, then the corresponding message will not be output. Values greater than zero indicate how often the message is output.

For periodic output messages the rate relates to the event the message is related to. For example, the UBX-NAV-PVT (navigation, position, velocity and time solution) is related to the navigation epoch. If the rate of this message is set to one (1), it will be output for every navigation epoch. If the rate is set to two (2), it will be output every other navigation epoch. The rates of the output messages are individually configurable per communication interface. See the CFG-MSGOUT-* configuration group.

Some messages, such as UBX-MON-VER, are non-periodic and will only be output as an answer to a poll request.

The UBX-INF-* and NMEA-Standard-TXT information messages are non-periodic output messages that do not have a message rate configuration. Instead they can be enabled for each communication interface via the CFG-INFMSG-* configuration group.

☞ All message output is additionally subject to the protocol configuration of the communication interfaces. Messages of a given protocol will not be output until the protocol is enabled for output on the interface (see Communication interface configuration).

3.1.4.3 GNSS signal configuration

The GNSS constellations and signal bands are selected using keys from configuration group CFG-SIGNAL-*. Each GNSS constellation can be enabled or disabled independently except for QZSS and SBAS which are dependant on GPS selection. A GNSS constellation is considered to be enabled when the constellation enable key is set and at least one of the constellation's band keys is enabled.

3.1.4.4 NMEA high precision mode

RCB-F9T supports NMEA high precision mode. This mode increases the number of significant digits of the position output; latitude and longitude will have seven digits after the decimal point, and altitude will have three digits after the decimal point. By default it is not enabled since it violates the NMEA standard. NMEA high precision mode cannot be used while in NMEA compatibility mode or when NMEA output is limited to 82 characters. See configuration item CFG-NMEA-HIGHPREC in the applicable Interface description [2] for more details.

☞ NMEA high precision mode is disabled by default meaning that the default NMEA output will be insufficient to report a high precision position.

3.1.5 Differential timing mode configuration

In differential timing mode the RCB-F9T can operate either as a reference base station or as a differential timing receiver station. Using the RTCM3 protocol, the base station sends timing corrections to the differential timing receiver via a communication link enabling the differential timing receiver to compute its time relative to the base station with high accuracy.

This section describes how to configure the RCB-F9T high accuracy timing board as a reference base station and as differential timing receiver station. The section begins with a note describing the RTCM protocol and corresponding supported message types.

3.1.5.1 RTCM corrections

RTCM is a standard-based binary protocol for the communication of GNSS correction information. The RCB-F9T high accuracy timing board supports RTCM as specified by RTCM 10403.3, Differential GNSS (Global Navigation Satellite Systems) Services – Version 3 (October 7, 2016).

The RTCM specification is currently at version 3.3 and RTCM version 2 messages are not supported by this standard.

To modify the RTCM input/output settings, see the configuration section in the applicable Interface description [2].

3.1.5.2 List of supported RTCM input messages

Message type	Description
RTCM 1005	Stationary RTK reference station ARP
RTCM 1077	GPS MSM7
RTCM 1087	GLONASS MSM7
RTCM 1097	Galileo MSM7
RTCM 1127	BeiDou MSM7
RTCM 1230	GLONASS code-phase biases
RTCM 4072.1	Additional reference station information (u-blox proprietary RTCM Message)

Table 3: RCB-F9T supported input RTCM version 3.3 messages

3.1.5.3 List of supported RTCM output messages

Message type	Description
RTCM 1005	Stationary RTK reference station ARP
RTCM 1077	GPS MSM7
RTCM 1087	GLONASS MSM7
RTCM 1097	Galileo MSM7
RTCM 1127	BeiDou MSM7
RTCM 1230	GLONASS code-phase biases
RTCM 4072.1	Additional reference station information (u-blox proprietary RTCM Message)

Table 4: RCB-F9T supported output RTCM version 3.3 messages

3.1.5.4 Timing receiver position

Time mode is a special receiver mode where the position of the receiver is known and fixed and only the time and frequency is calculated using all available satellites. This mode allows for maximum time accuracy, for single-SV solutions, and also for using the receiver as a stationary reference station.

In order to use time mode, the receiver's position must be known as exactly as possible. Errors in the fixed position will translate into time errors depending on the satellite constellation.

The following procedures can be used to initialize the timing receiver position:

- Using built-in survey-in procedure to estimate the position.
- Entering coordinates independently generated or taken from an accurate position such as a survey marker.

3.1.5.4.1 Survey-in

Survey-in is a procedure that is carried out prior to entering Time mode. It estimates the receiver position by building a weighted mean of all valid 3D position solutions.

Two major parameters are required when configuring:

- A **minimum observation** time defines the minimum observation time independent of the actual number of fixes used for the position estimate. Values can range from one day for high accuracy requirements to a few minutes for coarse position determination.
- A **3D position standard deviation** defines a limit on the spread of positions that contribute to the calculated mean.

Survey-in ends when both requirements are successfully met. The Survey-in status can be queried using the UBX-TIM-SVIN message.

To configure a timing receiver into Survey-in mode (CFG-TMODE-MODE=SURVEY_IN), the following items are required:

Configuration item	Description
CFG-TMODE-MODE	Receiver mode (disabled, survey-in or fixed)
CFG-TMODE-SVIN_MIN_DUR	Survey-in minimum duration
CFG-TMODE-SVIN_ACC_LIMIT	Survey-in position accuracy limit. The accuracy of given coordinates in 0.0001 meters (i.e. value 100 equals 1 cm)

Table 5: Configuration items used for setting a timing receiver into Survey-in mode

☞ Set the configuration items shown above into flash memory to perform a survey-in procedure automatically on startup.

3.1.5.4.2 Fixed position

Here the timing receiver position coordinates are entered manually. Any error in the timing receiver position will directly translate into timing errors.

To configure into Fixed mode (CFG-TMODE-MODE=FIXED), the following items are relevant:

Configuration item	Description
CFG-TMODE-MODE	Receiver mode (disabled or survey-in or fixed)
CFG-TMODE-POS_TYPE	Determines whether the ARP position is given in ECEF or LAT/LON/HEIGHT
CFG-TMODE-ECEF_X	ECEF X coordinate of the ARP position, coordinate in centimeters
CFG-TMODE-ECEF_Y	ECEF Y coordinate of the ARP position, coordinate in centimeters
CFG-TMODE-ECEF_Z	ECEF Z coordinate of the ARP position, coordinate in centimeters
CFG-TMODE-LAT	Latitude of the ARP position, coordinate in 1e-7 degrees
CFG-TMODE-LON	Longitude of the ARP position, coordinate in 1e-7 degrees
CFG-TMODE-HEIGHT	Height of the ARP position, coordinate in centimeters
CFG-TMODE-ECEF_X_HP	High-precision ECEF X coordinate of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-ECEF_Y_HP	High-precision ECEF Y coordinate of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-ECEF_Z_HP	High-precision ECEF Z coordinate of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-LAT_HP	High-precision latitude of the ARP position, coordinate in 1e-9 degrees
CFG-TMODE-LON_HP	High-precision longitude of the ARP position, coordinate in 1e-9 degrees
CFG-TMODE-HEIGHT_HP	High-precision height of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-FIXED_POS_ACC	Fixed position 3D accuracy estimate

Table 6: Configuration items used for setting a timing receiver into fixed mode

Once the receiver is set in fixed mode, select the position format to use: either LLH or ECEF with optional high precision (mm) coordinates compared to the standard cm value.

For example, with CFG-TMODE-POS_TYPE=ECEF the timing receiver antenna position can be entered to cm precision using CFG-TMODE-ECEF_X, CFG-TMODE-ECEF_Y, CFGTMODE-ECEF_Z. For high precision (mm) coordinates use CFG-TMODEECEF_X_HP, CFG-TMODE-ECEF_Y_HP, CFG-TMODE-ECEF_Z_HP. The same applies with corresponding coordinates used with CFG-TMODE-POS_TYPE=LLH.

⚠   If the timing receiver is moved during operation then new position coordinates must be configured.

3.1.5.5 Reference base station

When the RCB-F9T high accuracy timing board acts as a base timing station, it sends RTCM 3.3 differential corrections to differential timing receivers. Corrections are generated after a timing fix calculation in order to remove the base receiver's clock offset.

3.1.5.5.1 Reference base station: RTCM output configuration

At this point the timing receiver should report a TIME fix, not a 3D fix.

The desired RTCM messages must be selected and configured on UART1 rate 1:

• RTCM 1005 Stationary RTK reference station ARP
• RTCM 1077 GPS MSM7
• RTCM 1088 GLONASS MSM7
• RTCM 1097 Galileo MSM7
• RTCM 1127 BeiDou MSM7
• RTCM 1230 GLONASS code-phase biases
• RTCM 4072.1 Additional reference station information

The configuration messages for these are shown in the Table 7.

The following configuration items output the recommended messages for a default satellite constellation setting. Note that these are given for the UART1 interface:

Configuration item	Description
CFG-UART1OUTPROT-NMEA	CFG-UART1OUTPROT-NMEA to 0
CFG-UART1OUTPROT-RTCM3X	CFG-UART1OUTPROT-RTCM3X to 1
CFG-UART1OUTPROT-UBX	CFG-UART1OUTPROT-UBX to 0
CFG-MSGOUT-RTCM_3X_TYPE1005_UART1	Output rate of the RTCM-3X-TYPE1005 message on port UART1: RTCM base station message
CFG-MSGOUT-RTCM_3X_TYPE1077_UART1	Output rate of the RTCM-3X-TYPE1077 message on port UART1: RTCM GPS MSM7
CFG-MSGOUT-RTCM_3X_TYPE1087_UART1	Output rate of the RTCM-3X-TYPE1087 message on port UART1: RTCM GLONASS MSM7
CFG-MSGOUT-RTCM_3X_TYPE1097_UART1	Output rate of the RTCM-3X-TYPE1097 message on port UART1: RTCM Galileo MSM7
CFG-MSGOUT-RTCM_3X_TYPE1127_UART1	Output rate of the RTCM-3X-TYPE1127 message on port UART1: RTCM Additional reference station information
CFG-MSGOUT-RTCM_3X_TYPE1230_UART1	Output rate of the RTCM-3X-TYPE1230 message on port UART1: RTCM GLONASS code-phase biases
CFG-MSGOUT-RTCM_3X_TYPE4072_1_UART1	Output rate of the RTCM-3X-TYPE4072.1 message on port UART1: RTCM Additional reference station information

Table 7: Configuration items used for setting a reference base station

3.1.5.6 Differential timing receiver station

When the RCB-F9T acts as a differential timing receiver, it receives differential corrections RTCM 3.3 messages from a reference base station and aligns its time pulse to it.

Connect the differential timing receiver to the reference server or to the NTRIP server. When the differential timing receiver receives the configured RTCM correction stream, it will automatically start using the corrections.

☞ Reception of RTCM 4072.1 is required to start using differential correction data.

3.1.6 Primary and secondary output

3.1.6.1 Introduction

u-blox GNSS receivers output various navigation results and data calculated as part of the navigation solution. These include results such as position, altitude, velocity, status flags, accuracy estimate figures, satellite/signal information and more.

The RCB-F9T can provide this output in two streams:

• **Primary output:** Reports the results of a full navigation solution using all capabilities of the RCB-F9T,
• **Secondary output:** Reports the results of a GNSS standalone navigation solution.

Both the primary output and secondary output provide a similar set of information but the two outputs report different results. The primary output is reported in the form of UBX-NAV-* messages, while the secondary output is reported in the form of UBX-NAV2-* messages. Therefore, the UBX message class can be used to distinguish between the primary output and the secondary output. For the specification of the UBX-NAV2-* messages and for a full list of available UBX-NAV2-* messages, see the applicable Interface description [2].

☞ The secondary output is complementary to the primary output. It does not provide the full navigation solution of the primary output. It can be used to expand the applications of the RCB-F9T to enable using a second navigation solution in parallel with the primary navigation solution.

The rest of this section describes how to configure and use the secondary output, what is the expected output behavior, and provides examples that illustrate potential uses for the secondary output, while highlighting the differences between the primary and the secondary output.

3.1.6.2 Configuration

Configuring the secondary output to the application's needs requires:

* Enabling the secondary output
* Configuring the desired secondary output UBX-NAV2-* messages
* Optionally, configuring the properties of the secondary output navigation solution

The configuration items relevant to the secondary output are in the CFG-NAV2-* configuration group. The configuration items for enabling and configuring the output rate of the UBX-NAV2-* messages are in the CFG-MSGOUT-* group and are of the form CFG-MSGOUT-UBX_NAV2_*. An example set of secondary output configuration items is shown in the table below. For all available configuration items, see the applicable Interface description [2].

Configuration item	Description
CFG-NAV2-OUT_ENABLED	Enables secondary output
CFG-NAV2-SBAS_USE_INTEGRITY	Enables using SBAS integrity information in the secondary output
CFG-MSGOUT-UBX_NAV2_PVT_*	Enables UBX-NAV2-PVT secondary output message
CFG-MSGOUT-UBX_NAV2_TIMEGPS_*	Enables UBX-NAV2-TIMEGPS secondary output message

Table 8: Example secondary output configuration items

Enabling the secondary output: The first necessary step to enable the secondary output is to configure the CFG-NAV2-OUT_ENABLED configuration item appropriately. This will enable the secondary output navigation solution to run in parallel with the primary output navigation solution. By default, the secondary output is disabled. Note that if you do not follow the next step, there will be no secondary output visible in the RCB-F9T communication interfaces in the form of UBX-NAV2-* messages.

☞ Both primary and secondary output report a navigation solution computed at the same navigation rate. Enabling the secondary output may affect the maximum achievable navigation update rate due to the extra computational load.

Configuring the desired secondary output UBX-NAV2-* messages: The second necessary step is to configure the desired CFG-MSGGOUT-UBX_NAV2_* configuration items appropriately. These set the message output rates for the UBX-NAV2-* messages that you wish to output. By default, all UBX-NAV2-* message output rates are set to 0 and as such are not being output.

☞ Due to the increased message output, the interface load will be higher while the secondary output messages are enabled. Therefore, the interface baud rate may need to be adapted accordingly. Alternatively, it is possible to configure the UBX-NAV2-* messages with a different output rate from that of their primary output UBX-NAV-* counterparts.

Configuring the properties of the secondary output navigation solution: Optionally, it is possible to configure the properties of the secondary output navigation solution in order to adapt it to the application's needs.

A minimal subset of the primary output navigation solution configuration is available for the secondary output navigation solution configuration. All such available configuration items are in the CFG-NAV2-* configuration group (see applicable Interface description [2]).

Configuring any of the CFG-NAV2-* configuration items changes the behavior of the secondary output navigation solution only and not the primary output one. All such configuration items have a primary output configuration counterpart and have the same default value as their primary output configuration counterpart.

For example, the CFG-NAV2-SBAS_USE_INTEGRITY configuration item allows configuring the SBAS integrity feature differently for the primary output and the secondary output. Its primary output counterpart is the CFG-SBAS-USE_INTEGRITY configuration item and the default value of both configuration items is the same.

3.1.6.3 Expected output behavior

Once the secondary output is enabled and the desired secondary output UBX-NAV2-* messages are configured, the RCB-F9T will output both primary and secondary output data in the form of the enabled UBX-NAV-* and UBX-NAV2-* messages respectively.

In every navigation epoch, a set of UBX-NAV-* messages will be output followed by another set of UBX-NAV2-* messages. Both sets will be referring to the navigation solution of the same navigation epoch.

Each set will be delimited at its end with a UBX-NAV-EOE or a UBX-NAV2-EOE message respectively. In other words, a UBX-NAV-EOE message will be output at the end of the UBX-NAV-* class enabled messages and a UBX-NAV2-EOE message will be output at the end of the UBX-NAV2-* class enabled messages. For example, if only UBX-NAV-PVT, UBX-NAV2-PVT, UBX-NAV-TIMEGPS and UBX-NAV2-TIMEGPS are enabled on the same port with message output rate 1, then every navigation epoch output will be as follows: UBX-NAV-PVT, UBX-NAV-TIMEGPS, UBX-NAV-EOE, UBX-NAV2-PVT, UBX-NAV2-TIMEGPS, UBX-NAV2-EOE.

☞ Secondary output messages appear after the primary output messages. This results in a higher latency for the secondary output messages than the primary output messages.

☞ Contrary to UBX-NAV2-* messages, secondary output NMEA-NAV2-* messages are not delimited by an NMEA-equivalent to UBX-NAV-EOE.

The specification of the UBX-NAV2-* messages resembles that of the UBX-NAV-* messages. The payload specification of a UBX-NAV2 message is identical to the payload specification of its UBX-NAV counterpart, allowing to easily adapt any existing message parsers. The primary output will contain results and data reflecting the full navigation solution of the RCB-F9T. The secondary output will contain results and data reporting a GNSS standalone navigation solution.

3.1.7 Legacy configuration interface compatibility

Although there is some backwards compatibility for the legacy UBX-CFG configuration messages, users are strongly advised to adopt the configuration interface described in this document.

See Legacy UBX-CFG message fields reference section in the applicable Interface description [2].

3.1.8 Navigation configuration

This section presents various configuration options related to the navigation engine. These options can be configured through various configuration groups, such as CFG-NAVSPG-*, CFG-ODO-*, and CFG-MOT-*.

3.1.8.1 Platform settings

u-blox receivers support different dynamic platform models (see the table below) to adjust the navigation engine to the expected application environment. These platform settings can be changed dynamically without performing a power cycle or reset. The settings improve the receiver's

interpretation of the measurements and thus provide a more accurate position output. Setting the receiver to an unsuitable platform model for the given application environment is likely to result in a loss of receiver performance and position accuracy.

The dynamic platform model can be configured through the CFG-NAVSPG-DYNMODEL configuration item. The supported dynamic platform models and their details can be seen in Table 9 and Table 10 below.

Platform	Description
Portable	Applications with low acceleration, e.g. portable devices. Suitable for most situations.
Stationary (default)	Used in timing applications (antenna must be stationary) or other stationary applications. Velocity restricted to 0 m/s. Zero dynamics assumed.
Pedestrian	Applications with low acceleration and speed, e.g. how a pedestrian would move. Low acceleration assumed.
Automotive	Used for applications with equivalent dynamics to those of a passenger car. Low vertical acceleration assumed.
At sea	Recommended for applications at sea, with zero vertical velocity. Zero vertical velocity assumed. Sea level assumed.
Airborne <1g	Used for applications with a higher dynamic range and greater vertical acceleration than a passenger car. No 2D position fixes supported.
Airborne <2g	Recommended for typical airborne environments. No 2D position fixes supported.
Airborne <4g	Only recommended for extremely dynamic environments. No 2D position fixes supported.
Wrist	Only recommended for wrist-worn applications. Receiver will filter out arm motion.

Table 9: Dynamic platform models

Platform	Max altitude [m]	Max horizontal velocity [m/s]	Max vertical velocity [m/s]	Sanity check type	Max position deviation
Portable	12000	310	50	Altitude and velocity	Medium
Stationary	9000	10	6	Altitude and velocity	Small
Pedestrian	9000	30	20	Altitude and velocity	Small
Automotive	6000	100	15	Altitude and velocity	Medium
At sea	500	25	5	Altitude and velocity	Medium
Airborne <1g	80000	100	6400	Altitude	Large
Airborne <2g	80000	250	10000	Altitude	Large
Airborne <4g	80000	500	20000	Altitude	Large
Wrist	9000	30	20	Altitude and velocity	Medium

Table 10: Dynamic platform model details

Applying dynamic platform models designed for high acceleration systems (e.g. airborne <2g) can result in a higher standard deviation in the reported position.

If a sanity check against a limit of the dynamic platform model fails, then the position solution is invalidated. Table 10 above shows the types of sanity checks which are applied for a particular dynamic platform model.

3.1.8.2 Navigation input filters

The navigation input filters in CFG-NAVSPG-* configuration group provide the input data of the navigation engine.

Configuration item	Description
CFG-NAVSPG-FIXMODE	By default, the receiver calculates a 3D position fix if possible but reverts to 2D position if necessary (**auto 2D/3D**). The receiver can be forced to only calculate 2D (**2D only**) or 3D (**3D only**) positions.
CFG-NAVSPG-CONSTR_ALT, CFG-NAVSPG-CONSTR_ALTVAR	The fixed altitude is used if fixMode is set to 2D only. A variance greater than zero must also be supplied.
CFG-NAVSPG-INFIL_MINELEV	Minimum elevation of a satellite above the horizon in order to be used in the navigation solution. Low elevation satellites may provide degraded accuracy, due to the long signal path through the atmosphere.
CFG-NAVSPG-INFIL_NCNOTHRS, CFG-NAVSPG-INFIL_CNOTHRS	A navigation solution will only be attempted if there are at least the given number of SVs with signals at least as strong as the given threshold.

Table 11: Navigation input filter parameters

If the receiver only has three satellites for calculating a position, the navigation algorithm uses a constant altitude to compensate for the missing fourth satellite. When a satellite is lost after a successful 3D fix (min four satellites available), the altitude is kept constant at the last known value. This is called a 2D fix.

☞ u-blox receivers do not calculate any navigation solution with less than three satellites.

3.1.8.3 Navigation output filters

The result of a navigation solution is initially classified by the fix type (as detailed in the `fixType` field of UBX-NAV-PVT message). This distinguishes between failures to obtain a fix at all ("No Fix") and cases where a fix has been achieved, which are further subdivided into specific types of fixes (e.g. 2D, 3D, dead reckoning).

☞ The RCB-F9T firmware does not support the dead reckoning position fix type.

Where a fix has been achieved, a check is made to determine whether the fix should be classified as valid or not. A fix is only valid if it passes the navigation output filters as defined in CFG-NAVSPG-OUTFIL. In particular, both PDOP and accuracy values must be below the respective limits.

☞ Important: Users are recommended to check the `gnssFixOK` flag in the UBX-NAV-PVT or the NMEA valid flag. Fixes not marked valid should not be used.

UBX-NAV-STATUS message also reports whether a fix is valid in the `gpsFixOK` flag. This message has only been retained for backwards compatibility and users are recommended to use the UBX-NAV-PVT message.

3.1.8.3.1 Speed (3D) low-pass filter
The CFG-ODO-OUTLPVEL configuration item offers the possibility to activate a speed (3D) low-pass filter. The output of the speed low-pass filter is published in the UBX-NAV-VELNED message (`speed` field). The filtering level can be set via the CFG-ODO-VELLPGAIN configuration item with values between 0 (heavy low-pass filtering) and 255 (weak low-pass filtering).

☞ The internal filter gain is computed as a function of speed. Therefore, the level as defined in the CFG-ODO-VELLPGAIN configuration item defines the nominal filtering level for speeds below 5 m/s.

3.1.8.3.2 Course over ground low-pass filter
The CFG-ODO-OUTLPCOG configuration item offers the possibility to activate a course over ground low-pass filter when the speed is below 8 m/s. The output of the course over ground (also named heading of motion 2D) low-pass filter is published in the UBX-NAV-PVT message (`headMot` field), UBX-NAV-VELNED message (`heading` field), NMEA-RMC message (`cog` field) and NMEA-VTG message (`cogt` field). The filtering level can be set via the CFG-ODO-COGLPGAIN configuration item with values between 0 (heavy low-pass filtering) and 255 (weak low-pass filtering).

☞ The filtering level as defined in the CFG-ODO-COGLPGAIN configuration item defines the filter gain for speeds below 8 m/s. If the speed is higher than 8 m/s, no course over ground low-pass filtering is performed.

3.1.8.3.3 Low-speed course over ground filter

The CFG-ODO-USE_COG activates a low-speed course over ground filter and the CFG-ODO-COGMAXSPEED, CFG-ODO-COGMAXPOSACC configuration items offer the possibility to configure this feature (also named heading of motion 2D). This filter derives the course over ground from position at very low speed. The output of the low-speed course over ground filter is published in the UBX-NAV-PVT message (`headMot` field), UBX-NAV-VELNED message (`heading` field), NMEA-RMC message (`cog` field) and NMEA-VTG message (`cogt` field). If the low-speed course over ground filter is not configured, then the course over ground is computed as described in section Freezing the course over ground.

3.1.8.4 Static hold

Static hold mode allows the navigation algorithms to decrease the noise in the position output when the velocity is below a predefined "Static Hold Threshold". This reduces the position wander caused by environmental factors such as multi-path and improves position accuracy especially in stationary applications. By default, static hold mode is disabled.

If the speed drops below the defined "Static Hold Threshold", the static hold mode will be activated. Once static hold mode has been entered, the position output is kept static and the velocity is set to zero until there is evidence of movement again. Such evidence can be velocity, acceleration, changes of the valid flag (e.g. position accuracy estimate exceeding the position accuracy mask, see also section Navigation output filters), position displacement, etc.

The CFG-MOT-GNSSDIST_THRS configuration item additionally allows for configuration of distance threshold. If the estimated position is farther away from the static hold position than this threshold, static mode will be quit. The CFG-MOT-GNSSSPEED_THRS configuration item allows you to set a speed that the static hold will release.
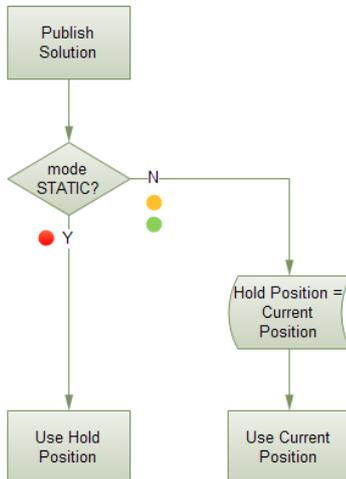
Figure 2: Position publication in static hold mode
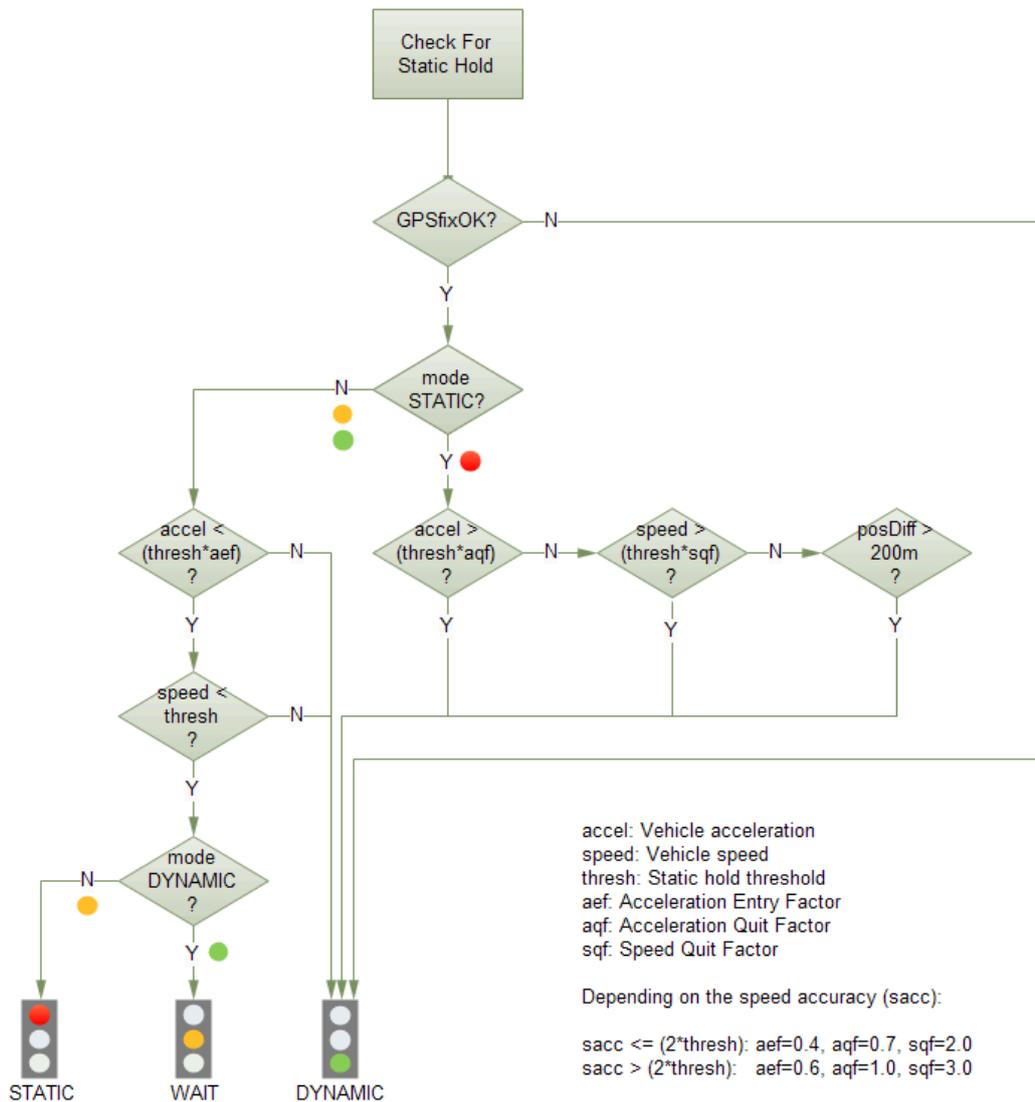
Figure 3: Flowchart of the static hold mode

3.1.8.5 Freezing the course over ground

If the low-speed course over ground filter is deactivated or inactive (see section Low-speed course over ground filter), the receiver derives the course over ground from the GNSS velocity information. If the velocity cannot be calculated with sufficient accuracy (e.g., with bad signals) or if the absolute speed value is very low (under 0.1 m/s) then the course over ground value becomes inaccurate too. In this case the course over ground value is frozen, i.e. the previous value is kept and its accuracy is degraded over time. These frozen values will not be output in the NMEA messages NMEA-RMC and NMEA-VTG unless the NMEA protocol is explicitly configured to do so (see NMEA protocol configuration in the applicable Interface description [2]).

mode: Static hold mode
SOG: Speed over ground
cogAcc: Course over ground accuracy (sigma)
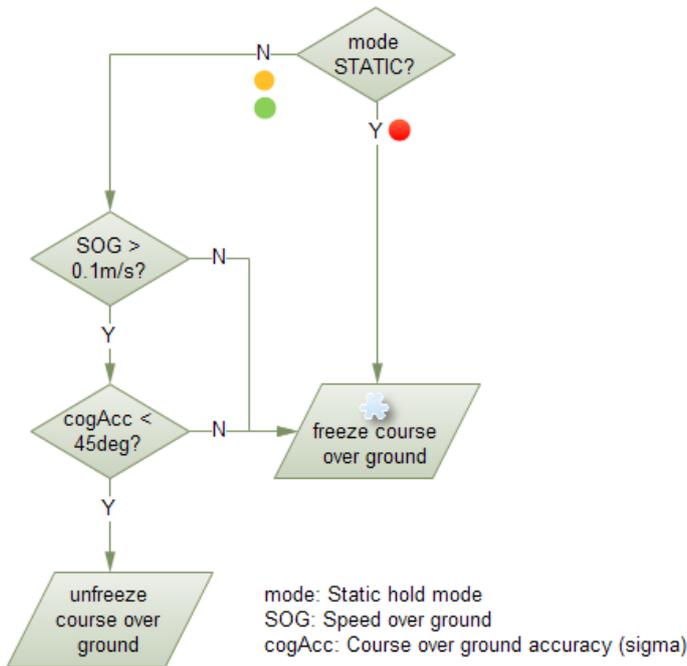
Figure 4: Flowchart of the course over ground freezing

3.2 SBAS

Whilst the RCB-F9T can make use of SBAS satellites, experience has shown that employing these signals can degrade the timing performance and hence SBAS use is not enabled by default. The following section describes the receiver operation when SBAS reception is required by users.

The RCB-F9T is capable of receiving multiple SBAS signals concurrently, even from different SBAS systems (WAAS, EGNOS, MSAS, etc.). They can be tracked and used for navigation simultaneously. Every SBAS satellite that broadcasts ephemeris or almanac information can be used for navigation, just like a normal GNSS satellite.

For receiving correction data, the RCB-F9T automatically chooses the best SBAS satellite as its primary source. It will select only one since the information received from other SBAS satellites is redundant and could be inconsistent. The selection strategy is determined by the proximity of the satellites, the services offered by the satellite, the configuration of the receiver (test mode allowed/ disallowed, integrity enabled/disabled) and the signal link quality to the satellite.

If corrections are available from the chosen SBAS satellite and used in the navigation calculation, the differential status will be indicated in several output messages such as UBX-NAV-PVT, UBX-NAV-STATUS, UBX-NAV-SAT, NMEA-GGA, NMEA-GLL, NMEA-RMC and NMEA-GNS (see the applicable Interface description [2]). The message UBX-NAV-SBAS provides detailed information about which corrections are available and applied.

The most important SBAS feature for accuracy improvement is ionosphere correction. The measured data from regional Ranging and Integrity Monitoring Stations (RIMS) are combined to make a Total Electron Content (TEC) map. This map is transferred to the receiver via SBAS satellites to allow a correction of the ionosphere error on each received signal.

Message type	Message content	Source
0(0/2)	Test mode	All
1	PRN mask assignment	Primary

Message type	Message content	Source
2, 3, 4, 5	Fast corrections	Primary
6	Integrity	Primary
7	Fast correction degradation	Primary
9	Satellite navigation (ephemeris)	All
10	Degradation	Primary
12	Time offset	Primary
17	Satellite almanac	All
18	Ionosphere grid point assignment	Primary
24	Mixed fast / long-term corrections	Primary
25	Long-term corrections	Primary
26	Ionosphere delays	Primary

Table 12: Supported SBAS messages

Each satellite services a specific region and its correction signal is only useful within that region. Planning is crucial to determine the best possible configuration, especially in areas where signals from different SBAS systems can be received:

- **Example 1 - SBAS receiver in North America:** In the eastern parts of North America, make sure that EGNOS satellites do not take preference over WAAS satellites. The satellite signals from the EGNOS system should be disallowed by using the PRN mask.
- **Example 2 - SBAS receiver in Europe:** Some WAAS satellite signals can be received in the western parts of Europe, therefore it is recommended that the satellites from all but the EGNOS system should be disallowed using the PRN mask.

☞ Although u-blox receivers try to select the best available SBAS correction data, it is recommended to configure them to exclude unwanted SBAS satellites.

To configure the SBAS functionalities use the CFG-SBAS-* configuration group.

Parameter	Description
CFG-SIGNAL-SBAS_ENA	Enabled/disabled status of the SBAS subsystem
CFG-SBAS-USE_TESTMODE	Allow/disallow SBAS usage from satellites in test mode
CFG-SBAS-USE_RANGING	Use the SBAS satellites for navigation (ranging)
CFG-SBAS-USE_DIFFCORR	Combined enable/disable switch for fast, long-term, and ionosphere corrections
CFG-SBAS-USE_INTEGRITY	Apply integrity information data
CFG-SBAS-PRNSCANMASK	Allows selectively enabling/disabling SBAS satellites

Table 13: SBAS configuration parameters

☞ When SBAS integrity data is applied, the navigation engine stops using all signals for which no integrity data are available (including all non-GPS signals). It is not recommended to enable SBAS integrity on borders of SBAS service regions in order not to inadvertently restrict the number of available signals.

☞ SBAS integrity information is required for at least 5 GPS satellites. If this condition is not met, SBAS integrity data will not be applied.

☞ SBAS is only used if no correction service is available. If the connection stream is lost during the operation, the receiver will switch to using the SBAS corrections after the time set in CFG-NAVSPG-CONSTR_DGNSSTO (60 s by default) has elapsed.

☞ When the receiver switches from a solution using correction data to a standard position solution, the reference frame of the output position will switch from the one of the correction

data to that of the standard position solution. For an SBAS solution this reference frame will be aligned within a few cm of WGS84 (and modern ITRF realizations).

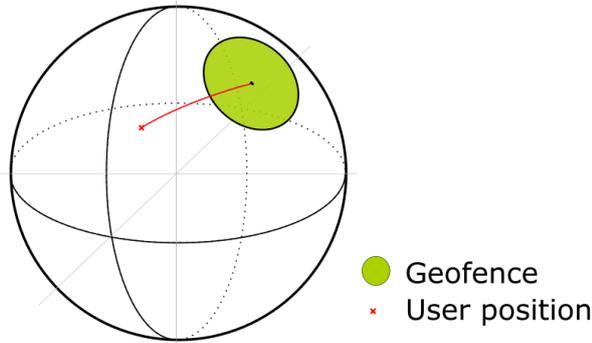## 3.3 Geofencing

3.3.1 Introduction

Figure 5: Geofence

The geofencing feature allows for the configuration of up to four circular areas (geofences) on the Earth's surface. The receiver will then evaluate for each of these areas whether the current position lies within the area or not and signal the state via UBX messaging and PIO toggling.

3.3.2 Interface

Geofencing can be configured using the CFG-GEOFENCE-* configuration group. The geofence evaluation is active whenever there is at least one geofence configured.

The current state of each geofence plus the combined state is output in UBX-NAV-GEOFENCE with every navigation epoch.

3.3.3 Geofence state evaluation

With every navigation epoch the receiver will evaluate the current solution's position versus the configured geofences. There are three possible outcomes for each geofence:

- *Inside* - The position is inside the geofence with the configured confidence level
- *Outside* - The position lies outside of the geofence with the configured confidence level
- *Unknown* - There is no valid position solution or the position uncertainty does not allow for unambiguous state evaluation

The position solution uncertainty (standard deviation) is multiplied with the configured confidence sigma level and taken into account when evaluating the geofence state (red circle in Figure 6).

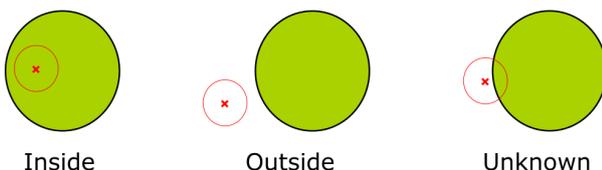Inside   Outside   Unknown

Figure 6: Geofence states

The combined state for all geofences is evaluated as the combination (Union) of all geofences:

- *Inside* - The position lies inside of at least one geofence

- *Outside* - The position lies outside of all geofences
- *Unknown* - All remaining states

3.4 Logging

3.4.1 Introduction

The logging feature allows position fixes and arbitrary byte strings from the host to be logged in the receiver's flash memory. Logging of position fixes happens independently of the host system, and can continue while the host is powered down.

The following table lists all the logging-related messages:

Message	Description
UBX-LOG-CREATE	Creates a log file and activates the logging system
UBX-LOG-ERASE	Erases a log file and deactivates the logging subsystem
UBX-LOG-INFO	Provides information about the logging system
UBX-LOG-STRING	Enables a host process to write a string of bytes to the log file

Table 14: Logging control and configuration messages

Message	Description
UBX-LOG-RETRIEVE	Starts the log retrieval process
UBX-LOG-RETRIEVEPOS	A position log entry returned by the receiver
UBX-LOG-RETRIEVEPOSEXTRA	Odometer position data
UBX-LOG-RETRIEVESTRING	A byte string log entry returned by the receiver
UBX-LOG-FINDTIME	Finds the index of the first entry (given time)

Table 15: Logging retrieval messages

3.4.2 Setting the logging system up

An empty log can be created using the UBX-LOG-CREATE message and a log can be deleted with the UBX-LOG-ERASE message. The logging system will only run if a log is in existence, so most logging messages will be rejected with a UBX-ACK-NAK message if there is no log present. Only one log can be created at any one time so a UBX-ACK-NAK message will be returned if a log already exists. The message specifies the maximum size of the log in bytes (with some preset values provided). Both the logging subsystem and the receiver file-store have implementation overheads, so the total space available for log entries will be somewhat smaller than the size specified.

UBX-LOG-CREATE also allows the log to be specified as a circular log. If the log is circular, a set of older log entries will be deleted when it fills up, and the space freed up is used for new log entries. By contrast, if a non-circular log becomes full then new entries which do not fit will be rejected. UBX-LOG-CREATE also causes the logging system to start up so that further logging messages can be processed. The logging system will start up automatically on power-up if there is a log in existence. The log will remain in the receiver until specifically erased using the UBX-LOG-ERASE message.

The CFG-LOGFILTER-* configuration group controls whether logging of entries is currently enabled and selects position fix messages for logging.
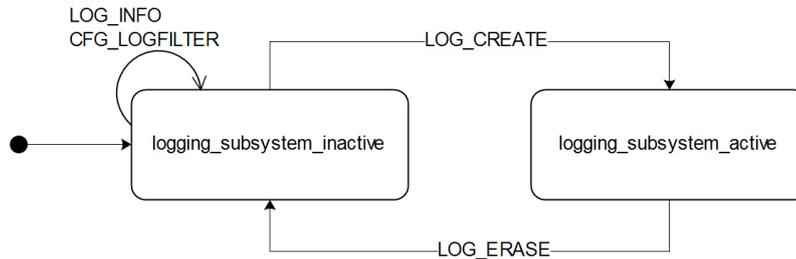
Figure 7: The top level active/inactive states of the logging subsystem

3.4.3 Information about the log

The receiver can be polled for a UBX-LOG-INFO message which will give information about the log. This will include the maximum size that the log can grow to (which, due to overheads, will be smaller than that requested in UBX-LOG-CREATE) and the amount of log space currently occupied. It will also report the number of entries currently in the log together with the time and date of the newest and oldest messages that have a valid time stamp.

Log entries are compressed and have housekeeping information associated with them, so the actual space occupied by log messages may be difficult to predict. The minimum size for a position fix entry is 9 bytes and the maximum 24 bytes, the typical size is 10 or 11 bytes. If the odometer is enabled then this will use at least another three bytes per fix.

Each log also has a fixed overhead which is dependent on the log type. The approximate size of this overhead is shown in the following table.

Log type	Overhead
circular	Up to 40 kB
non-circular	Up to 8 kB

Table 16: Log overhead size

The number of entries that can be logged in any given flash size can be estimated as follows:

Approx. number of entries = (flash size available for logging - log overhead)/typical entry size

For example, if 1500 kB of flash is available for logging (after other flash usage such as the firmware image is taken into account) a non-circular log would be able to contain approximately 139000 entries: ((1500*1024)- (8*1024))/11 = 138891.

3.4.4 Recording

The CFG-LOGFILTER-RECORD_ENA configuration item must be set to *true* to enable recording into the log. Nothing will be recorded if recording is disabled, otherwise position fix and UBX-LOG_STRING entries can be recorded. When recording is enabled an entry will also be created from each UBX-LOG-STRING message. These will be timestamped if the receiver has current knowledge of time.

The CFG-LOGFILTER-* configuration group has several values which can be used to select position fix entries for logging. If CFG-LOGFILTER-APPLY_ALL_FILTERS is *false*, then all position fixes will be logged (subject to a maximum rate of 1 Hz). Otherwise, a position is logged if any of the or if all of MIN_INTERVAL, TIME_THRS, SPEED_THRS or POSITION_THRS thresholds are exceeded. If a threshold is set to zero it is ignored.

Position fixes are only recorded if a valid fix is obtained. Failed and invalid fixes are not recorded. Position fixes are compressed to reduce the amount of flash space used. In order to improve the

compression, the fix values are rounded. This means that the values returned by the logging system may differ slightly from those that are gathered in real time.

The recorded data for a fix comprises:

- The time and date of the fix recorded to a precision of one second.
- Latitude and longitude to a precision of one millionth of a degree. Depending on position on Earth this is a precision in the order of 0.1 m.
- Altitude (height above mean sea level) to a precision of 0.1 m. Entries with an altitude lower than -470 m (lower than the lowest point on earth) or higher than 20,000 m may not be recorded in the log.
- Ground speed to a precision of 1 cm/s.
- The fix type (only successful fix types, since these are the only ones recorded).
- The number of satellites used in the fix is recorded, but there is a maximum count which can be recorded. If the actual count exceeds this maximum count then the maximum count will be recorded. If a log entry is retrieved with a satellite count equal to the maximum this means that value or more. The maximum count is 51.
- A horizontal accuracy estimate is recorded to give an indication of fix quality. This is an approximate compressed representation of the accuracy as determined by the fix process. Any accuracy less than 0.7 m will be recorded as 0.7 m and any value above 1 km will be recorded as 1 km. Within these limits, the recorded accuracy will always be greater than the fix accuracy number (by up to 40%).
- Heading to a precision of one degree.
- Odometer distance data (if odometer is enabled).
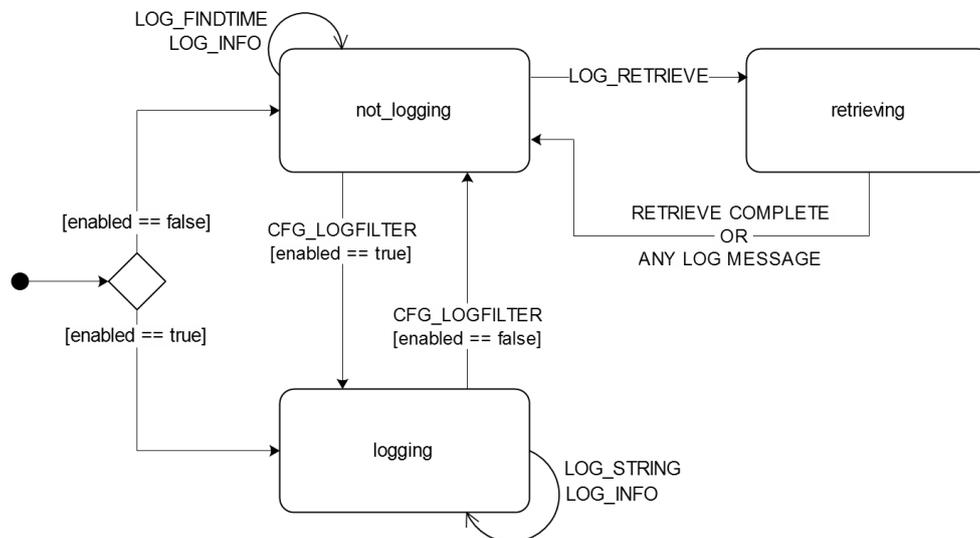
Figure 8: The states of the active logging subsystem

3.4.5 Retrieval

UBX-LOG-RETRIEVE starts the process which allows the receiver to output log entries. UBX-LOG-INFO may be helpful to a host system in order to understand the current log status before retrieval is started.

Once retrieval has started, one message will be output from the receiver for each log entry requested. Sending any logging message to the receiver during retrieval will cause the retrieval to stop before the message is processed.

To maximize the speed of transfer it is recommended that a high communications data rate is used and GNSS processing is stopped during the transfer (see UBX-CFG-RST).

UBX-LOG-RETRIEVE can specify a start entry index and entry count. The maximum number of entries that can be returned in response to a single UBX-LOG-RETRIEVE message is 256. If more entries than this are required the message will need to be sent multiple times with different startEntry indices. It might be useful to stop recording via CFG_LOGFILTER-RECORD_ENA while retrieving log entries from a circular log to avoid deletion of the requested entries between the request and transmission.

The receiver will send a UBX-LOG-RETRIEVEPOS message for each position fix log entry and a UBX-LOG-RETRIEVESTRING message for each string log entry. If the odometer was enabled at the time a position was logged, then a UBX-LOG-RETRIEVEPOSEXTRA will also be sent. Messages will be sent in the order in which they were logged, so UBX-LOG-RETRIEVEPOS and UBX-LOG-RETRIEVESTRING messages may be interspersed in the message stream.

The UBX-LOG-FINDTIME message can be used to search a log for the index of the first entry less than or equal to the given time. This index can then be used with the UBX-LOG-RETRIEVE message to provide time-based retrieval of log entries.

3.4.6 Command message acknowledgment

Some log operations may take a long time to execute because of the time taken to write to flash memory. The time for some operations may be unpredictable since the number and timing of flash operations may vary. In order to allow host software to synchronize to these delays logging messages will always produce a response. This will be UBX-ACK-NAK in case of error, otherwise UBX-ACK-ACK unless there is some other defined response to the message.

It is possible to send a small number of logging commands without waiting for acknowledgment, since there is a command queue, but this risks confusion between the acknowledgments for the commands. Also a command queue overflow would result in commands being lost.

3.5 Communication Interface

u-blox receivers are equipped with a communication interface which is multi-protocol capable. The interface can be used to transmit GNSS measurements, monitor status information and configure the receiver.

More than one protocol (e.g. UBX protocol and NMEA) can be assigned to a single port (multi-protocol capability), which is particularly useful for debugging purposes.

RCB-F9T provides a UART interface for communication with a host CPU. The interface is configured via the configuration methods described in the applicable Interface description [2]

The following table shows the port number reported in the UBX-MON-COMMS messages.

Port no.	UBX-MON-COMMS portId	Electrical interface
1	0x0100	UART1

Table 17: Port number assignment

☞ It is important to isolate interface pins when the RCB-F9T VCC is removed. They can be allowed to float or connected to a high impedance.

3.5.1 UART

The UART serves as the host interface. It supports a configurable baud rate and protocol selection.

☞ The default baud rate is 115200 baud. To prevent buffering problems it is recommended not to run at a lower baud rate than 38400 baud.

3.6 Predefined PIOs

In addition to the communication ports, there are some predefined PIOs provided by RCB-F9T to interact with the receiver. These PIOs are described in this section.

☞ If hardware backup mode is used a proper isolation of the interfaces is needed.

3.6.1 RESET_N

The RCB-F9T provides the ability to reset the receiver. The RESET_N pin is an input-only pin with an internal pull-up resistor. Driving RESET_N low for at least 100 ms will trigger a cold start.

☞ The RESET_N pin will delete all information and trigger a cold start. It should only be used as a recovery option.

3.6.2 TIMEPULSE

The RCB-F9T provides time pulse signals on the TIMEPULSE and TIMEPULSE2 pins.

More information about the time pulse feature and its configuration can be found in the Time pulse section.

☞ The TIMEPULSE2 and the SAFEBOOT_N functions share the same PIO pin via series resistors, hence the TIMEPULSE2 pin should not be pulled low or high at reset or startup in the application circuit, otherwise this can provoke or inhibit safeboot operation.

3.7 Antenna supervisor

The RCB-F9T includes circuitry to check an active antenna connection for open and short circuits and to shut off the antenna supply if a short circuit is detected. The circuitry connects with the three antenna supervison pins on the ZED-F9T module: ANT_OFF, ANT_SHORT_N and ANT_DET as shown in Figure 1. Once enabled, the receiver antenna supervisor function produces status messages, reporting in NMEA and/or UBX protocol.

The antenna supervisor monitors the antenna supply current consumption for open or short circuit conditions:

• Antenna open: current consumption is less than 16 mA (typical value)
• Antenna short circuit: current consumption is more than 215 mA (typical value)

The antenna supervisor can be configured through the CFG-HW-ANT_* configuration items. The current configuration of the antenna supervisor can also be checked by polling the related CFG-HW_ANT_* configuration items.

The current active antenna status can be determined by polling the UBX-MON-RF message. If an antenna is connected, the initial state after power-up is "Active Antenna OK" in the u-center UBX-MON-RF view.

☞ The antenna supervisor functionality is enabled by default in the RCB-F9T.

The following sections describes the three pin functions.

3.7.1 Antenna supply control - ANT_OFF

Setting the configuration item CFG-HW-ANT_CFG_VOLTCTRL to '1' enables the antenna supply On/Off control.

☞   The antenna voltage control is enabled by default in the RCB-F9T.

When enabled:

- ANT_OFF output controls the external antenna supply (active low).
- Polling `UBX-MON-RF`: Antenna status = OK, Antenna power status = ON

Start-up message at power up if configuration is stored:-

`$GNTXT,01,01,02,ANTSUPERV=AC SD *37`

`$GNTXT,01,01,02,ANTSTATUS=INIT*3B`

`$GNTXT,01,01,02,ANTSTATUS=OK*25`

`ANTSUPERV=AC SD` - (Antenna controlled and short detection activated - see below)

3.7.2 Antenna short detection - ANT_SHORT_N

Setting the configuration item CFG-HW-ANT_CFG_SHORTDET to true (1) enables the antenna short detection function.

☞   Antenna short detection is enabled by default in the RCB-F9T.

When enabled and the ANT_SHORT_N pin is pulled low a short circuit is signalled (otherwise the pin is pulled up):-

- A `$GNTXT,01,01,02,ANTSTATUS=SHORT*73` message is issued
- ANT_OFF is set high to disable the antenna supply
- Polling `UBX-MON-RF`: Antenna status = SHORT, Antenna power status = OFF (Antenna power control powers down when short has been detected)

Otherwise under normal operation:-

- Polling `UBX-MON-RF`: Antenna status = OK, Antenna power status = ON

Start up messages at power up if configuration is stored:-

$GNTXT,01,01,02,ANTSUPERV=AC SD *37

$GNTXT,01,01,02,ANTSTATUS=INIT*3B

$GNTXT,01,01,02,ANTSTATUS=OK*25

ANTSUPERV=AC SD (Antenna control and short detection activated)

3.7.3 Antenna short detection auto recovery

Setting the configuration item CFG-HW-ANT_CFG_RECOVER to true (1) enables the antenna short detection auto recovery function.

☞   The antenna short detection auto recovery is enabled by default in the RCB-F9T.

Start-up message at power up if configuration is stored:-

`$GNTXT,01,01,02,ANTSUPERV=AC SD PDoS SR*3E`

`$GNTXT,01,01,02,ANTSTATUS=INIT*3B`

`$GNTXT,01,01,02,ANTSTATUS=OK*25`

`ANTSUPERV=AC SD PDoS SR` (SR indicates short circuit recovery)

If the antenna supply is shorted (ANT_SHORT_N pulled low):-

- A `$GNTXT,01,01,02,ANTSTATUS=SHORT*73` message is issued
- ANT_OFF = high (disabled supply)
- Polling `UBX-MON-RF`: Antenna status = SHORT, Antenna power status = OFF

After a time out period (30s?) the receiver will reconnect the supply (ANT_OFF = LOW) and retest for a short condition.

If a short is not present the antenna condition is reported:-

- `$GNTXT,01,01,02,ANTSTATUS=OK*25`
- Polling `UBX-MON-RF` in u-center: Antenna status = OK, Antenna power status = ON

Otherwise the supply is cut off and another connection attempt made after the timeout period.

3.7.4 Antenna open circuit detection - ANT_DETECT

Setting the configuration item CFG-HW-ANT_CFG_OPENDET to true (1) enables antenna open circuit detection.

☞ The antenna open circuit detection is enabled by default in the RCB-F9T.

When enabled if the ANT-DETECT pin is high the antenna is assumed to be connected under nominal current and voltage conditions.

Start-up message at power up if configuration is stored:

`$GNTXT,01,01,02,ANTSUPERV=AC SD OD PDoS SR*15`

`$GNTXT,01,01,02,ANTSTATUS=INIT*3B`

`$GNTXT,01,01,02,ANTSTATUS=OK*25`

`ANTSUPERV=AC SD OD PDoS SR` (OD indicates open circuit detection enabled)

If ANT_DETECT is pulled low to indicate no antenna:-

A `$GNTXT,01,01,02,ANTSTATUS=OPEN*35` is issued

If ANT_DETECT is left floating or is pulled high to indicate antenna connection:

A `$GNTXT,01,01,02,ANTSTATUS=OK*25` is issued

3.8 Multiple GNSS assistance (MGA)

The u-blox AssistNow services provide a proprietary implementation of an A-GNSS protocol compatible with u-blox GNSS receivers.

The MGA services consist of AssistNow Online and Offline variants delivered by HTTP or HTTPS protocol. AssistNow Online optionally provides immediate satellite ephemerides, health information and time aiding data suitable for GNSS receiver systems with direct internet access.

When a client device makes an AssistNow request, the service responds with the requested data using standard UBX protocol MGA messages. These messages are ready for direct transmission from the client to the receiver port without requiring any modification.

3.8.1 Authorization

To use the AssistNow services, customers will need to obtain an authorization token from u-blox. Go to https://www.u-blox.com/en/solution/services/assistnow or contact your local technical support to get more information and to request access to the service.

3.8.2 Preserving MGA and operational data during power-off

The time-to-fix after a receiver power interruption is dependent on the amount of operational data available at startup. Satellite broadcast information plus an estimate of accurate time can be fetched form the AssistNow service. In addition, the following techniques can restore previously stored data prior to power down.

- **Save-on-shutdown:**The receiver can be instructed to dump its current state to flash memory as part of the shutdown procedure; this data is then automatically retrieved when the receiver is restarted. For more information, see section Save-on-shutdown feature for more info. For information on the UBX-UPD-SOS messages consult the applicable Interface description [2].
- **Database dump:** The receiver can be made to dump the state of its navigation database in the form of a sequence of UBX messages reported to the host; these messages can be stored by the host and then sent back to the receiver when it has been restarted. See the description of the UBX-MGA-DBD messages in the applicable Interface description [2] for more information.

3.9 Clocks and time

This section introduces and explains the concepts of receiver clocks and time bases.

3.9.1 Receiver local time

The receiver is dependent on a local oscillator for both the operation of its radio parts and also for timing within its signal processing. No matter what nominal frequency the local oscillator has, u-blox receivers subdivide the oscillator signal to provide a 1-kHz reference clock signal, which is used to drive many of the receiver's processes. In particular, the measurement of satellite signals is arranged to be synchronized with the "ticking" of this 1-kHz clock signal.

When the receiver first starts, it has no information about how these clock ticks relate to other time systems; it can only count time in 1 millisecond steps. However, as the receiver derives information from the satellites it is tracking or from aiding messages, it estimates the time that each 1-kHz clock tick takes in the time base of the chosen GNSS system. This estimate of GNSS time based on the local 1-kHz clock is called receiver local time.

As receiver local time is a mapping of the local 1-kHz reference onto a GNSS time base, it may experience occasional discontinuities, especially when the receiver first starts up and the information it has about the time base is changing. Indeed, after a cold start, the receiver local time will initially indicate the length of time that the receiver has been running. However, when the receiver obtains some credible timing information from a satellite or an aiding message, it will jump to an estimate of GNSS time.

3.9.2 Navigation epochs

Each navigation solution is triggered by the tick of the 1-kHz clock nearest to the desired navigation solution time. This tick is referred to as a **navigation epoch**. If the navigation solution attempt is successful, one of the results is an accurate measurement of time in the time base of the chosen

GNSS system, called **GNSS system time**. The difference between the calculated GNSS system time and receiver local time is called **clock bias** (and **clock drift** is the rate at which this bias is changing).

In practice the receiver's local oscillator will not be as stable as the atomic clocks to which GNSS systems are referenced and consequently clock bias will tend to accumulate. However, when selecting the next navigation epoch, the receiver will always try to use the 1-kHz clock tick which it estimates to be closest to the desired fix period as measured in GNSS system time. Consequently the number of 1-kHz clock ticks between fixes will occasionally vary. This means that when producing one fix per second, there will normally be 1000 clock ticks between fixes, but sometimes, to correct drift away from GNSS system time, there will be 999 or 1001.

The GNSS system time calculated in the navigation solution is always converted to a time in both the GPS and UTC time bases for output.

Clearly when the receiver has chosen to use the GPS time base for its GNSS system time, conversion to GPS time requires no work at all, but conversion to UTC requires knowledge of the number of leap seconds since GPS time started (and other minor correction terms). The relevant GPS-to-UTC conversion parameters are transmitted periodically (every 12.5 minutes) by GPS satellites, but can also be supplied to the receiver via the UBX-MGA-GPS-UTC aiding message. By contrast when the receiver has chosen to use the GLONASS time base as its GNSS system time, conversion to GPS time is more difficult as it requires knowledge of the difference between the two time bases, but as GLONASS time is closely linked to UTC, conversion to UTC is easier.

When insufficient information is available for the receiver to perform any of these time base conversions precisely, predefined default offsets are used. Consequently plausible times are nearly always generated, but they may be wrong by a few seconds (especially shortly after receiver start). Depending on the configuration of the receiver, such "invalid" times may well be output, but with flags indicating their state (e.g. the "valid" flags in UBX-NAV-PVT).

☞ u-blox receivers employ multiple GNSS system times and/or receiver local times (in order to support multiple GNSS systems concurrently), so users should not use UBX messages reporting GNSS system time or receiver local time. It is recommended to use messages that report UTC time and other messages are retained only for backwards compatibility reasons.

3.9.3 iTOW timestamps

All the main UBX-NAV messages (and some other messages) contain an **iTOW** field which indicates the GPS time at which the navigation epoch occurred. Messages with the same iTOW value can be assumed to have come from the same navigation solution.

Note that iTOW values may not be valid (i.e. they may have been generated with insufficient conversion data) and therefore it is not recommended to use the iTOW field for any other purpose.

☞ The original designers of GPS chose to express time/date as an integer week number (starting with the first full week in January 1980) and a time of week (often abbreviated to TOW) expressed in seconds. Manipulating time/date in this form is far easier for digital systems than the more conventional year/month/day, hour/minute/second representation. Consequently, most GNSS receivers use this representation internally, only converting to a more conventional form at external interfaces. The iTOW field is the most obvious externally visible consequence of this internal representation.

If reliable absolute time information is required, users are recommended to use the UBX-NAV-PVT navigation solution message which also contains additional fields that indicate the validity (and

accuracy in UBX-NAV-PVT) of the calculated times (see also the GNSS times section below for further messages containing time information).

3.9.4 GNSS times

Each GNSS has its own time reference for which detailed and reliable information is provided in the messages listed in the table below.

Time reference	Message
GPS time	UBX-NAV-TIMEGPS
BeiDou time	UBX-NAV-TIMEBDS
GLONASS time	UBX-NAV-TIMEGLO
Galileo time	UBX-NAV-TIMEGAL
NavIC time	UBX-NAV-TIMENAVIC
UTC time	UBX-NAV-TIMEUTC

Table 18: GNSS times

3.9.5 Time validity

Information about the validity of the time solution is given in the following form:

- Time validity: Information about time validity is provided in the `valid` flags (e.g. `validDate` and `validTime` flags in the UBX-NAV-PVT message). If these flags are set, the time is known and considered valid for use. These flags are shown in table GNSS times in section GNSS times above as well as in the UBX-NAV-PVT message.
- Time validity confirmation: Information about confirmed validity is provided in the `confirmedDate` and `confirmedTime` flags in the UBX-NAV-PVT message. If these flags are set, the time validity can be confirmed by using an additional independent source, meaning that the probability of the time to be correct is very high. Note that information about time validity confirmation is only available if the `confirmedAvai` bit in the UBX-NAV-PVT message is set.

☞ `validDate` means that the receiver has knowledge of the current date. However, it must be noted that this date might be wrong for various reasons. Only when the `confirmedDate` flag is set, the probability of the incorrect date information drops significantly.

☞ `validTime` means that the receiver has knowledge of the current time. However, it must be noted that this time might be wrong for various reasons. Only when the `confirmedTime` flag is set, the probability of incorrect time information drops significantly.

☞ `fullyResolved` means that the UTC time is known without full seconds ambiguity. When deriving UTC time from GNSS time the number of leap seconds must be known, with the exception of GLONASS. It might take several minutes to obtain such information from the GNSS payload. When the one second ambiguity has not been resolved, the time accuracy is usually in the range of ~20s.

3.9.6 UTC representation

UTC time is used in many NMEA and UBX messages. In NMEA messages it is always reported rounded to the nearest hundredth of a second. Consequently, it is normally reported with two decimal places (e.g. 124923.52). Although compatibility mode (selected using CFG-NMEA-COMPAT) requires three decimal places, rounding to the nearest hundredth of a second remains, so the extra digit is always 0.

UTC time is also reported within some UBX messages, such as UBX-NAV-TIMEUTC and UBX-NAV-PVT. In these messages date and time are separated into seven distinct integer fields. Six of these (year, month, day, hour, min and sec) have fairly obvious meanings and are all guaranteed to match the corresponding values in NMEA messages generated by the same navigation epoch. This facilitates simple synchronization between associated UBX and NMEA messages.

The seventh field is called nano and it contains the number of nanoseconds by which the rest of the time and date fields need to be corrected to get the precise time. So, for example, the UTC time 12:49:23.521 would be reported as: hour: 12, min: 49, sec: 23, nano: 521000000.

It is however important to note that the first six fields are the result of rounding to the nearest hundredth of a second. Consequently the nano value can range from -5000000 (i.e. -5 ms) to +994999999 (i.e. nearly 995 ms).

When the nano field is negative, the number of seconds (and maybe minutes, hours, days, months or even years) will have been rounded up. Therefore, some or all of them must be adjusted in order to get the correct time and date. Thus in an extreme example, the UTC time 23:59:59.9993 on 31st December 2011 would be reported as: year: 2012, month: 1, day: 1, hour: 0, min: 0, sec: 0, nano: -700000.

Of course, if a resolution of one hundredth of a second is adequate, negative nano values can simply be rounded up to 0 and effectively ignored.

The UBX-NAV-TIMEUTC message gives information about UTC time reference clock.

The preferred variant of UTC time can be specified using CFG-NAVSPG-UTCSTANDARD configuration item.

☞ UTC time is derived directly from the GNSS time scale, which in turn is realized by the receiver's navigation solution. The derivation of the UTC time includes various parameters that are having their own errors which are then added on top of receiver's navigation solution error. Because of that, UTC time is not recommended to be used in high accuracy timing applications. The best timing accuracy and stability is achieved when receiver outputs GNSS time scale rather than UTC.

3.9.7 Leap seconds

Occasionally it is decided (by one of the international time keeping bodies) that, due to the slightly uneven spin rate of the Earth, UTC has moved sufficiently out of alignment with mean solar time (i.e. the Sun no longer appears directly overhead at 0 longitude at midday). A "leap second" is therefore announced to bring UTC back into close alignment. This normally involves adding an extra second to the last minute of the year, but it can also happen on 30th June. When this happens UTC clocks are expected to go from 23:59:59 to 23:59:60 and only then on to 00:00:00.

It is also theoretically possible to have a negative leap second, in which case there will only be 59 seconds in a minute and 23:59:58 will be followed by 00:00:00.

u-blox receivers are designed to handle leap seconds in their UTC output and consequently users processing UTC times from either NMEA or UBX messages should be prepared to handle minutes that are either 59 or 61 seconds long.

Leap second information can be polled from the u-blox receiver with the message UBX-NAV-TIMELS.

3.9.8 Real-time clock

u-blox receivers contain circuitry to support a real-time clock, which (if correctly fitted and powered) keeps time while the receiver is otherwise powered off. When the receiver powers up, it attempts to

use the real-time clock to initialize receiver local time and in most cases this leads to appreciably faster first fixes.

3.9.9 Date

All GNSS frequently transmit information about the current time within their data message. In most cases, this is a time of week (often abbreviated to TOW), which indicates the elapsed number of seconds since the start of the week (midnight Saturday/Sunday). In order to map this to a full date, it is necessary to know the week and so the GNSS also transmit a week number, typically every 30 seconds. Unfortunately the GPS L1C/A data message was designed in a way that only allows the bottom 10 bits of the week number to be transmitted. This is not sufficient to yield a completely unambiguous date as every 1024 weeks (a bit less than 20 years), the transmitted week number value "rolls over" back to zero. Consequently, GPS L1 receivers cannot tell the difference between, for example, 1980, 1999 or 2019 etc.

Fortunately, although BeiDou and Galileo have similar representations of time, they transmit sufficient bits for the week number to be unambiguous for the foreseeable future (the first ambiguity will be in 2078 for Galileo and not until 2163 for BeiDou). GLONASS has a different structure, based on a time of day, but again transmits sufficient information to avoid any ambiguity during the expected lifetime of the system (the first ambiguous date will be in 2124). Therefore, u-blox 9 receivers using Protocol Version 24 and above regard the date information transmitted by GLONASS, BeiDou and Galileo to be unambiguous and, where necessary, use this to resolve any ambiguity in the GPS date.

☞ Customers attaching u-blox receivers to simulators should be aware that GPS time is referenced to 6th January 1980, GLONASS to 1st January 1996, Galileo to 22nd August 1999 and BeiDou to 1st January 2006; the receiver cannot be expected to work reliably with signals simulated before these dates.

3.9.9.1 GPS-only date resolution

In circumstances where only GPS L1C/A signals are available and for receivers with earlier firmware versions, the receiver establishes the date by assuming that all week numbers must be at least as large as a reference rollover week number. This reference rollover week number is hard-coded at compile time and is normally set a few weeks before the software is completed, but it can be overridden by CFG-NAVSPG-WKNROLLOVER configuration item to any value the user wishes.

The following example illustrates how this works: Assume that the reference rollover week number set in the firmware at compile time is 1524 (which corresponds to a week in calendar year 2009, but would be transmitted by the satellites as 500). In this case, if the receiver sees transmissions containing week numbers in the range of 500 … 1023, these will be interpreted as week numbers 1524 … 2047 (calendar year 2009 … 2019), whereas transmissions with week numbers from 0 to 499 are interpreted as week numbers 2048 … 2547 (calendar year 2019 … 2028).

☞ It is important to set the reference rollover week number appropriately when supplying u-blox receivers with simulated signals, especially when the scenarios are in the past.

3.10 Timing functionality

In addition to positioning and navigation applications, GNSS signals are widely used as low-cost precision time or frequency references used by remote or distributed wireless communication, industrial, financial, and power distribution equipment. By capitalizing on atomic clocks which are on-board positioning satellites, GNSS signals which contain embedded timing information can be used to synchronize equipment, as well as to provide UTC time. For wireless communication

standards that utilize Time Division Multiplex (TDM) and applications such as femtocell base stations, a precision time reference is mandatory.
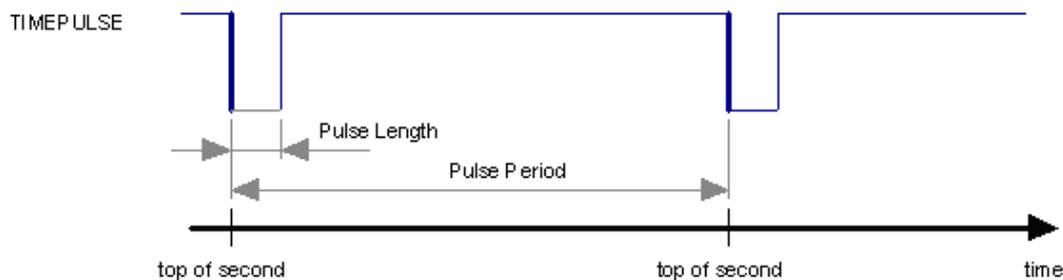
3.10.1 Time pulse

3.10.1.1 Introduction

Figure 9: Time pulse

3.10.1.2 Recommendations

- The time pulse can be aligned to a wide variety of GNSS times or to variants of UTC derived from them (see the section on time bases). However, it is strongly recommended that the choice of time base is aligned with the available GNSS signals (so to produce GPS time or UTC(USNO), ensure GPS signals are available, and for GLONASS time or UTC(SU) ensure the presence GLONASS signals). This will involve coordinating the setting of CFG-SIGNAL-* configuration group with the choice of time pulse time base.
- When using time pulse for timing applications requiring absolute time accuracy, e.g. with requirements specifying offset to UTC, it is recommended to calibrate the user's full setup for TP output against a reference timing source. To achieve best absolute and consistent accuracy (e.g. for mass deployment), it is recommended that the user should calibrate each single setup and calibrate under different GNSS modes and different temperatures which are applicable to the user's application and operating requirements. The user should take the calibrated values and configure the compensation accordingly (see the section on Time pulse configuration)
- To get the best timing accuracy with the antenna, a fixed and *accurate* position is needed.
- If relative time accuracy between multiple receivers is required, do not mix receivers of different product families. If this is required, the receivers must be calibrated accordingly, by setting cable delay and user delay.
- The recommended configuration when using the UBX-TIM-TP message is to set both the measurement rate (CFG-RATE-MEAS) and the time pulse frequency (CFG-TP-*) to 1 Hz.

☞ Since the rate of UBX-TIM-TP is bound to 1 Hz, more than one UBX-TIM-TP message can appear between two pulses if the time pulse frequency is set lower than 1 Hz. In this case all UBX-TIM-TP messages in between time pulses T1 and T2 belong to T2 and the last UBX-TIM-TP before T2 reports the most accurate quantization error. In general, if the time pulse rate is not configured to 1 Hz, there will not be a single UBX-TIM-TP message for each time pulse.

☞ When using SBAS, it is recommended to use the SBAS_IONOONLY mode.

The sequential order of the signal present at the TIMEPULSE pin and the respective output message for the simple case of 1 pulse per second (1PPS) is shown in the following figure.
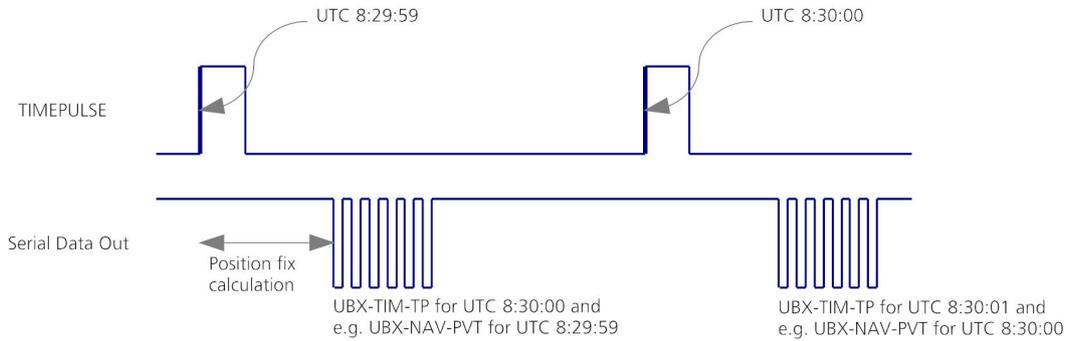

Figure 10: Time pulse and TIM-TP

3.10.1.3 GNSS time bases

GNSS receivers must handle a variety of different time bases as each GNSS has its own reference system time. What is more, although each GNSS provides a model for converting their system time into UTC, they all support a slightly different variant of UTC. So, for example, GPS supports a variant of UTC as defined by the US National Observatory, while BeiDou uses UTC from the National Time Service Center, China (NTSC). While the different UTC variants are normally closely aligned, they can differ by as much as a few hundreds of nanoseconds.

Although u-blox receivers can combine a variety of different GNSS times internally, the user must choose a single type of GNSS time and, separately, a single type of UTC for input (on EXTINT pins) and output (via the TIMEPULSE pin) and the parameters reported in corresponding messages.

The CFG-TP-TIMEGRID_TP* configuration item allows the user to choose between any of the supported GNSS (GPS, GLONASS, BeiDou, etc.) time bases and UTC. Also, the CFG-NAVSPG-UTCSTANDARD configuration item allows the user to select which variant of UTC the receiver should use. This includes an "automatic" option which causes the receiver to select an appropriate UTC version itself, based on the GNSS configuration, using, in order of preference, USNO if GPS is enabled, SU if GLONASS is enabled, NTSC if BeiDou is enabled, European if Galileo is enabled, finally, NPLI if NAVIC is enabled.

The receiver will assume that an input time pulse uses the same GNSS time base as specified for the time pulse output. So if the user selects GLONASS time for time pulse output, any time pulse input must also be aligned to GLONASS time (or to the separately chosen variant of UTC). Where UTC is selected for time pulse output, any GNSS time pulse input will be assumed to be aligned to GPS time.

☞ u-blox receivers allow users to independently choose GNSS signals used in the receiver (using CFG-SIGNAL-*) and the input/output time base (using CFG-TP-*). For example it is possible to instruct the receiver to use GPS and GLONASS satellite signals to generate BeiDou time. This practice will compromise time pulse accuracy if the receiver cannot measure the timing difference between the constellations directly and is therefore not recommended.

☞ The information that allows GNSS times to be converted to the associated UTC times is only transmitted by the GNSS at relatively infrequent periods. For example GPS transmits UTC(USNO) information only once every 12.5 minutes. Therefore, if a time pulse is configured to use a variant of UTC time, after a cold start, substantial delays before the receiver has sufficient information to start outputting the time pulse can be expected.

3.10.1.4 Time pulse configuration

u-blox RCB-F9T receivers provide a time pulse (TIMEPULSE) signal with a configurable pulse period, length and polarity (rising or falling edge).

It is possible to define different signal behavior (i.e. output frequency and pulse length) depending on whether or not the receiver is locked to a reliable time source. Time pulse signal can be configured using the configuration group CFG-TP-*.

3.10.1.5 Configuring time pulse with CFG-TP-*

The configuration group CFG-TP-* can be used to change the time pulse settings, and includes the following parameters defining the pulse:

- **timepulse enable** - If this item is set, the time pulse is active.
- **frequency/period type** - Determines whether the time pulse is interpreted as frequency or period.
- **length/ratio type** - Determines whether the time pulse length is interpreted as length [us] or pulse ratio [%].
- **antenna cable delay** - Signal delay owning to RF components (e.g. antenna, cable, and splitter etc.) before the receiver input. This delay parameter affects the receiver calculation of GNSS time and it is used to compensate for the signal transit time prior to the receiver and any uncompensated delay from the receiver; a positive value compensates this delay, i.e. advances the time pulse
- **pulse frequency/period** - Frequency or pulse time period when locked mode is not configured or active.
- **pulse frequency/period lock** - Frequency or pulse time period, as soon as the receiver has calculated a valid time from a received signal. Only used if the corresponding item is set to use another setting in locked mode.
- **pulse length/ratio** - Length or duty cycle of the generated pulse, either specifies a time or ratio for the pulse to be on/off.
- **pulse length/ratio lock** - Length or duty cycle of the generated pulse, as soon as the receiver has calculated a valid time from a received signal. Only used if the corresponding item is set to use another setting in locked mode.
- **user delay** - A time offset of the TP output for adjustment in a user application. It adjusts the time pulse position only with respect to GNSS time. Configuring a positive value will add a delay, i.e. retard the pulse with respect to GNSS time. Conversely, a negative value will advance the pulse. This configuration is available for all supported TP outputs.
- **lock to GNSS freq** - If this item is set, uses the frequency gained from the GNSS signal information rather than the local oscillator's frequency.
- **locked other setting** - If this item is set, the alternative setting will be used as soon as the receiver can calculate a valid time. This mode can be used, for example, to disable time pulse if the time is not locked, or to indicate a lock with different duty cycles.
- **align to TOW** - If this item is set, pulses are aligned to the top of a second.
- **polarity** - If set, the first edge of the pulse is a rising edge (pulse polarity: rising).
- **grid UTC/GNSS** - Selection between UTC (0), GPS (1), GLONASS (2), BeiDou (3) and (4) Galileo timegrid. Also affects the time output by UBX-TIM-TP message.

☞ The maximum pulse length cannot exceed the pulse period.

☞ Time pulse settings shall be chosen in such a way that neither the high nor the low period of the output is less than 50 ns (except when disabling it completely), otherwise pulses can be lost.

☞ RCB-F9T time pulse 1 default configuration: UTC time, frequency is 1 Hz and pulse length is 100 ms when GNSS is not locked and 200 ms when GNSS is locked.

3.10.1.5.1 Example

The example below shows the 1PPS TIMEPULSE signal generated on the time pulse output according to the specific parameters of the CFG-TP-* configuration group:

- **CFG-TP-TP1_ENA** = 1
- **CFG-TP-PERIOD_TP1** = 1 000 000 µs
- **CFG-TP-LEN_TP1** = 100 000 µs
- **CFG-TP-TIMEGRID_TP1** = 1 (GPS)
- **CFG-TP-PULSE_LENGTH_DEF** = 0 (Period)
- **CFG-TP-ALIGN_TO_TOW_TP1** = 1
- **CFG-TP-USE_LOCKED_TP1** = 1
- **CFG-TP-POL_TP1** = 1
- **CFG-TP-PERIOD_LOCK_TP1** = 1 000 000 µs
- **CFG-TP-LEN_LOCK_TP1** = 100 000 µs

The 1 Hz output is maintained whether or not the receiver is locked to GPS time. The alignment to TOW can only be maintained when GPS time is locked.
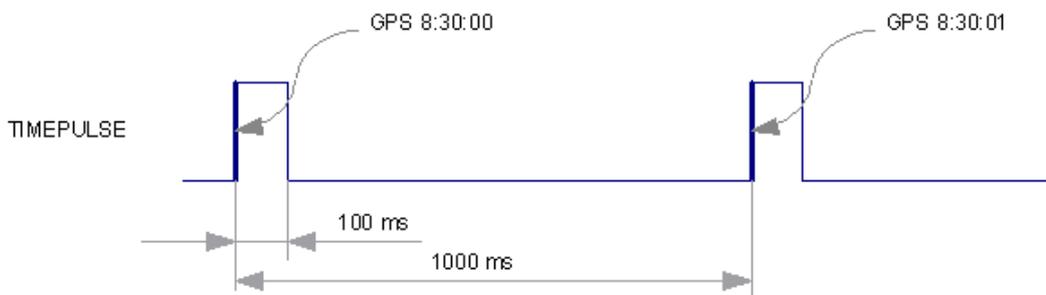

Figure 11: Time pulse signal with the example parameters

3.11 Security

The security concept of RCB-F9T covers:

- the security of the receiver
- communication between the receiver and the GNSS satellites

Some receiver security functions monitor and detect threats and report them to the host system. Other security functions mitigate threats and allow the receiver to operate normally.

The table below gives an overview about possible threats and which functionality is available to detect and/or mitigate it.

Threat	u-blox solution
Over air signal security	Spoofing detection and monitoring
	Jamming interference detection and monitoring
GNSS receiver security	Secure boot
	Secure firmware update

Table 19: u-blox security options

3.11.1 Spoofing detection and monitoring

Spoofing is the process where a counterfeit GNSS signal is transmitted locally to deceive the receiver/user and produce an erroneous position fix and/or time solution.

The detection algorithm monitors GNSS signals for implausible changes or inconsistencies. These are evaluated with regards to spoofing.

A detection is successful when a signal is observed to transition from an initially genuine one to a spoofed version. Hence detection is not possible if the receiver is started under spoofing conditions. The detection algorithms also rely on availability of signals from multiple GNSS constellations to improve the spoofing detection capabilities.

3.11.2 Jamming interference detection and monitoring

The field `jamInd` of the UBX-MON-RF message can be used as an indicator for continuous wave (narrow-band) jammers/interference only. The interpretation of the value depends on the application. It is necessary to run the receiver in an unjammed environment to determine an appropriate threshold for the unjammed case. If the value rises significantly above this threshold, this indicates that a continuous wave jammer is present.

This monitoring function is always enabled.

The indicator reports any currently detected narrow-band interference over all currently configured signal bands.

3.11.2.1 Jamming and interference monitor (ITFM) / broadband interference monitoring

The field `flags` of the UBX-MON-RF message can be used as an indicator for both broadband and continuous wave (CW) jammers/interference. It is independent of the (CW only) jamming indicator described in Jamming/interference indicator above.

This monitor reports whether jamming has been detected or suspected by the receiver. The receiver monitors the background noise and looks for significant changes. Normally, with no interference detected, it will report "OK". If the receiver detects that the noise has risen above a preset threshold, the receiver reports "Warning". If in addition, there is no current valid fix, the receiver reports "Critical".

The monitor has four states as shown in the following table:

Value	Reported state	Description
0	Unknown	Jamming/interference monitor not enabled, uninitialized or antenna disconnected
1	OK	no interference detected
2	Warning	position OK but interference is visible (above the thresholds)
3	Critical	no reliable position fix and interference is visible (above the thresholds); interference is probable reason why there is no fix

Table 20: Jamming and interference monitor reported states

The monitor is disabled by default. The monitor is enabled by setting the CFG-ITFM-ENABLE configuration item. In this message it is also possible to specify the thresholds at which broadband and CW jamming are reported. These thresholds should be interpreted as the dB level above "normal". It is also possible to specify whether the receiver expects an active or a passive antenna.

☞ The monitoring algorithm relies on comparing the currently measured spectrum with a reference from when a good fix was obtained. Thus the monitor will only function when the receiver has had at least one (good) first fix, and will report "Unknown" before this time.

The monitor reports any currently detected interference over all currently configured signal bands.

3.11.3 Consolidated signal security information

The UBX-SEC-SIG [1] message consolidates all information related to the jamming/interferrence and spoofing detection functions into a single message. It provides a direct method for monitoring the current security status to alert a host to potential jamming or spoofing threats. In addition, the UBX-SEC-SIGLOG message provides a log of past signal security events where an event is triggered by the detection logic, thus allowing a review of up to 16 past occurances of possible jamming or spoofing episodes. See the applicable Interface description [2].

3.11.4 GNSS receiver security

3.11.4.1 Secure boot

The RCB-F9T boots only with firmware images that are signed by u-blox. This prevents the execution of non-genuine firmware images on the receiver.

3.11.4.2 Secure firmware update

The firmware image is signed by u-blox. The RCB-F9T verifies the signature during the firmware update.

3.12 u-blox protocol feature descriptions

3.12.1 Broadcast navigation data

This section describes the data reported via UBX-RXM-SFRBX.

UBX-RXM-SFRBX reports the broadcast navigation data message the receiver has collected from each tracked signal. When enabled, a separate message is generated each time the receiver decodes a complete subframe of data from a tracked signal. The data bits are reported as received, including preambles and error checking bits as appropriate. However, because there is considerable variation in the data structure of the different GNSS signals, the form of the reported data also varies. This document uses the term "subframe", but other GNSS data structures might use different terms, for example, GLONASS uses "strings" and Galileo uses "pages".

3.12.1.1 Parsing navigation data subframes

Each UBX-RXM-SFRBX message contains a subframe of data bits appropriate for the relevant GNSS, delivered in a number of 32-bit words, as indicated by numWords field.

Due to the variation in data structure between different GNSS, the most important step in parsing a UBX-RXM-SFRBX message is to identify the form of the data. This should be done by reading the gnssId field, which indicates which GNSS the data was decoded from. In almost all cases, this is sufficient to indicate the structure. Because of this, the following sections are organized by GNSS. However, in some cases the identity of the GNSS is not sufficient, and this is described, where appropriate, in the following sections.

In most cases, the data does not map perfectly into a number of 32-bit words and, consequently, some of the words reported in UBX-RXM-SFRBX messages contain fields marked as "Pad". These fields should be ignored and no assumption should be made about their contents.

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[1] TIM 2.13,TIM2.20 FW onwards

UBX-RXM-SFRBX messages are only generated when complete subframes are detected by the receiver and all appropriate parity checks have passed.

Where the parity checking algorithm requires data to be inverted before it is decoded (e.g. GPS L1C/A), the receiver carries this out before the message output. Therefore, users can process data directly and do not need to worry about repeating any parity processing.

The meaning of the content of each subframe depends on the sending GNSS and is described in the relevant interface control documents (ICD).

3.12.1.2 GPS

The data message structure in the GPS L1C/A (LNAV) and L2C/L5 (CNAV) signals is different and thus the UBX-RXM-SFRBX message structure differs as well. For the GPS L1C/A and L2C/L5 signals it is as follows:

3.12.1.2.1 GPS L1C/A

For GPS L1C/A signals, there is a fairly straightforward mapping between the reported subframe and the structure of subframe and words described in the GPS ICD. Each subframe comprises ten data words, which are reported in the same order they are received.
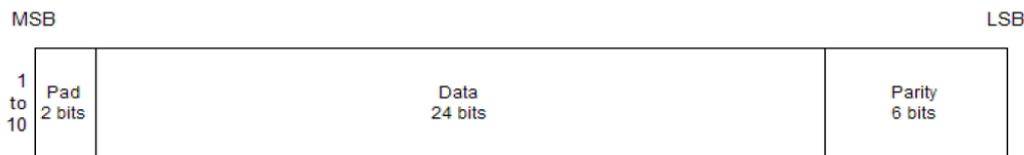
Each word is arranged as follows:

Figure 12: GPS L1C/A subframe word

3.12.1.2.2 GPS L2C

For GPS L2C signals each reported subframe contains the CNAV message as described in the GPS ICD. The ten words are arranged as follows:

Figure 13: GPS L2C subframe words

3.12.1.2.3 GPS L5

For GPS L5 signals each reported subframe contains the CNAV message as described in the GPS ICD. The ten words are arranged as follows:
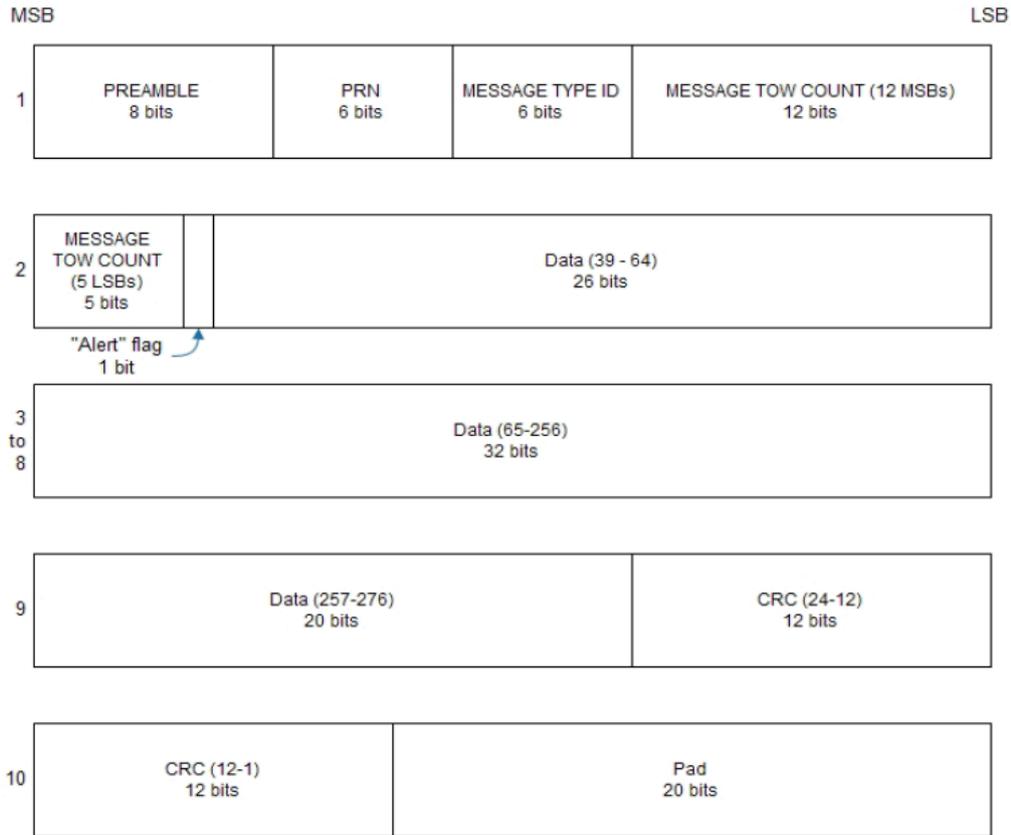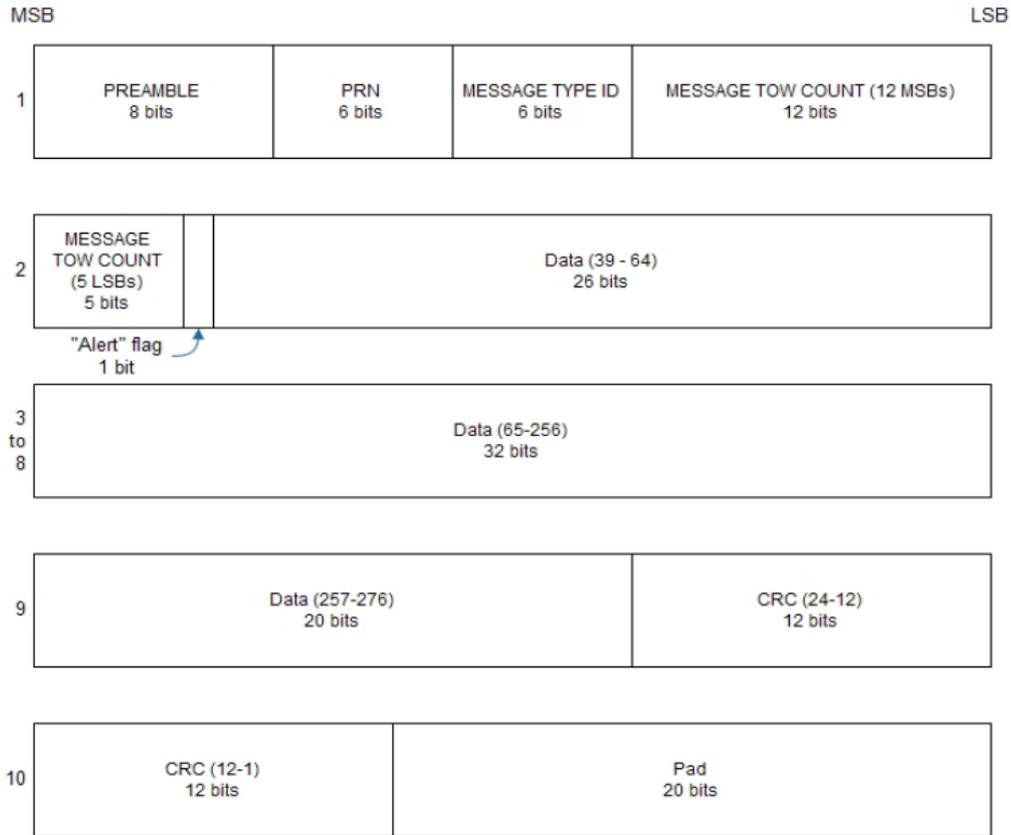
Figure 14: GPS L5 subframe words

3.12.1.3 GLONASS

For GLONASS L1OF signal, the UBX-RXM-SFRBX message contains a string content within the frame structure as described in the GLONASS ICD. This string comprises 85 data bits which are reported over three 32-bit words in the message. Data bits 1 to 8 are always a hamming code, while bits 81 to 84 are a string number and bit 85 is the idle chip, which should always have a value of zero. The meaning of other bits varies with string and frame number.

The fourth and final 32-bit word in the UBX-RXM-SFRBX message contains frame and superframe numbers (where available). These values are not actually transmitted by the satellites, but are deduced by the receiver and are included to aid decoding of the transmitted data. However, the receiver does not always know these values, in which case a value of zero is reported.

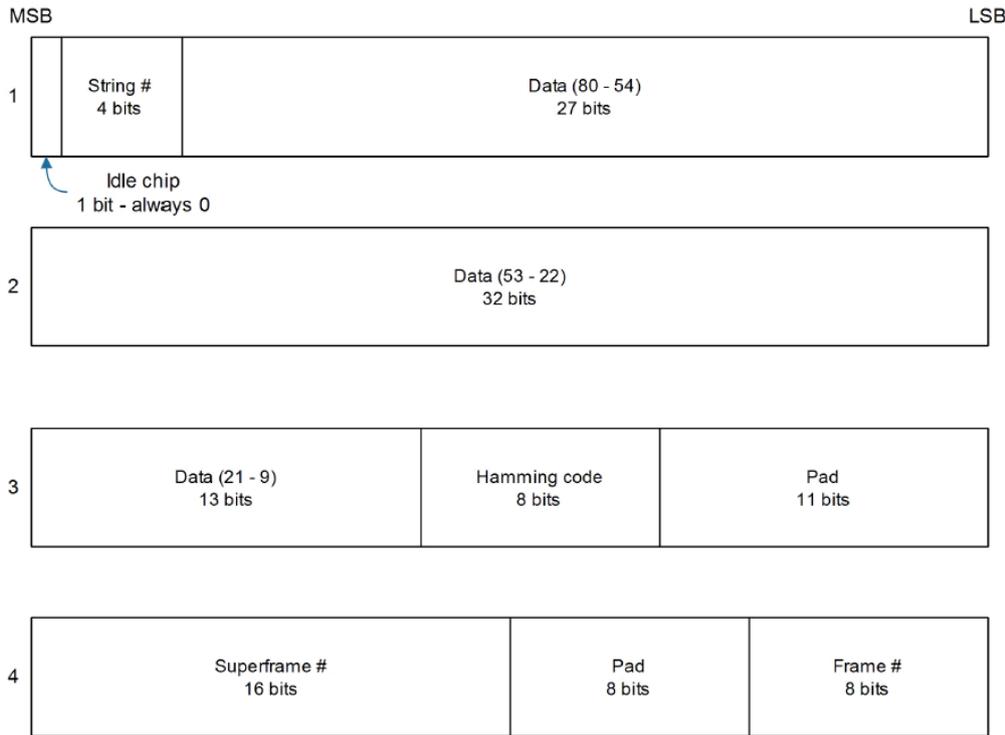The four words are arranged as follows:

Figure 15: GLONASS navigation message data

In some circumstances, (especially on startup) the receiver may be able to decode data from a GLONASS satellite before it can identify it. When this occurs UBX-RXM-SFRBX messages will be issued with an svId of 255 to indicate "unknown".

3.12.1.4 BeiDou

For BeiDou signals there is a fairly straightforward mapping between the reported subframe and the structure of subframe and words described in the BeiDou ICD. Each subframe comprises ten data words, which are reported in the same order they are received.

Each word is arranged as follows:
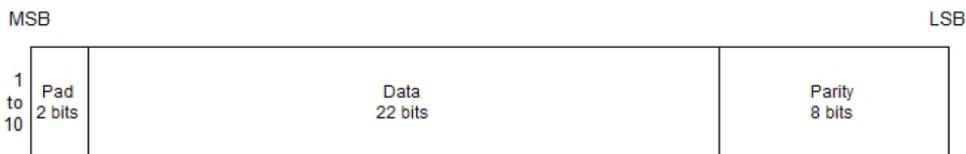
Figure 16: BeiDou subframe word

Note that as the BeiDou data words only comprise 30 bits, the 2 most significant bits in each word reported by UBX-RXM-SFRBX are padding and should be ignored.

3.12.1.5 Galileo

The Galileo E1-B and E5b in-phase signals transmit the I/NAV data message but in different configurations to enhance download time for dual frequency receivers. The UBX-RXM-SFRBX structure for the I/NAV message is shown below.

The Galileo E1-B and E5b in-phase signals (RCB-F9T-0) transmit the I/NAV data message but in different configurations to enhance download time for dual frequency receivers. The Galileo E1-B and E5a signals (RCB-F9T-1) transmit the I/NAV and F/NAV message respectively. The UBX-RXM-SFRBX structure for the I/NAV and F/NAV messages are shown below.

3.12.1.5.1 Galileo E1-B

For the Galileo E1-B signal, each reported subframe contains a pair of I/NAV pages as described in the Galileo ICD. Galileo pages can either be "Nominal" or "Alert" pages. For Galileo "Nominal" pages the eight words are arranged as follows:

Figure 17: Galileo E1-B subframe words

Alert pages are reported in very similar manner, but the page type bits will have value 1 and the structure of the eight words will be slightly different (as indicated by the Galileo ICD).

3.12.1.5.2 Galileo E5b

For the Galileo E5b in-phase signal data component, each reported subframe contains a pair of I/NAV pages as described in the Galileo ICD. Galileo pages can either be "Nominal" or "Alert" pages. For Nominal pages the eight words are arranged as follows:

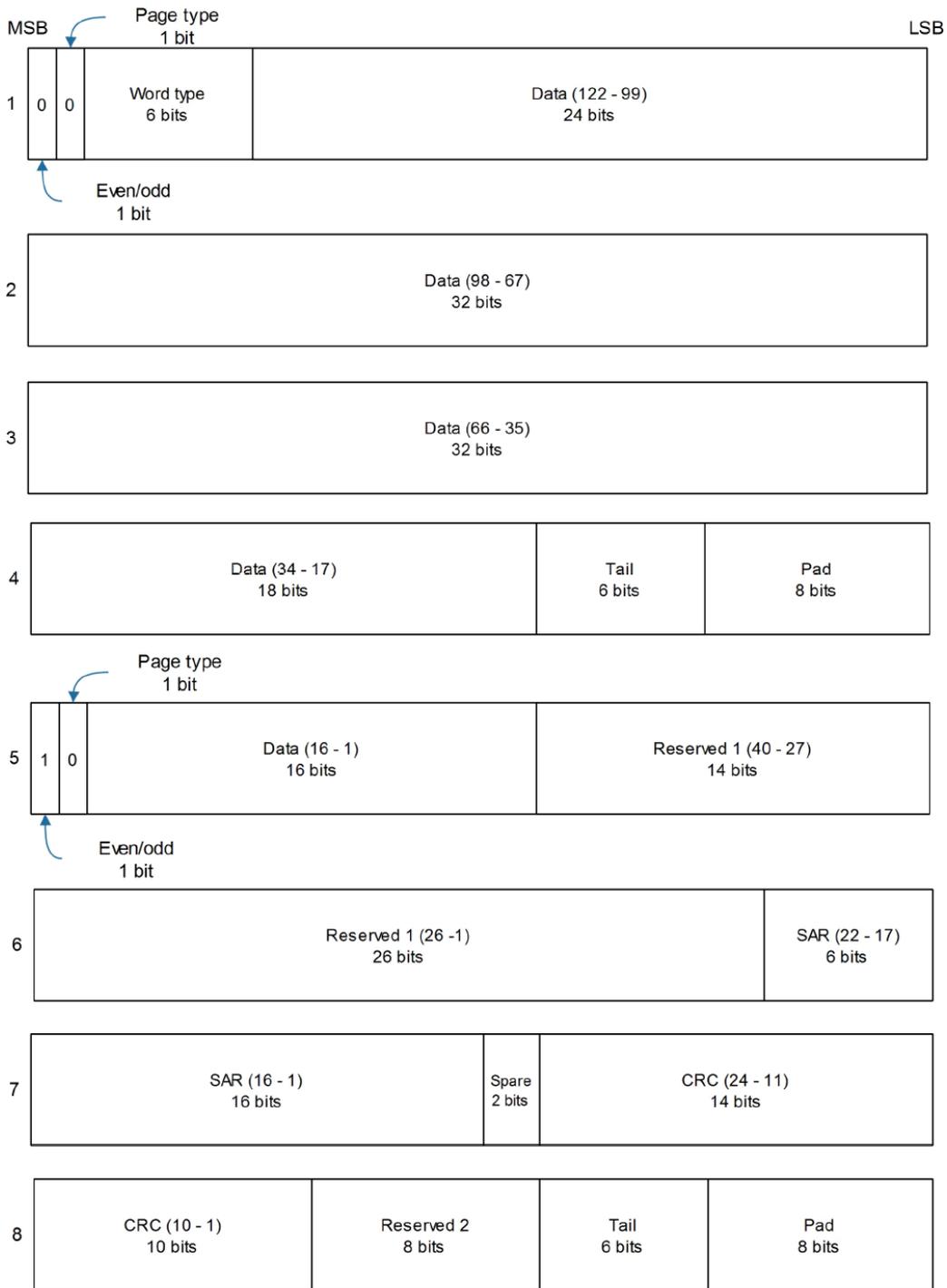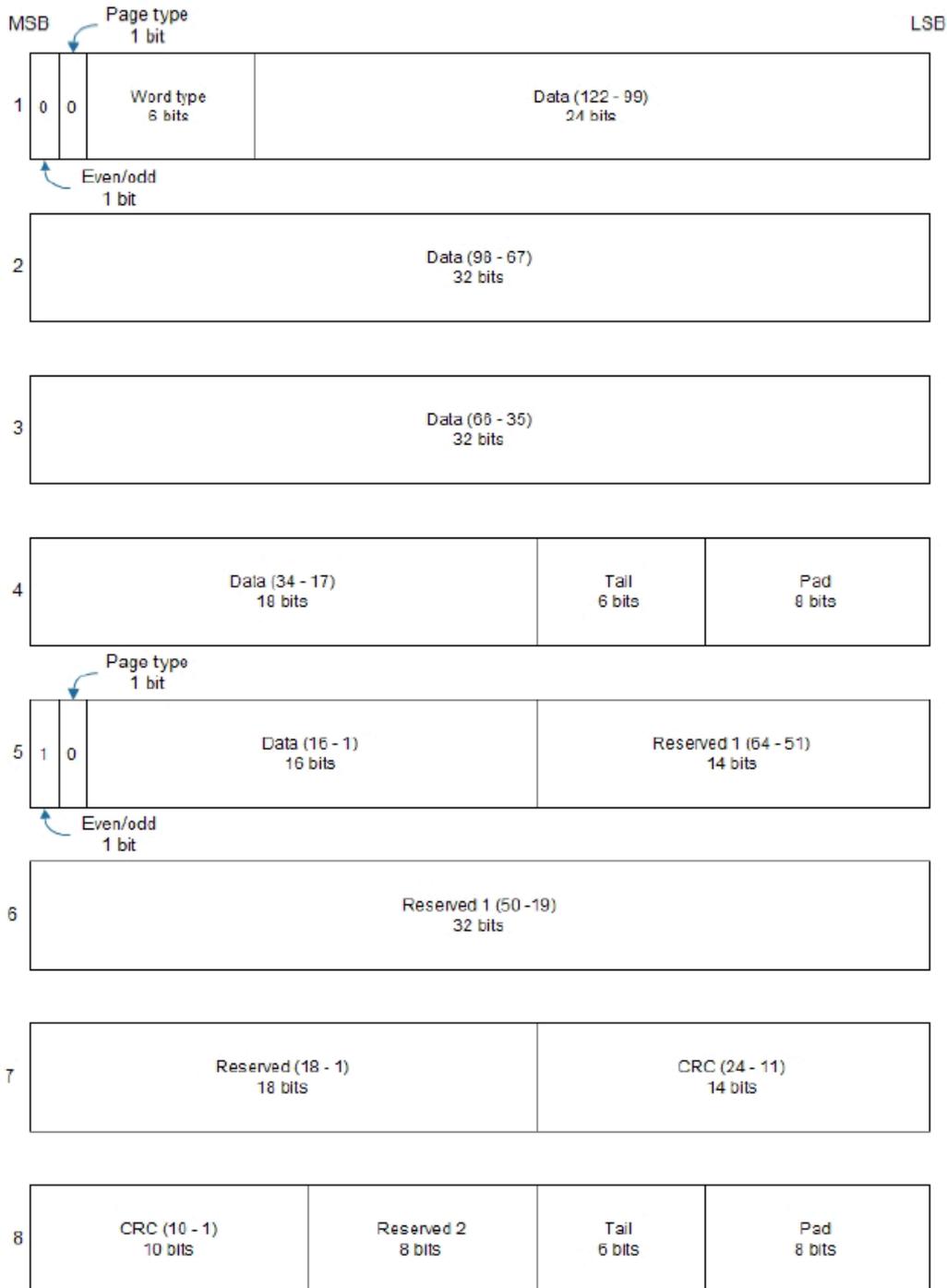**Figure 18: Galileo E5b subframe words**

3.12.1.5.3 Galileo E5a

For the Galileo E5a in-phase signal data component, each reported subframe contains a number of F/NAV pages as described in the Galileo ICD. For each page the eight words are arranged as follows:

MSB   LSB

1	Page type 6 bits	Data (208 - 183) 26 bits

2	Data (182 - 151) 32 bits

3	Data (150 - 119) 32 bits

4	Data (118 - 87) 32 bits

5	Data (86 - 55) 32 bits

6	Data (54 - 23) 32 bits

7	Data (22 - 1) 22 bits	CRC (24 - 15) 10 bits

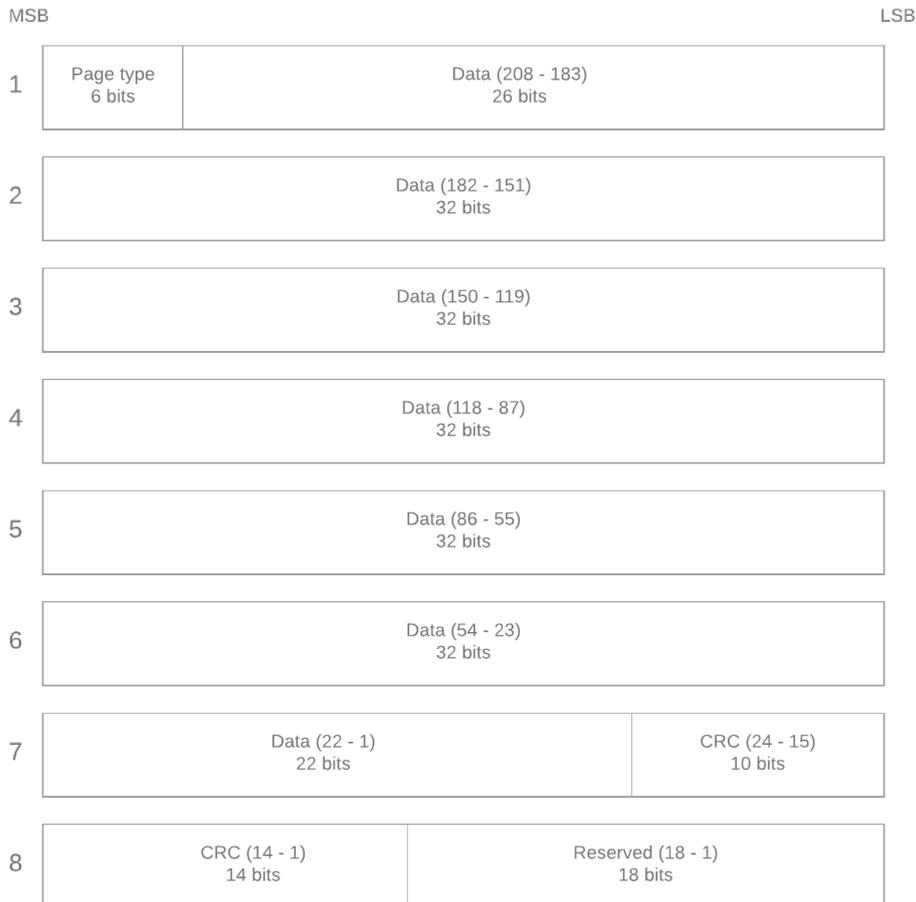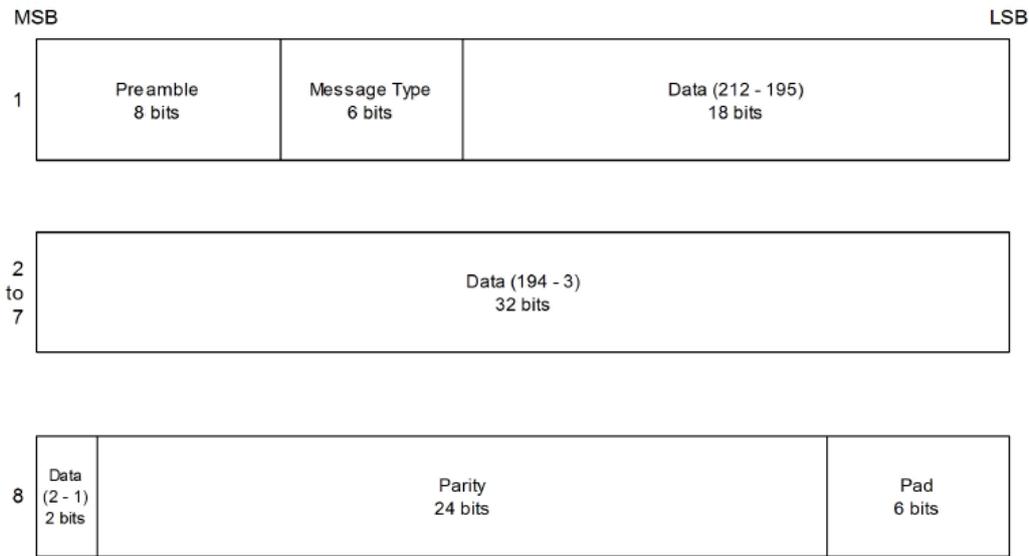|		
8	CRC (14 - 1) 14 bits	Reserved (18 - 1) 18 bits

Figure 19: Galileo E5a subframe words

3.12.1.6 SBAS

For SBAS (L1C/A) signals each reported subframe contains eight 32-bit data words to deliver the 250 bits transmitted in each SBAS data block.

The eight words are arranged as follows:

Figure 20: SBAS subframe words

3.12.1.7 QZSS

The structure of the data delivered by QZSS L1C/A signals is effectively identical to that of GPS (L1C/A). Similarly the structure of the data delivered by the QZSS L2C and L5 signals are effectively identical to that of GPS L2C and L5 respectively.

3.12.1.8 Summary

The following table gives a summary of the different data message formats reported by the UBX-RXM-SFRBX message:

GNSS	Signal	gnssId	sigId	numWords	period
GPS	L1C/A	0	0	10	6s
GPS	L2CL	0	3	10	12s
GPS	L2CM	0	4	10	12s
GPS	L5 I	0	6	10	6s
SBAS	L1C/A	1	0	9	1s
Galileo	E1 B	2	1	8	2s
Galileo	E5b I	2	5	8	2s
Galileo	E5a I	2	3	8	10s
BeiDou	B1I D1	3	0	10	6s
BeiDou	B1I D2	3	1	10	0.6s
BeiDou	B2I D1	3	2	10	6s
BeiDou	B2I D2	3	3	10	0.6s
BeiDou	B2a	3	7	9	3s
QZSS	L1C/A	5	0	10	6s
QZSS	L2CM	5	4	10	12s
QZSS	L2CL	5	5	10	12s
QZSS	L5 I	5	8	10	6s
GLONASS	L1OF	6	0	3	2s

GNSS	Signal	gnssId	sigId	numWords	period
GLONASS	L2OF	6	2	3	2s

Table 21: Data message formats reported by UBX-RXM-SFRBX

3.12.2 Save-on-shutdown feature

The save-on-shutdown feature (SOS) enables the u-blox receiver to store the contents of the battery-backed RAM to an external flash memory and restore it upon startup. This allows the u-blox receiver to preserve some of the features available only with a battery backup (preserving configuration and satellite orbit knowledge) without having a battery backup supply present. It does not, however, preserve any kind of time knowledge. Save-on-shutdown must be commanded by the host. The restoring of data on startup is automatically done if the corresponding data is present in the flash. Data expiration is not checked.

The following outlines the suggested shutdown procedure when using the save-on-shutdown feature:

- With the UBX-CFG-RST message, the host commands the u-blox receiver to stop, specifying reset mode 0x08 ("Controlled GNSS stop") and a BBR mask of 0 ("Hotstart").
- The host commands the saving of the contents of BBR to the flash memory using the UBX-UPD-SOS-BACKUP message.
- For a valid request the u-blox receiver reports on the success of the backup operation with a UBX-UPD-SOS-ACK message.
- The host powers off the u-blox receiver.

The startup procedure is as follows:

- The host powers on the u-blox receiver.
- The u-blox receiver detects the previously stored data in the flash. It restores the corresponding memory and reports the success of the operation with a UBX-UPD-SOS-RESTORED message on the port on which it had received the save command message (if the output protocol filter on that port allows it). It does not report anything if no stored data has been detected.
- Additionally the u-blox receiver outputs a UBX-INF-NOTICE and/or a NMEA-TXT message with the contents `RESTORED` in the boot screen (depends on the configuration of the port and information messages) upon success.
- Optionally the host can deliver coarse time assistance using UBX-MGA-INI-TIME_UTC for better startup performance.

Once the u-blox receiver has started up it is recommended to delete the stored data using a UBX-UPD-SOS-CLEAR message. The u-blox receiver responds with a UBX-ACK-ACK / UBX-ACK-NAK message.

3.12.3 Spectrum analyzer

The UBX-MON-SPAN message provides a low-resolution RF spectrum analyzer function sufficient to identify noise or jammers in the receiver's reception band(s). It can be used for monitoring potential interferers during customer integration and in normal operation to identify interference, e.g. when the UBX-MON-RF message detects a possible jamming threat. See Jamming/interference indicator for more details. u-center provides a visualization of the message spectrum output(s) with features for max-hold and averaging.

☞ This message is intended for comparative analysis of the RF spectrum rather than absolute and precise measurement.

The message is output once per second when enabled. Depending on the receiver type, one or two measurement blocks will be output, indicated by the numRfBlocks flag field. The first block provides L1 spectrum data which can be followed by an L2 or L5 block with multi-band receivers.

Each block comprises the following data:
- 256 spectrum data points (0.25 dB units)
- Spectrum span (Hz)
- Spectrum bin resolution (Hz)
- Center frequency (Hz)
- PGA setting (dB)

The frequency of each point can be calculated by $Freq(i) = center\ frequency + spectrum\ span * (i-128) / 256$, where i=0-255. The number of points = span/resolution and is scaled in units of 0.25 dB. Changes in the PGA gain value can indicate an increased input in RF signal activity compared to normal operation.

Figure 21 shows the spectrum view in u-center with the view/hold option selected. The red line represents the frozen spectrum before modifying the external gain, while the black line represents the current measurement.
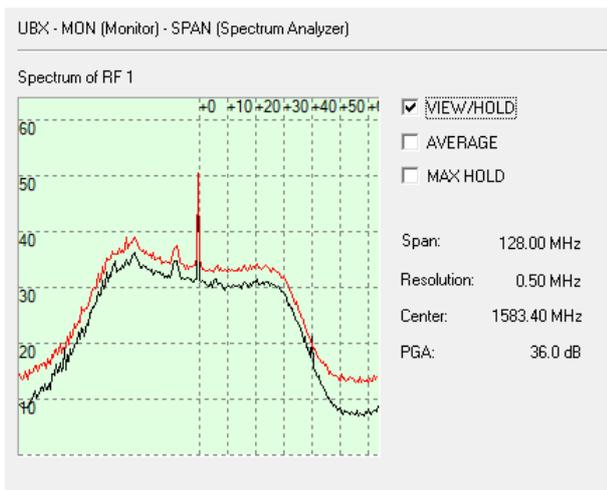

Figure 21: Spectrum analyzer view in u-center with the option view/hold selected

☞ The span frequency depends on the number of constellations enabled which impacts the spectrum resolution owing to a fixed set of points. For further details about this message see the Interface description [2].

☞ A spur may be visible at the center frequency, this comes internally from the receiver and does not cause any performance degradation.

3.12.4 Sky view signal masking

When a stationary receiver's antenna has a poor view of the sky, the resultant performance can be compromised owing to signal distortion produced by processing non-line-of-sight signals. A legacy configuration CFG-NAVSPG-INFIL_MINELEV key can set a common minimum elevation angle below which satellites will not be used. The default angle is set to 10 deg. The configuration provides a common minimum elevation cut-off for all satellite azimuth angles.

A second method is to use The CFG-NAVMASK-EL_MASK key which allows users to mask individual portions of the sky to prevent receiving signals in a known blocked direction. This is especially useful

for timing receivers when surveyed into urban locations with a restricted sky view. Customers can e.g. use local mapping data to predict the sky view and set appropriate masking parameters. The CFG-NAVMASK-EL_MASK configuration allows masking of set parts of the sky in increments of nominally 5 deg. in azimuth and elevation.

Users should take note that satellites may be blocked by the elevation masking message (CFG-NAVSPG-INFIL_MINELEV) described above when used together.

For more information about these messages and the configuration keys see the applicable Interface description [2].

3.13 Forcing a receiver reset

Typically, in GNSS receivers, a distinction is made between cold, warm, and hot start, depending on the type of valid information the receiver has at the time of the restart.

- **Cold start:** In cold start mode, the receiver has no information from the last position (e.g. time, velocity, frequency etc.) at startup. Therefore, the receiver must search the full time and frequency space, and all possible satellite numbers. If a satellite signal is found, it is tracked to decode the ephemeris (18-36 seconds under strong signal conditions), whereas the other channels continue to search satellites. Once there is a sufficient number of satellites with valid ephemeris, the receiver can calculate position and velocity data. Other GNSS receiver manufacturers call this startup mode **Factory startup**.
- **Warm start:** In warm start mode, the receiver has approximate information for time, position, and coarse satellite position data (Almanac). In this mode, after power-up, the receiver normally needs to download ephemeris before it can calculate position and velocity data. As the ephemeris data usually is outdated after 4 hours, the receiver will typically start with a warm start if it has been powered down for more than 4 hours. In this scenario, several augmentations are possible. See Multiple GNSS assistance.
- **Hot start:** In hot start mode, the receiver was powered down only for a short time (4 hours or less), so that its ephemeris is still valid. Since the receiver does not need to download ephemeris again, this is the fastest startup method.

Using the UBX-CFG-RST message, you can force the receiver to reset and clear data, in order to see the effects of maintaining/losing such data between restarts. For this, the UBX-CFG-RST message offers the `navBbrMask` field, where hot, warm and cold starts can be initiated, and also other combinations thereof.

The reset type can also be specified. This is not related to GNSS, but to the way the software restarts the system.

- **Hardware reset** uses the on-chip watchdog, to electrically reset the chip. This is an immediate, asynchronous reset. No Stop event is generated.
- **Controlled software reset** terminates all running processes in an orderly manner and, once the system is idle, restarts operation, reloads its configuration and starts to acquire and track GNSS satellites.
- **Controlled software reset (GNSS only)** only restarts the GNSS tasks, without reinitializing the full system or reloading any stored configuration.
- **Hardware reset (after shutdown)** uses the on-chip watchdog. This is a reset after shutdown.
- **Controlled GNSS stop** stops all GNSS tasks. The receiver will not be restarted, but will stop any GNSS-related processing.
- **Controlled GNSS start** starts all GNSS tasks.

3.14 Firmware upload

RCB-F9T is supplied with firmware. u-blox may release updated images containing, for example, security fixes, enhancements, bug fixes, etc. Therefore it is important that customers implement a firmware update mechanism in their system.

A firmware image is a binary file containing the software to be run by the GNSS receiver. A firmware update is the process of transferring a firmware image to the receiver and storing it in non-volatile flash memory.

Contact u-blox for more information on firmware update.

4 Design

This section provides information to help carry out a successful RCB-F9T board integration.

4.1 Pin assignment

The pin assignment of the RCB-F9T module is shown in Figure 22. The defined configuration of the PIOs is listed in Table 22.

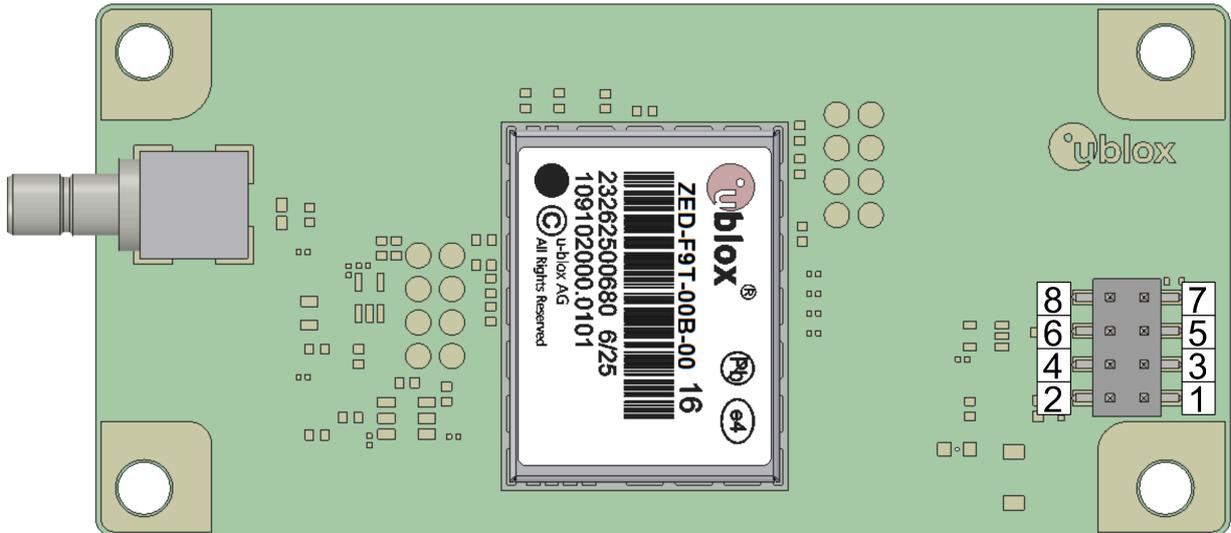**Figure 22: RCB-F9T pin assignment**

Pin no.	Name	I/O	Description
1	VCC_ANT	I	Antenna power supply. 5.0 V max 100 mA
2	VCC	I	Operating voltage, 3.3 V
3	TXD	O	UART TXD, LVCMOS
4	RST	I	Hardware reset
5	RXD	I	UART RXD, LVCMOS
6	TP1	O	Time pulse1, LVCMOS
7	TP2	O	Time pulse2, LVCMOS
8	GND	-	Ground

Table 22: RCB-F9T pin assignment

☞ See Figure 26 for a detailed view of the board measurements.

☞ The labelling of the u-blox module in Figure 22 is for the illustration purpose only.

4.2 Power supply

The u-blox RCB-F9T timing board has two power supply pins: VCC, and VCC_ANT.

4.2.1 VCC: Main supply voltage

The **VCC** pin is connected to the main supply voltage. During operation, the current drawn by the module can vary by some orders of magnitude. For this reason, it is important that the supply

circuitry be able to support the peak power for a short time (see the applicable Data sheet [1] for specification).

☞ To reduce peak current during power on, users can employ an LDO that has a built-in current limiter

☞ Do not add any series resistance greater than 0.2 Ω to the VCC supply as it will generate input voltage noise due to dynamic current conditions.

☞ For the RCB-F9T board the equipment must be supplied by an external limited power source in compliance with the clause 2.5 of the standard IEC 60950-1.

4.2.2 RCB-F9T VCC_ANT: Antenna power supply

The **VCC_ANT** pin is for active antenna powering and typical voltage level should be 5.0 V.

The RCB-F9T board is having a current limiting circuitry that limits the current to the RF connector and if too high current consumption is triggered, then over current protection is activated. For this reason, it is important that the connected active antenna does not consume more current than 100 mA.

☞ VCC_ANT is used only for active antenna powering. If active antenna powering is not needed, then the VCC_ANT can be left to unconnected.

4.3 Antenna

The RCB-F9T requires an active antenna with an integrated LNA to ensure good performance under nominal signal reception.

When implementing a custom antenna installation, it is recommended that an OEM active antenna module be used that meets our specification. Implementing a custom active antenna design is an important exercise to meet the required bandwidths and group delay specifications compared to previous L1-only designs.

A typical dual band antenna design block diagram is shown below taken from the u-blox ANN-MB active antenna product.
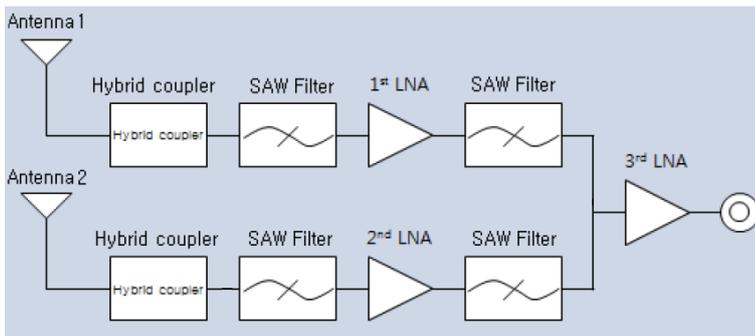

Figure 23: u-blox low cost dual-band antenna internal structure

☞ A suitable ground plane is required for the antenna to achieve good performance.

☞ Location of the antenna is critical to reach the stated performance. For timing receivers locate to provide a good all round sky view. Unsuitable locations within a vehicle could include, under vehicle dash, rear-view mirror location, etc.

A set of recommended specifications for a dual band active antenna is given below.

Parameter	Specification	
Active antenna recommendations	Minimum gain[2]	17 dB
	Maximum gain[2]	50 dB
	Noise figure	<4 dB
Group delay variation in-band [3][4]	10 ns max at each GNSS system bandwidth. Note: Inter-signal requirement 50 ns max.	
Out-of-band rejection	40 dB typ	
Antenna element specification	L1 band antenna gain [5]	1559 - 1606 MHz: 3 dBic typ.
	L2/E5b band antenna gain[5]	1197 - 1249 MHz: 2 dBic typ.
	L5/E5a band antenna gain[5]	1164 - 1188 MHz: 2 dBic typ.
	Polarization	RHCP
	Axial ratio	2 dB max, at Zenith
Phase center variation	<10 mm over elevation/azimuth	
EMI immunity out-of-band[6]	30 V/m	
ESD circuit protection	15 kV human body model air discharge	

Table 23: Antenna specifications for RCB-F9T modules

The antenna system should include filtering to ensure adequate protection from nearby transmitters. Take care in the selection of antennas placed close to cellular or Wi-Fi transmitting antennas.

4.4 EOS/ESD precautions

⚠ To avoid overstress damage during production or in the field it is essential to observe strict EOS/ESD/EMI handling and protection measures.

⚠ To prevent overstress damage at the RF_IN of your receiver, never exceed the maximum input power as specified in the applicable Data sheet [1].

When integrating GNSS receivers into wireless systems, pay special attention to electromagnetic and voltage susceptibility issues. Wireless systems include components which can produce Electrostatic Discharge (ESD), Electrical Overstress (EOS) and Electro-Magnetic Interference (EMI). CMOS devices are more sensitive to such influences because their failure mechanism is defined by the applied voltage, whereas bipolar semiconductors are more susceptible to thermal overstress. The following design guidelines help in designing robust yet cost-effective solutions.

4.4.1 ESD protection measures

⚠ GNSS receivers are sensitive to Electrostatic Discharge (ESD). Special precautions are required when handling. Most defects caused by ESD can be prevented by following strict ESD protection rules for production and handling. When implementing passive antenna patches or external

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[2] Including passive losses (filters, cables, connectors etc.)

[3] GNSS system bandwidths: B1I 1559… 1563 MHz; L1,E1,B1C 1573… 1578 MHz; L1OF 1598… 1606 MHz; E5b,B2I 1192… 1212 MHz; L2C 1223… 1231 MHz; L2OF 1242… 1249 MHz

[4] GNSS system bandwidths:
ZED-F9T-00B: B1I 1559…1563 MHz; L1,E1,B1C 1573…1578 MHz; L1OF 1598…1606 MHz; E5b,B2I 1192…1212 MHz; L2C 1223…1231 MHz; L2OF 1242…1249 MHz

ZED-F9T-10B: B1I 1559…1563 MHz; L1,E1,B1C 1573…1578 MHz; L1OF 1598…1606 MHz; L5,E5a,B2a 1166…1286 MHz

[5] Measured with a ground plane d=150 mm

[6] Exception L1,L2 bands +/- 200 MHz, emphasis on cellular bands

antenna connection points, then additional ESD measures as shown in the figure below can also avoid failures in the field.
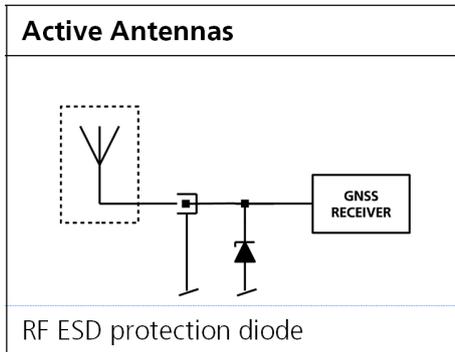

Figure 24: RF ESD precautions

4.4.2 EOS precautions

Electrical overstress (EOS) usually describes situations when the maximum input power exceeds the maximum specified ratings. EOS failure can happen if RF emitters are close to a GNSS receiver or its antenna. EOS causes damage to the chip structures. If the RF_IN is damaged by EOS, it is hard to determine whether the chip structures have been damaged by ESD or EOS.

EOS protection measures as shown in the figure below are recommended for any designs combining wireless communication transceivers (e.g. GSM, GPRS) and GNSS in the same design or in close proximity.
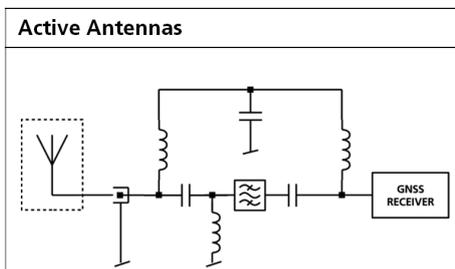

Figure 25: Active antenna EOS protection

4.4.3 Safety precautions

The RCB-F9T must be supplied by an external limited power source in compliance with the clause 2.5 of the standard IEC 60950-1. In addition to external limited power source, only Separated or Safety Extra-Low Voltage (SELV) circuits are to be connected to the module including interfaces and antennas.

☞ For more information about SELV circuits see section 2.2 in Safety standard IEC 60950-1.

4.5 Electromagnetic interference on I/O lines

Any I/O signal line with a length greater than approximately 3 mm can act as an antenna and may pick up arbitrary RF signals transferring them as noise into the receiver. This specifically applies to unshielded lines, in which the corresponding GND layer is remote or missing entirely, and lines close to the edges of the printed circuit board.

If, for example, a cellular signal radiates into an unshielded high-impedance line, it is possible to generate noise in the order of volts and not only distort receiver operation but also damage it

permanently. Another type of interference can be caused by noise generated at the PIO pins that emits from unshielded I/O lines. Receiver performance may be degraded when this noise is coupled into the GNSS antenna.

EMI protection measures are particularly useful when RF emitting devices are placed next to the GNSS receiver and/or to minimize the risk of EMI degradation due to self-jamming. An adequate layout with a robust grounding concept is essential in order to protect against EMI.

☞ Intended Use: In order to mitigate any performance degradation of a radio equipment under EMC disturbance, system integration shall adopt appropriate EMC design practice and not contain cables over three meters on signal and supply ports.

4.5.1 General notes on interference issues

Received GNSS signal power at the antenna is very low. At the nominal received signal strength (-128 dBm) it is below the thermal noise floor of -111 dBm. Due to this fact, a GNSS receiver is susceptible to interference from nearby RF sources of any kind. Two cases can be distinguished:

• Out-of-band interference: Typically any kind of wireless communications system (e.g. LTE, GSM, CDMA, 3G, WLAN, Bluetooth, etc.) may emit its specified maximum transmit power in close proximity to the GNSS receiving antenna, especially if such a system is integrated with the GNSS receiver. Even at reasonable antenna selectivity, destructive power levels may reach the RF input of the GNSS receiver. Also, larger signal interferers may generate intermodulation products inside the GNSS receiver front-end that fall into the GNSS band and contribute to in-band interference.
• In-band interference: Although the GNSS band is kept free from intentional RF signal sources by radio-communications standards, many devices emit RF power into the GNSS band at levels much higher than the GNSS signal itself. One reason is that the frequency band above 1 GHz is not well regulated with regards to EMI, and even if permitted, signal levels are much higher than GNSS signal power. Notably, all types of digital equipment, such as PCs, digital cameras, LCD screens, etc. tend to emit a broad frequency spectrum up to several GHz of frequency. Also wireless transmitters may generate spurious emissions that fall into GNSS band.

As an example, GSM uses power levels of up to 2 W (+33 dBm). The absolute maximum power input at the RF input of the GNSS receiver can be +15 dBm. The GSM specification allows spurious emissions for GSM transmitters of up to +36 dBm, while the GNSS signal is less than -128 dBm. By simply comparing these numbers it is obvious that interference issues must be seriously considered in any design of a GNSS receiver. Different design goals may be achieved through different implementations:

• The primary focus is to prevent damaging the receiver from large input signals. Here the GNSS performance under interference conditions is not important and suppression of the signal is permitted. It is sufficient to just observe the maximum RF power ratings of all of the components in the RF input path.
• GNSS performance must be guaranteed even under interference conditions. In such a case, not only the maximum power ratings of the components in the receiver RF path must be observed. Further, non-linear effects like gain compression, NF degradation (desensitization) and intermodulation must be analyzed.

☞ Pulsed interference with a low-duty cycle such as GSM may be destructive due to the high peak power levels.

4.5.2 In-band interference mitigation

With in-band interference, the signal frequency is very close to the GNSS frequency. Such interference signals are typically caused by harmonics from displays, micro-controller operation, bus systems, etc. Measures against in-band interference include:

- Maintaining a good grounding concept in the design
- Shielding
- Layout optimization
- Low-pass filtering of noise sources, e.g. digital signal lines
- Remote placement of the GNSS antenna, far away from noise sources
- Adding an LTE, CDMA, GSM, WCDMA, BT band-pass filter before antenna

4.5.3 Out-of-band interference

Out-of-band interference is caused by signal frequencies that are different from the GNSS carrier frequency. The main sources are wireless communication systems such as LTE, GSM, CDMA, WCDMA, Wi-Fi, BT, etc.

Measures against out-of-band interference include maintaining a good grounding concept in the design and adding a GNSS band-pass filter into the antenna input line to the receiver.

For GSM applications, such as typical handset design, an isolation of approximately 20 dB can be reached with careful placement of the antennas. If this is insufficient, an additional SAW filter is required on the GNSS receiver input to block the remaining GSM transmitter energy.

4.6 Thermal management

During design-in do not place the receiver near sources of heating or cooling. The receiver oscillator is sensitive to sudden changes in ambient temperature which can adversely impact satellite signal tracking. Sources can include co-located power devices, cooling fans or thermal conduction via the PCB. Take into account the following questions when designing in the receiver.

- Is the receiver placed away from heat sources?
- Is the receiver placed away from air-cooling sources?
- Is the receiver shielded by a cover/case to prevent the effects of air currents and rapid environmental temperature changes?

⚠   High temperature drift and air vents can affect the GNSS performance. For best performance, avoid high temperature drift and air vents near the receiver.

5 Product handling

5.1 ESD handling precautions

⚠ u-blox chips and modules contain highly sensitive electronic circuitry and are Electrostatic Sensitive Devices (ESD). Observe precautions for handling! Failure to observe these precautions can result in severe damage to the GNSS receiver!

- Unless there is a galvanic coupling between the local GND (i.e. the work table) and the PCB GND, then the first point of contact when handling the PCB must always be between the local GND and PCB GND.
- Before mounting an antenna patch, connect ground of the device.

- When handling the RF pin, do not come into contact with any charged capacitors and be careful when contacting materials that can develop charges (e.g. patch antenna ~10 pF, coax cable ~50-80 pF/m or soldering iron).

- To prevent electrostatic discharge through the RF input, do not touch any exposed antenna area. If there is any risk that such exposed antenna area is touched in non-ESD protected work area, implement proper ESD protection measures in the design.
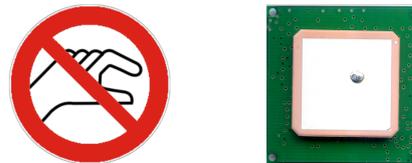
- When soldering RF connectors and patch antennas to the receiver's RF pin, make sure to use an ESD-safe soldering iron (tip)

Appendix

A RCB-F9T default configurations

The RCB-F9T has different default configurations from the ZED-F9T. Table 24 provides a complete list of the default configuration differences. See the Interface description [2] for additional information.

Configuration item	Key ID	Type	Scale	Unit	Default value
CFG-UART1-BAUDRATE	0x40520001	U4	-	-	115200
CFG-HW-ANT_CFG_VOLTCTRL	0x10a3002e	L	-	-	True
CFG-HW-ANT_CFG_SHORTDET	0x10a3002f	L	-	-	True
CFG-HW-ANT_CFG_OPENDET	0x10a30031	L	-	-	True
CFG-HW-ANT_CFG_PWRDOWN	0x10a30033	L	-	-	True
CFG-HW-ANT_CFG_RECOVER	0x10a30035	L	-	-	True
CFG-TP-PULSE_LENGTH_DEF	0x20050030	E1	-	-	0 - Ratio (Time pulse ratio)
CFG-TP-DUTY_TP1	0x5005002a	R8	-	%	10.000000
CFG-TP-DUTY_LOCK_TP1	0x5005002b	R8	-	%	20.000000
CFG-TP-TIMEGRID_TP1	0x2005000c	E1	-	-	0 - UTC (UTC time reference)

Table 24: RCB-F9T-specific UART baud rate, antenna supervisor and time pulse 1 default configurations

B RCB-F9T PCB dimensions

The RCB-F9T pcb dimensions are shown below in Figure 26 to provide accurate mounting and antenna connector alignment information.
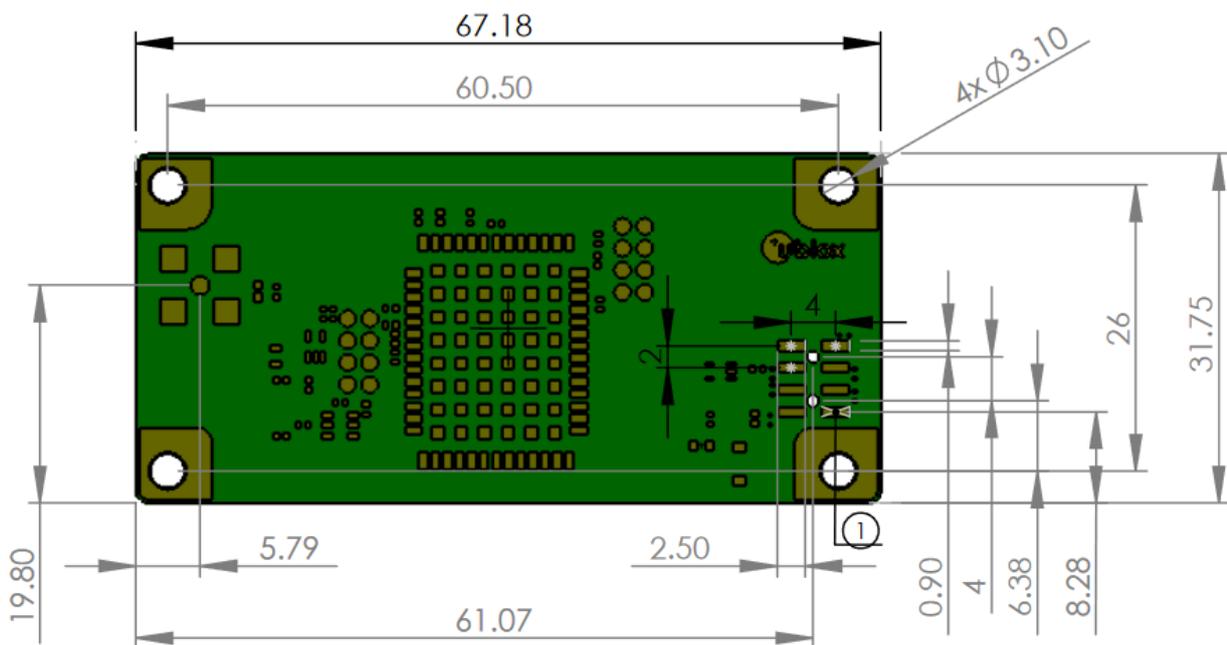

Figure 26: RCB-F9T PCB dimensions

Related documents

[1] RCB-F9T-0 Data sheet, UBX-18053607
RCB-F9T-1 Data sheet, UBX-21004244

[2] TIM 2.20 Interface description, UBX-21048598

[3] Radio Resource LCS Protocol (RRLP), (3GPP TS 44.031 version 11.0.0 Release 11)

☞ For regular updates to u-blox documentation and to receive product change notifications please register on our homepage https://www.u-blox.com.

Revision history

Revision	Date	Name	Status / comments
R01	28-Mar-2022	byou	Combined integration manual issued for RCB-F9T-0 and RCB-F9T-1 variants.
R02	13-Sept-2023	vema	Editorial changes

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