P

RCB-F9T

u-blox 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.

www.u-blox.com

UBX-19003747 - R04

Document information

Title	RCB-F9T	
Subtitle	u-blox RCB-F9T high accuracy timing board	
Document type	Integration manual	
Document number	UBX-19003747	
Revision and date	R04	25-Feb-2020
Document status	Early production information	

This document applies to the following products:

Product name	Type number	Firmware version	PCN reference
RCB-F9T	RCB-F9T-0-01	TIM 2.01	UBX-19057484

Contents

1 Integration manual structure

This document provides a wealth of information to enable a successful design with the RCB-F9T timing board. The manual is structured according to system, software and hardware aspects.

The first section, "System description" outlines the basics of the RCB-F9T timing board.

The following section "Receiver functionality" provides an exhaustive description of the receiver's functionality. Beginning with the new configuration concept both existing and new users should read this section to understand the new messages employed. Most of the following sub-sections should be familiar to existing users of u-blox positioning products, however some changes are introduced owing to the new configuration concept.

The sections from "Design" onwards addresses power supply recommendations and provides information about the RCB-F9T hardware interfaces. An antenna section provides design information and recommendation for this important component.

The final section addresses the major product handling concerns giving guidance on ESD precautions.

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 ZED-F9T timing receivers via a communication network. In differential timing mode the RCB-F9T can operate either as a master reference station, or as a slave station.

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

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

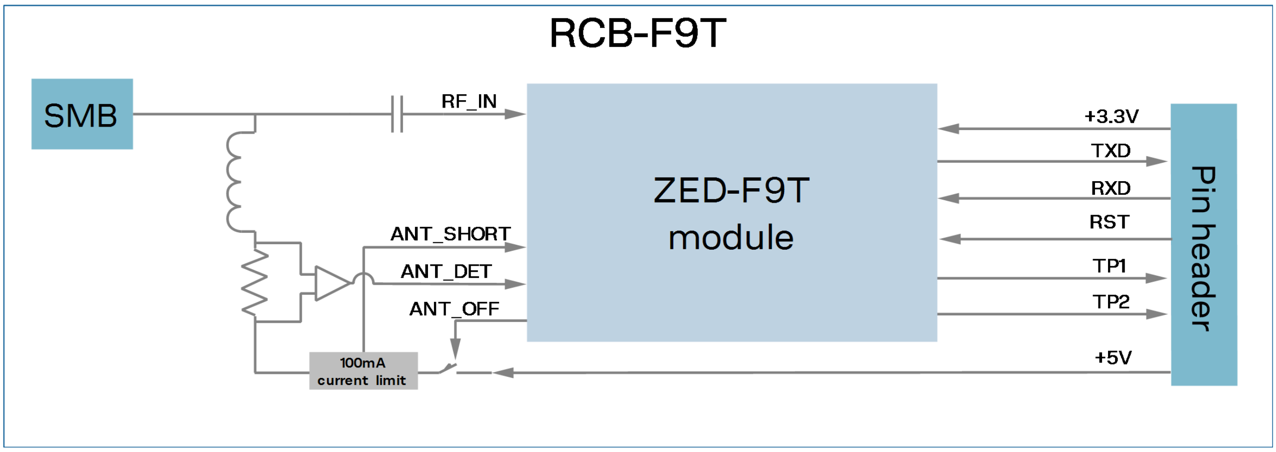


Figure 1: RCB-F9T block diagram

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

3 Receiver functionality

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

3.1 Receiver configuration

The 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 start-up of the receiver from several sources of configuration. The configuration interface and the available keys are described fully in the RCB-F9T Interface description [2].

☞ The configuration interface has changed from earlier u-blox positioning receivers. There is some backwards compatibility, however, users are strongly advised to adopt the configuration interface described in this document. See legacy UBX-CFG message fields reference section in the RCB-F9T 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 the UBX-CFG-VALSET, UBX-CFG-VALGET, and UBX-CFG-VALDEL messages. For more information about these messages and the configuration keys see the configuration interface section in the RCB-F9T 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:

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

SBAS is also supported but not enabled in the default GNSS configuration. SBAS is not recommended for timing applications.

For more information about default configuration, see the RCB-F9T 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 u-blox RCB-F9T Interface description [2] for information about further settings.

By default the RCB-F9T outputs NMEA 4.10 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 Message output configuration

The rate of NMEA, UBX and RTCM protocol output messages are 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 not 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 the previous section).

3.1.4.2 GNSS signal configuration

The GNSS constellations and bands are configurable with configuration keys from configuration group CFG-SIGNAL-*. Each GNSS constellation can be enabled or disabled independently. 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.

3.1.5 Differential timing mode configuration

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

This section describes how to configure the RCB-F9T high accuracy timing board as a master reference station and as slave 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 binary data protocol for 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 u-blox RCB-F9T Interface description [2].

3.1.5.2 List of supported RTCM input messages

Message	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

Table 2: RCB-F9T supported input RTCM version 3.3 messages

3.1.5.3 List of supported RTCM output messages

Message	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

Table 3: 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.

☞ The timing receiver should not be fed RTCM corrections while it is in survey-in mode.

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 4: 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 upon start-up.

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:

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 Master reference station

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

3.1.5.5.1 Master reference 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 Additional reference station information

The configuration messages for these are shown in the Table 5.

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 5: Configuration items used for setting a master reference station

3.1.5.6 Slave station

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

Connect the slave receiver to the reference server or to the NTRIP server. When the slave 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 Legacy configuration interface compatibility

There is some backwards-compatibility for the legacy UBX-CFG configuration messages. It is strongly recommended to adopt the new configuration interface, as the legacy configuration messages support will be removed in the future.

See Legacy UBX-CFG message fields reference section in the RCB-F9T Interface description [2].

3.1.7 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-*.

3.1.7.1 Platform settings

u-blox receivers support different dynamic platform models (see in 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 6 and Table 7 below.

Platform	Description
Portable (default)	Applications with low acceleration, e.g. portable devices. Suitable for most situations.
Stationary	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 6: 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

Platform	Max altitude [m]	Max horizontal velocity [m/s]	Max vertical velocity [m/s]	Sanity check type	Max position deviation
Airborne <1g	50000	100	100	Altitude	Large
Airborne <2g	50000	250	100	Altitude	Large
Airborne <4g	50000	500	100	Altitude	Large
Wrist	9000	30	20	Altitude and velocity	Medium

Table 7: Dynamic platform model details

3.1.7.2 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 8: Navigation input filter parameters

If the receiver only has three SVs for calculating a position, the navigation algorithm uses a constant altitude to compensate for the missing fourth SV. When a SV is lost after a successful 3D fix (min. four SVs 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 SVs.

3.1.7.3 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. These messages have only been retained for backwards compatibility and users are recommended to use the UBX-NAV-PVT message.

3.1.7.3.1 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 and must be comprised 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.

3.1.7.3.2 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 and must be comprised 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.

3.1.7.3.3 Low-speed course over ground filter

The CFG-ODO-USE_COG activates this feature and the CFG-ODO-COGMAXSPEED, CFG-ODO-COGMAXPOSACC configuration items offer the possibility to configure a low-speed course over ground filter (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.

3.1.7.4 Static hold

Static hold mode allows the navigation algorithms to decrease the noise in the position output when the velocity is below a pre-defined "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.

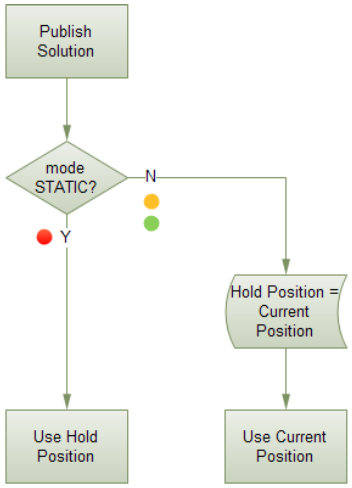


Figure 2: Position publication in static hold mode

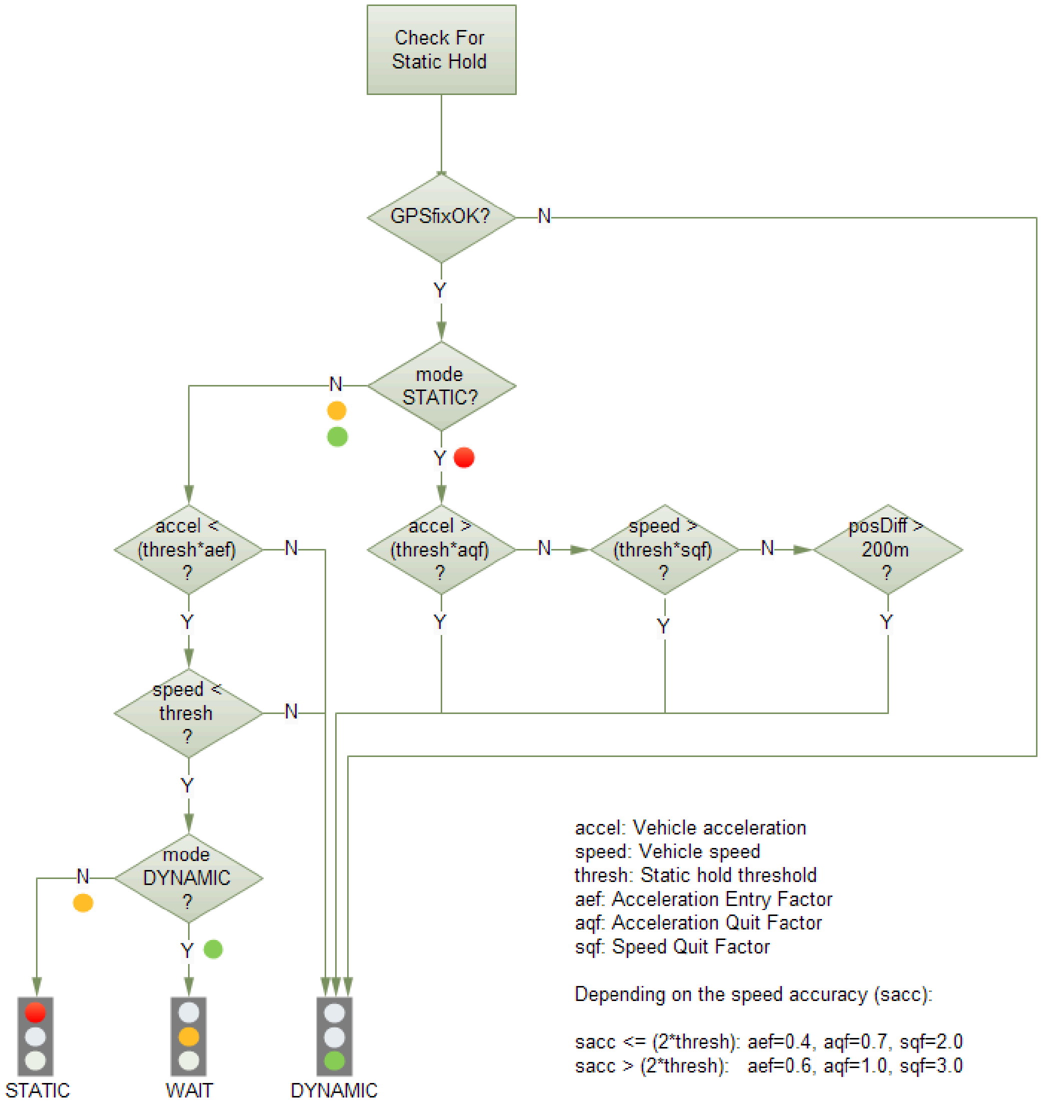


Figure 3: Flowchart of the static hold mode

3.1.7.5 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 RCB-F9T Interface description [2]).

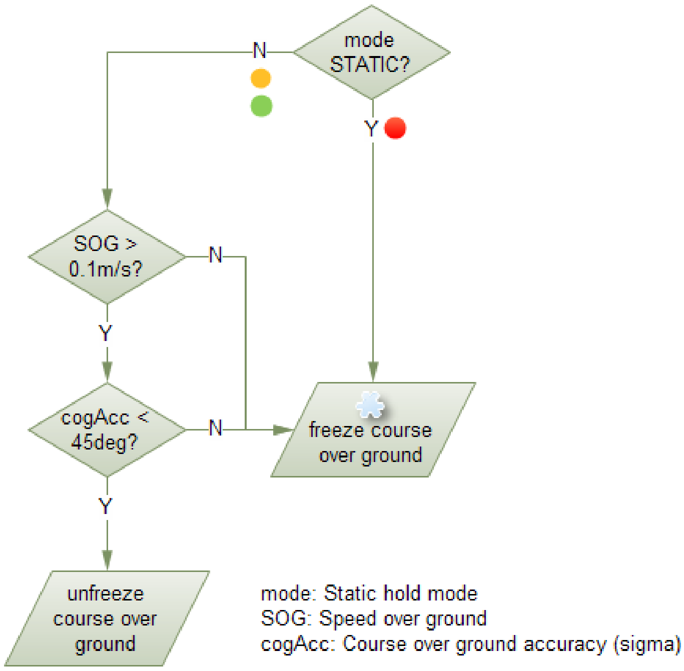


Figure 4: Flowchart of the course over ground freezing

3.2 Geofencing

3.2.1 Introduction

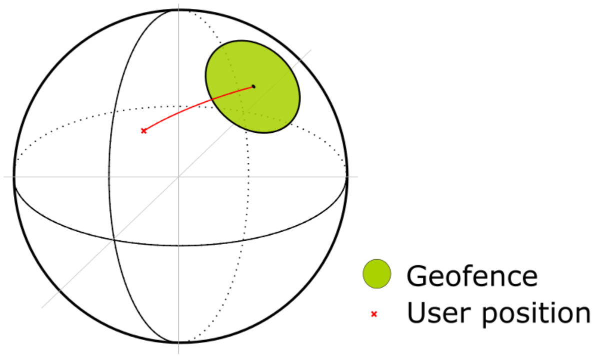


Figure 5: Geofence

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.

3.2.2 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.

Additionally the user can configure the receiver to output the combined geofence state on a physical pin (assigned to a PIO being used for geofence state indication).

3.2.3 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 number and taken into account when evaluating the geofence state (red circle in figure below).

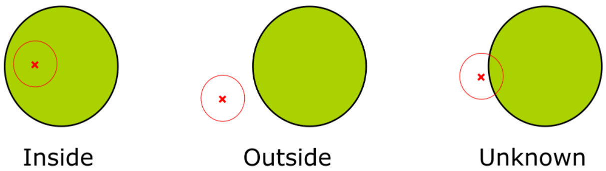


Figure 6: Geofence states

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

3.3 Interfaces

RCB-F9T provides a UART interface for communication with a host CPU.

☞ 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.

3.3.1 UART interface

RCB-F9T includes one UART port.

UART can be used for 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.

3.4 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 chapter.

3.4.1 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.

3.4.2 TIMEPULSE

The RCB-F9T provides time pulse signals on the TIMEPULSE and TIMEPULSE 2 pins.

☞ Shared TIMEPULSE2 and SAFEBOOT_N signals should be implemented maintaining the possibility to pull the SAFEBOOT_N pin low in the application.

☞ More information about the Timepulse feature, its possibility's and configuration can be found in the chapter Time pulse

3.5 Antenna supervisor

The RCB-F9T includes an active antenna supervisor that provides the means to check the antenna for open and short circuits and to shut off the antenna supply if a short circuit is detected. Once enabled, the active antenna supervisor produces status messages, reporting in NMEA and/or UBX protocol.

The RCB-F9T active antenna supervisor block diagram is shown in the Figure 1

The antenna supervisor is monitoring active antenna current consumption and based on that antenna open and short circuits are detected:

- Antenna open: Current consumption 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 active 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 active antenna supervisor is enabled by default in the RCB-F9T.

3.5.1 Antenna voltage control - ANT_OFF

Enable the antenna short detection by setting the configuration item CFG-HW-ANT_CFG_SHORTDET to true (1).

Result:

- UBX-MON-RF in u-center: Antenna status = OK. Antenna power status = ON
- ANT_OFF = active high to disable an external antenna therefore the pin is low to enable an external antenna.
- ANT_SHORT_N = active low to detect a short therefore the pin is high (PIO pull up enabled to be pulled low if shorted)

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 control and short detection activated)

Then if shorted (ANT_SHORT_N pulled low):

- UBX-MON-RF in u-center: Antenna status = SHORT. Antenna power status = ON (auto power down is not enabled = off by default)

`$GNTXT,01,01,02,ANTSTATUS=SHORT*73`

- ANT_OFF = active high therefore still low (still enabled as auto power down is not enabled)

☞ After a detected antenna short, the reported antenna status will keep on being reported as shorted. If the antenna short detection auto recovery is enabled, then the antenna status can recover after a timeout. To recover the antenna status immediately, a power cycle is required or configuring off and on again the antenna short detection functionality.

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

3.5.2 Antenna short detection - ANT_SHORT_N

To set short circuit detect ON:

CFG-HW-ANT_CFG_SHORTDET = 1

Result:

- MON-RF in u-center: Antenna status = OK. Antenna power status = ON
- ANT_OFF = active high to disable an external antenna therefore the pin is low to enable an external antenna.
- ANT_SHORT_N = active low to detect a short therefore the pin is high (PIO pull up enabled to be pulled low if shorted)

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 control and short detection activated)

Then if shorted (ANT_SHORT_N pulled low)

- MON-RF in u-center: Antenna status = SHORT. Antenna power status = ON (Antenna power control powerdown when short has not been enabled = off by default)
- $GNTXT,01,01,02,ANTSTATUS=SHORT*73
- ANT_OFF = active high therefore still low (still enabled as auto power down is not enabled)

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

☞ Power off and on required to clear short condition report. Or turn feature off an on again.

3.5.3 Antenna short detection auto recovery

Enable the antenna short detection auto recovery by setting the configuration item CFG-HW-ANT_CFG_RECOVER to true (1).

Result:

- UBX-MON-RF in u-center: Antenna status = OK. Antenna power status = ON
- ANT_OFF = active high there for the PIO is low to enable an external antenna
- ANT_SHORT_N = high (PIO pull up enabled to be pulled low if shorted)

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` (indicates short circuit recovery added - SR)

Then if antenna is shorted (ANT_SHORT_N pulled low):

- `$GNTXT,01,01,02,ANTSTATUS=SHORT*73`
- UBX-MON-RF in u-center: Antenna status = SHORT. Antenna power status = OFF
- ANT_OFF = high (to disable - active high)

After a time out period receiver will re-test the short condition by enabling ANT_OFF = LOW

If a short is not present it will report antenna condition is ok:

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

MON-RF in u-center: Antenna status = OK. Antenna power status = ON

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

3.5.4 Antenna open circuit detection - ANT_DETECT

Enable the antenna open circuit detection by setting the configuration item CFG-HW-ANT_CFG_OPENDET to true (1).

Result:

- UBX-MON-RF in u-center: Antenna status = OK. Antenna power status = ON
- ANT_OFF = active high therefore PIO is low to enable external antenna
- ANT_SHORT_N = active low therefore PIO is high (PIO pull up enabled to be pulled low if shorted)
- ANT_DETECT = active high therefore PIO is high (PIO pull up enabled to be pulled low if antenna not detected)

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` (indicates open circuit detection added - OD)

Then if ANT_DETECT is pulled low to indicate no antenna:

```
$GNTXT,01,01,02,ANTSTATUS=OPEN*35
```

Then if ANT_DETECT is left floating or it is pulled high to indicate antenna connected:

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

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

3.6 Multiple GNSS assistance (MGA)

The u-blox MGA services provide a proprietary implementation of an A-GNSS protocol compatible with u-blox GNSS receivers. When a client device makes an MGA request, the service responds with the requested data using UBX protocol messages. These messages are ready for direct transmission to the receiver communication port without requiring any modification by the MGA client.

AssistNow Online optionally provides satellite ephemerides, health information and time aiding data suitable for GNSS receiver systems with direct internet access.

3.6.1 Authorization

The AssistNow Online Service is only available for use by u-blox customers. In order to use the services, customers will need to obtain an authorization token from u-blox. This token must be supplied as a parameter whenever a request is made to either service. Please contact your local technical support or go to https://www.u-blox.com/en/solution/services/assistnow to get more information and request an authorization token.

3.6.2 Multiple servers

The implementation of the AssistNow Online Service is designed to be highly available and reliable. Nonetheless, there will be rare occasions when a server is not available (e.g. due to failure or some form of maintenance activity). In order to protect customers against the impact of such outages, u-blox runs at least two instances of the AssistNow Online Service on independent machines. Customers have a choice of requesting assistance data from any of these servers, as all will provide the same information. However, should one fail for whatever reason, it is highly unlikely that the other server(s) will also be unavailable. Therefore customers requiring the best possible availability are recommended to implement a scheme where they direct their requests to a chosen server, but, if that server fails to respond, have a fallback mechanism to use another server instead.

3.6.3 Preserving information during power-off

The performance of u-blox receivers immediately after they are turned on is enhanced by providing them with as much useful information as possible. AssistNow services are one way to achieve this, but retaining information from previous use of the receiver can be just as valuable. All the types of data delivered by assistance can be retained while the receiver is powered down for use when power is restored. Obviously the value of this data will diminish as time passes, but in many cases it remains very useful and can significantly improve time to first fix.

There are several ways in which a u-blox receiver can retain useful data while it is powered down, including:

- **Battery-backed RAM:** The receiver can be supplied with sufficient power to maintain a small portion of internal storage, while it is otherwise turned off. This is the best mechanism, provided that the small amount of electrical power required can be supplied continuously. V_BCKP is the pin to sustain battery-backed RAM.

- **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 the description of the UBX-UPD-SOS messages in the RCB-F9T Interface description [2].

3.6.4 AssistNow Online

AssistNow Online is u-blox's end-to-end Assisted GNSS (A-GNSS) solution for receivers that have access to the internet. Data supplied by the AssistNow Online Service can be directly uploaded to a u-blox receiver in order to substantially reduce time to first fix (TTFF), even under poor signal conditions (typically around 2 seconds; see RCB-F9T Data sheet [1] "Aided start"). The system works by collecting data such as ephemeris and almanac from the satellites through u-blox's "Global Reference Network" of receivers and providing this data to customers in a convenient form that can be forwarded directly to u-blox receivers.

The AssistNow Online Service uses a simple, stateless, HTTP interface. Therefore, it works on all standard mobile communication networks that support internet access, including GPRS, UMTS and Wireless LAN. No special arrangements need to be made with mobile network operators to enable AssistNow Online.

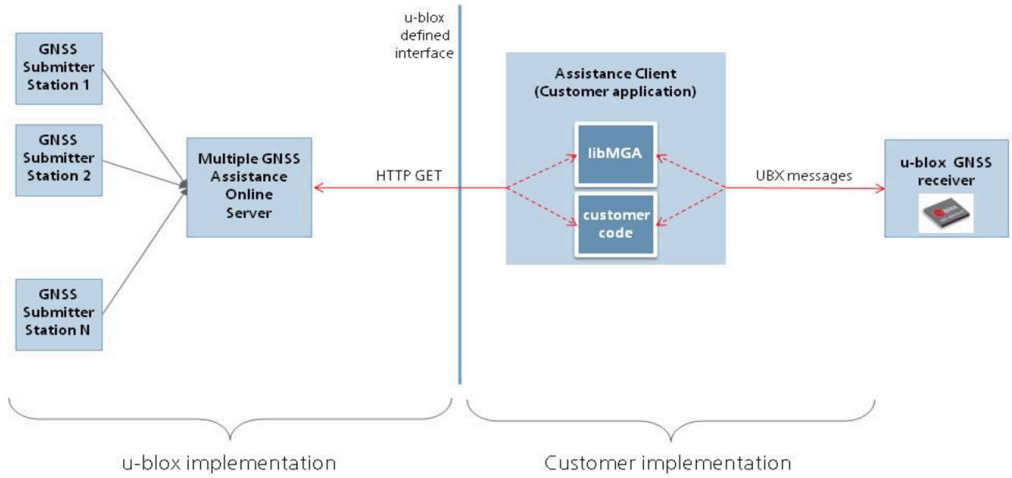


Figure 7: MGA architecture

The data returned by the AssistNow Online Service is a sequence of UBX-MGA messages, starting with an estimate of the current time in the form of a UBX-MGA-INI-TIME_UTC message.

☞ AssistNow Online currently supports GPS, GLONASS, BeiDou, Galileo, and QZSS.

☞ Customers may choose to use third party sources of assistance data instead of using the AssistNow Online Service. Customers choosing this option will need to ensure that the data is converted from the format used by the third party source to the appropriate MGA messages. However, it is important to ensure that the receiver has an estimate of the current time before it processes any other assistance data. For this reason, it is strongly recommended to send a UBX-MGA-INITIME_UTC or UBX-MGA-INI-TIME_GNSS as the first message of any assistance.

3.6.4.1 Host software

As u-blox receivers have no means to connect directly with the internet, the AssistNow Online system can only work if the host system that contains the receiver can connect to the internet, download the data from the AssistNow Online Service and forward it on to the receiver. In the simplest case that may involve fetching the data from the AssistNow Online Service (by means of a single HTTP or HTTPS GET request), and sending the resulting data to the receiver.

Depending on the circumstances, it may be beneficial for the host software to include:

- Creating an appropriate UBX-MGA-INI-TIME_UTC message to deliver a better estimation of the current time to the receiver, especially if the host system has a very good estimation of the current time and can deliver a time pulse to one of the receiver's EXTINT pins.
- Enabling and using flow control to prevent loss of data due to buffer overflow in the receiver.

☞ u-blox provides the source code for an example library, called libMGA, that provides all of the functionality we expect in most host software.

3.6.4.2 AssistNow Online sequence

A typical sequence of use of the AssistNow Online Service comprises the following steps:

- Power up the u-blox receiver.
- Request data from the AssistNow Online Service.
- Optionally send UBX-MGA-INI-TIME_UTC followed by hardware time synchronization pulse.
- Send the UBX messages obtained from the AssistNow Online Service to the receiver.

3.6.4.3 Flow control

u-blox receivers aim to process incoming messages as quickly as possible, but there will always be a small delay in processing each message. Uploading assistance data to the receiver can involve sending as many as one hundred individual messages to the receiver, one after the other. If the communication link is fast, and/or the receiver is busy (trying to acquire new signals), it is possible that the internal buffers will overflow and some messages will be lost. In order to combat this, u-blox receivers support an optional flow control mechanism for assistance.

Flow control is activated by setting the CFG-NAVSPG-ACKAIDING configuration item. As a result the receiver will issue an acknowledgment message (UBX-ACK-ACK) for each assistance message it successfully receives. The host software can examine these acknowledgments to establish whether there were any problems with the data sent to the receiver and deduce (by the lack of acknowledgment) if any messages have been lost. It may then be appropriate to resend some of the assistance messages.

The simplest way to implement flow control would be to send one UBX-MGA message at a time, waiting for the acknowledgment, before sending the next. However, such a strategy is likely to introduce significant delays into the whole assistance process. The best strategy will depend on the amount of assistance data being sent and the nature of the communications link (e.g. baud rate of serial link). u-blox recommends that when customers are developing their host software they start by sending all assistance messages and then analyze the resulting acknowledgments to see if any messages have been lost. Adding small delays during the transmission may be a simple but effective way to avoid loss of data.

3.6.4.4 Service parameters

The information exchange with the AssistNow Online Service is based on the HTTP protocol. The u-blox MGA service supports encrypted HTTPS communication. Upon reception of an HTTP GET request, the server will respond with the required messages in binary format or with an error string in text format. After delivery of all data, the server will terminate the connection.

The HTTP GET request from the client to the server should contain a standard HTTP query string in the request URL. The query string consists of a set of "key=value" parameters in the following form:

key=value;key=value;key=value;

The following rules apply:

- The order of keys is important.
- Keys and values are case-sensitive.
- Keys and values must be separated by an "equal" character ("=").
- Key/value pairs must be separated by semicolons (";").
- If a value contains a list, each item in the list must be separated by a comma (",").

The following table describes the keys that are supported:

Key name	Unit/range	Optional	Description
token	String	Mandatory	The authorization token supplied by u-blox when a client registers to use the service.
gnss	String	Mandatory	A comma-separated list of the GNSS for which data should be returned. Valid GNSS are: gps, gal, glo, bds and qzss (case-sensitive).
datatype	String	Mandatory	A comma-separated list of the data types required by the client. Valid data types are: eph, alm, aux and pos. Time data is always returned for each request. If the value of this parameter is an empty string, only time data will be returned.
lat	Numeric [degrees]	Optional	Approximate user latitude in WGS 84 expressed in degrees and fractional degrees. Must be in range -90 to 90. Example: lat=47.2.
lon	Numeric [degrees]	Optional	Approximate user longitude in WGS 84 expressed in degrees and fractional degrees. Must be in range -180 to 180. Example: lon=8.55.
alt	Numeric [meters]	Optional	Approximate user altitude above WGS 84 Ellipsoid. If this value is not provided, the server assumes an altitude of 0 meters. Must be in range -1000 to 50000.
pacc	Numeric [meters]	Optional	Approximate accuracy of submitted position (see the Position parameters (lat, lon, alt and pacc) section below). If this value is not provided, the server assumes an accuracy of 300 km. Must be in range 0 to 6000000.
tacc	Numeric [seconds]	Optional	The timing accuracy (see the Time parameters (tacc and latency) section below). If this value is not provided, the server assumes an accuracy of 10 seconds. Must be in range 0 to 3600.
latency	Numeric [seconds]	Optional	Typical latency between the time the server receives the request, and the time when the assistance data arrives at the u-blox receiver. The server can use this value to correct the time being transmitted to the client. If this value is not provided, the server assumes a latency of 0. Must be in range 0 to 3600.
filteronpos	(no value required)	Optional	If present, the ephemeris data returned to the client will only contain data for the satellites which are likely to be visible from the approximate position provided by the lat, lon, alt and pacc parameters. If the lat and lon parameters are not provided the service will return an error.
filteronsv	String	Optional	A comma-separated list of u-blox gnssId:svId pairs. The ephemeris data returned to the client will only contain data for the listed satellites.

Table 9: AssistNow Online parameter keys

Thus, as an example, a valid parameter string would be:

token=XXXXXXXXXXXXXXXXXXXXXX;gnss=gps,qzss;datatype=eph,pos,aux;lat=47.28;lon=8.56;pacc=1000

3.6.4.4.1 Position parameters (lat, lon, alt and pacc)

The position parameters (lat, lon, alt and pacc) are used by the server for two purposes:

- If the filteronpos parameter is provided, the server determines the currently visible satellites at the user position, and only sends the ephemeris data of those satellites which should be in view at the location of the user. This reduces bandwidth requirements. In this case the "pacc" value is taken into account, meaning that the server will return all SVs visible in the given uncertainty region.

- If the datatype "pos" is requested, the server will return the position and accuracy in the response data. When this data is supplied to the u-blox receiver, depending on the accuracy of the provided data, the receiver can then choose to select a better startup strategy. For example, if the position is accurate to 100 km or better, the u-blox receiver will choose to go for a more optimistic startup strategy. This will result in quicker startup time. The receiver will decide which strategy to choose, depending on the "pacc" parameter. If the submitted user position is less accurate than what is being specified with the "pacc" parameter, then the user will experience prolonged or even failed startups.

3.6.4.4.2 Time parameters (tacc and latency)

Time data is always returned with each request. The time data refers to the time at which the response leaves the server, corrected by an optional latency value. This time data provided by the service is accurate to approximately 10 ms but by default the time accuracy is indicated to be +/-10 seconds in order to account for network latency and any time between the client receiving the data and it being provided to the receiver.

If both the network latency and the client latency can safely be assumed to be very low (or are known), the client can choose to set the accuracy of the time message (tacc) to a much smaller value (e.g. 0.5 s). This will result in a faster TTFF. The latency can also be adjusted as needed. However, these fields should be used with caution: if the time accuracy is not correct when the time data reaches the receiver, the receiver may experience prolonged or even failed startups.

For optimal results, the client should establish an accurate sense of time itself (e.g. by calibrating its system clock using a local NTP service) and then modify the time data received from the service as appropriate.

3.7 Clocks and time

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

3.7.1 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 one of the GNSS systems in a multi-GNSS receiver. In previous generations of u-blox receivers this was always the GPS time-base, but for the current generation it could be GPS, GLONASS, Galileo, or BeiDou. 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.

3.7.2 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 the clock bias (and the 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, pre-defined 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.

3.7.3 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).

3.7.4 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
UTC time	UBX-NAV-TIMEUTC

Table 10: GNSS times

3.7.5 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.

3.7.6 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.

Which master clock the UTC time is referenced to is output in the message UBX-NAV-TIMEUTC.

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.

3.7.7 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.

3.7.8 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.

3.7.9 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.

3.7.9.1 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.

3.8 Timing functionality

The RCB-F9T provides precision time references used by remote or distributed wireless communication, industrial, financial, and power distribution equipment.

3.8.1 Time pulse

3.8.1.1 Introduction

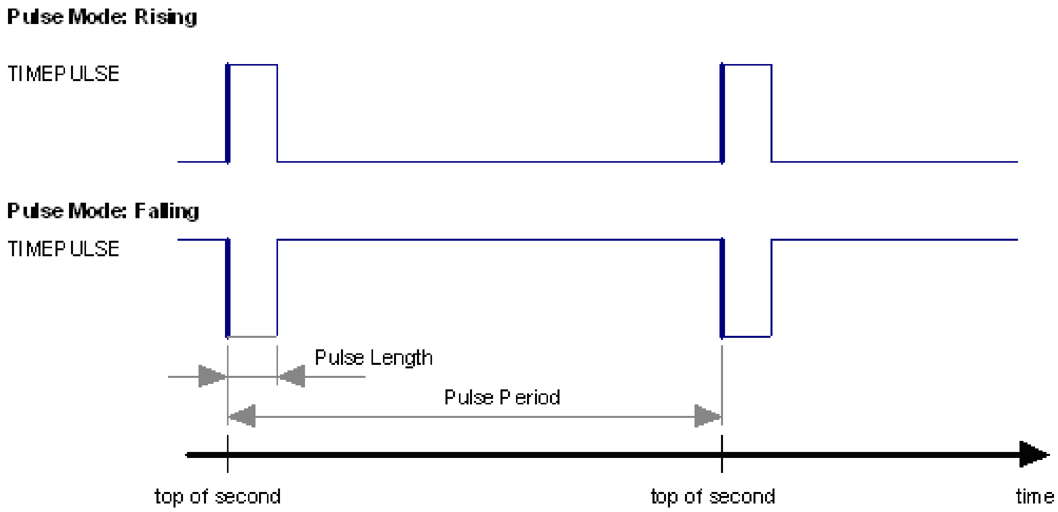


Figure 8: Time pulse

3.8.1.2 Recommendations

- The time pulse can be aligned to a wide variety of GNSS times or to variants of UTC derived from them (see the chapter 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 precision timing applications it is recommended to calibrate the antenna cable delay against a reference timing source.
- In order 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 a time pulse 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.

☞ SBAS is not recommended to use for timing applications.

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.

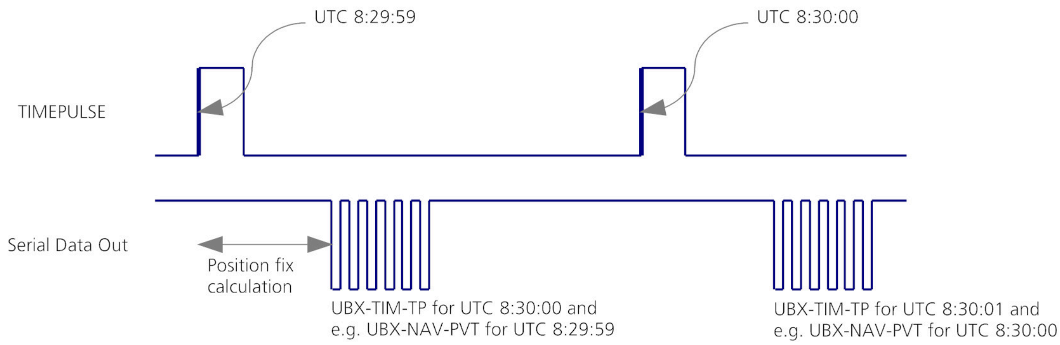


Figure 9: Time pulse and TIM-TP

3.8.1.3 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 EXTINTs) and output (via the time pulse) and the parameters reported in corresponding messages.

The CFG-TP-* configuration group allows the user to choose between any of the supported GNSS (GPS, GLONASS, BeiDou, etc) times and UTC. Also, the CFG-NAVSPG-* configuration group 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 and, finally, European if Galileo is enabled.

The receiver will assume that the input time pulse uses the same GNSS time base as specified for the output using CFG-TP-*. 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.

3.8.1.4 Time pulse configuration

u-blox RCB-F9T receivers provide a time pulse (TIMEPULSE) signal with a configurable pulse period, pulse 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-*.

3.8.1.5 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** - Time pulse is active if this item is set.
- **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 due to the cable between antenna and receiver.
- **pulse frequency/period** - Frequency or period time of the pulse when locked mode is not configured or active.
- **pulse frequency/period lock** - Frequency or period time of the pulse, as soon as 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 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** - The cable delay from the receiver to the user device plus signal delay of any user application.
- **lock to GNSS freq** - Use frequency gained from GNSS signal information rather than local oscillator's frequency if item is set.
- **locked other setting** - If this item is set, as soon as the receiver can calculate a valid time, the alternative setting is used. This mode can be used for example to disable time pulse if time is not locked, or indicate 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) and BeiDou (3) 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.

3.8.1.5.1 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** = 100 000 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** = 100 000 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.

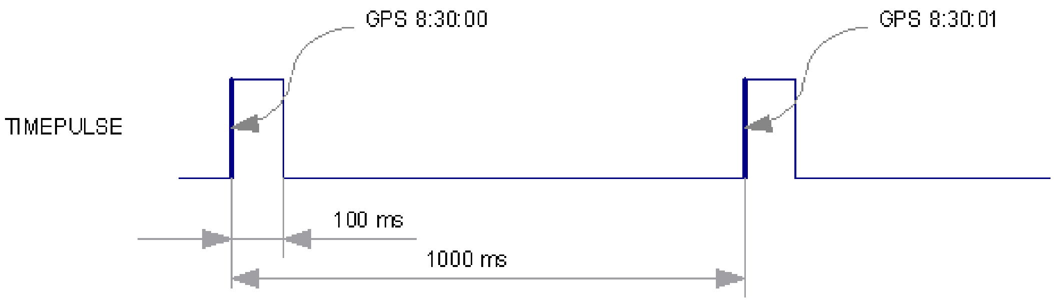


Figure 10: Time pulse signal with the example parameters

3.9 Security

The security concept of RCB-F9T covers the air interface between the receiver and the GNSS satellites and the integrity of the receiver itself.

There are functions to monitor/detect certain security threads and report it to the host system. Other functions try to mitigate the thread and allow the receiver to operate normally.

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

Threat	u-blox solution
Over air signal integrity	Spoofing detection/mitigation
	Jamming detection/mitigation
GNSS receiver integrity	Secure boot
	Secure firmware update

Table 11: u-blox security options

3.9.1 Spoofing detection / monitoring

Spoofing is the process whereby someone tries to forge a GNSS signal with the intention of fooling the receiver into calculating a different user position than the true one.

The spoofing detection feature monitors the GNSS signals for suspicious patterns indicating that the receiver is being spoofed. A flag in UBX-NAV-STATUS message (flags2 - `spoofDetState`) alerts the user to potential spoofing.

The spoofing detection feature monitors suspicious changes in the GNSS signal indicating external manipulation. Therefore the detection is only successful when the signal is genuine first and when the transition to the spoofed signal is being observed directly. When a receiver is started up to a spoofed signal the detection algorithms will be unable to recognize the spoofing. Also, the algorithms rely on availability of signals from multiple GNSS constellations; the detection does not work in single-GNSS mode.

3.9.2 Jamming/interference indicator

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.

3.9.2.1 Jamming/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 12: Jamming/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 is reporting any currently detected interference over all currently configured signal bands.

3.9.3 GNSS receiver integrity

3.9.3.1 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 run on the receiver.

3.9.3.2 Secure firmware update

The firmware image itself is encrypted and signed by u-blox. The RCB-F9T verify the signature at each start.

3.10 u-blox protocol feature descriptions

3.10.1 Broadcast navigation data

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

The UBX-RXM-SFRBX reports the broadcast navigation data message collected by the receiver from each tracked signal. When enabled, a separate message is generated every 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. Indeed, although this document uses the term "subframe" generically, it is not strictly the correct term for all GNSS (e.g. GLONASS has "strings" and Galileo has "pages").

3.10.1.1 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-RXMSFRBX 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 and the following sections are organized by GNSS for that reason. 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.

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).

3.10.1.2 GPS

The data structure in the GPS L1C/A and L2C signals is dissimilar and thus the UBX-RXM-SFRBX message structure differs as well. For the GPS L1C/A and L2C signals it is as follows:

3.10.1.2.1 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:

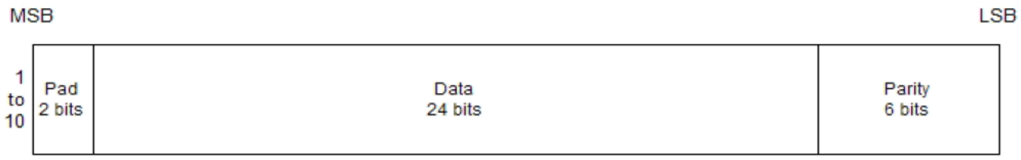


Figure 11: GPS L1C/A subframe word

3.10.1.2.2 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:

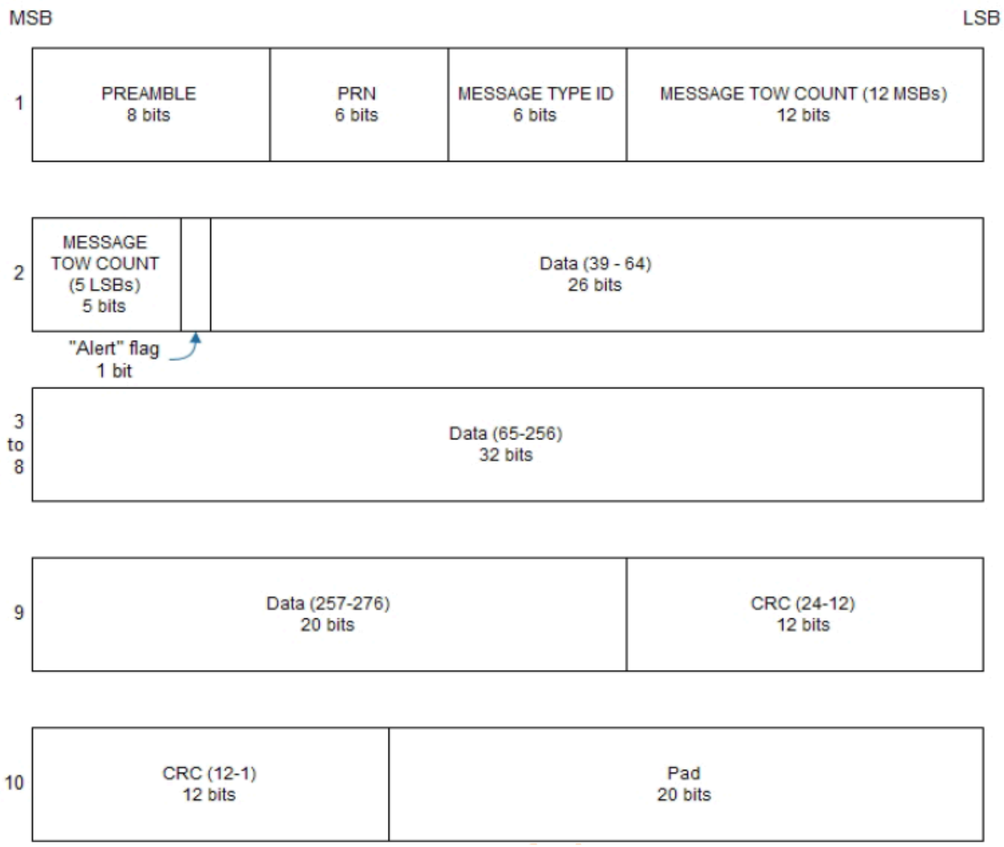


Figure 12: GPS L2C subframe words

3.10.1.3 GLONASS

For GLONASS L1OF and L2OF signals, each reported subframe contains a string as described in the GLONASS ICD. This string comprises 85 data bits which are reported over three 32-bit words in the UBX-RXM-SFRBX message. Data bits 1 to 8 are always a hamming code, whilst 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 vary 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 SVs, 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:

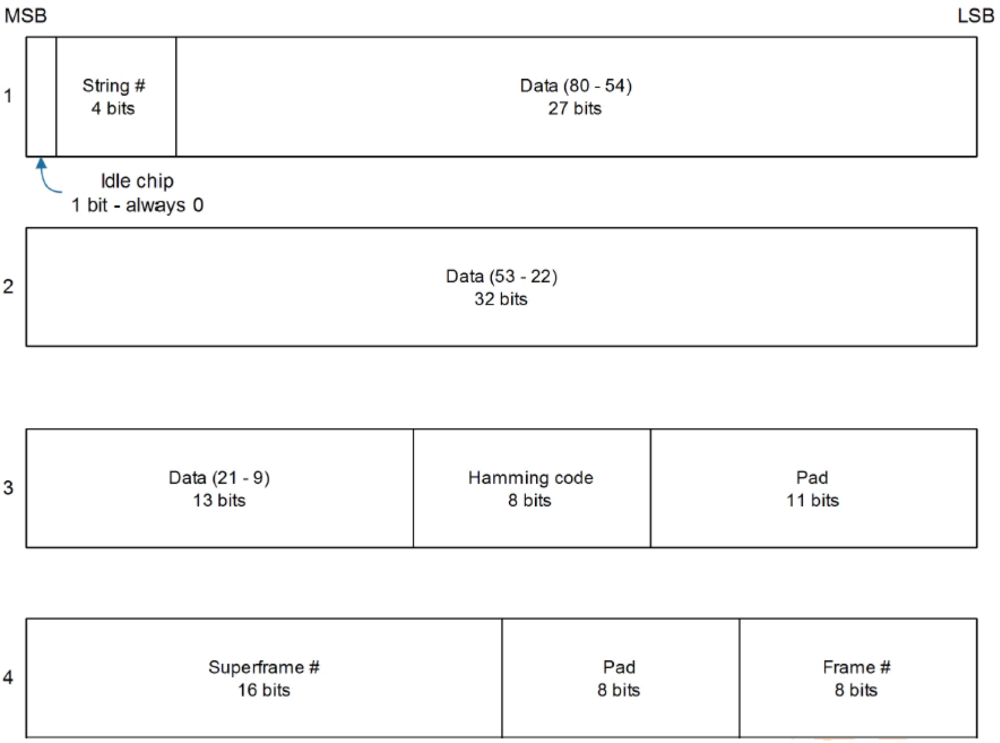


Figure 13: GLONASS subframe words

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

3.10.1.4 BeiDou

For BeiDou B1I D1, B1I D2, B2I D1, B2I D2 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:

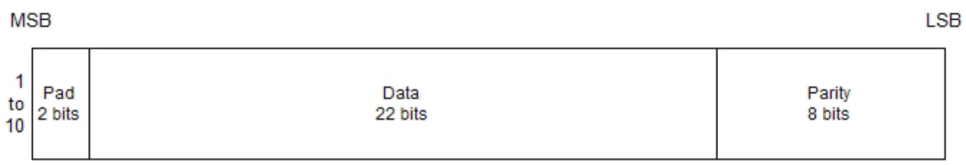


Figure 14: BeiDou subframe word

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.

3.10.1.5 Galileo

The Galileo E1 C/B and E5 bI/bQ signals both transmit the I/NAV message but in different configurations. The UBX-RXM-SFRBX structures for them are as follows.

3.10.1.5.1 Galileo E1 C/B

For Galileo E1 C/B signals, each reported subframe contains a pair of I/NAV pages as described in the Galileo ICD.

For Galileo "Nominal" pages the eight words are arranged as follows:

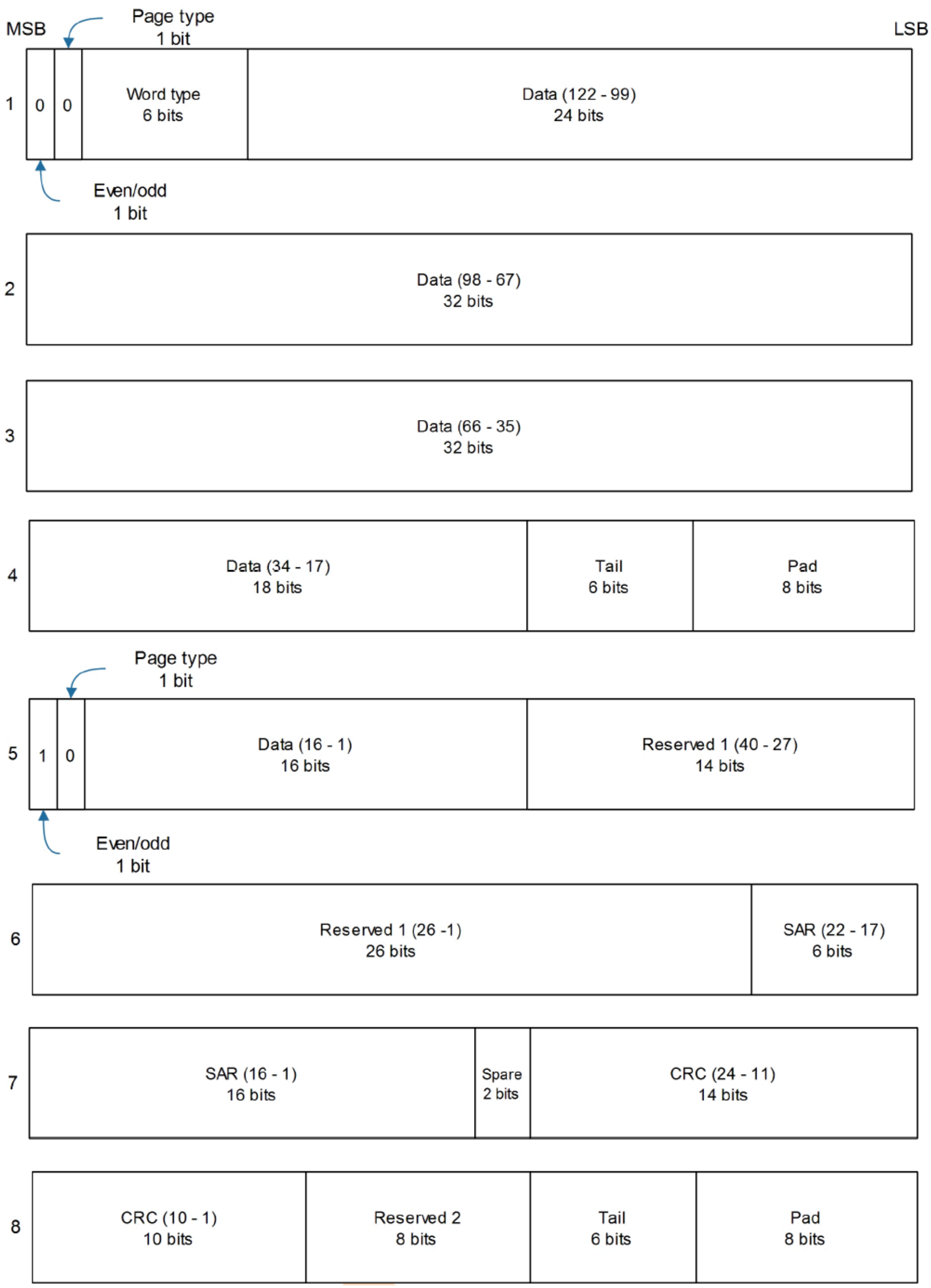


Figure 15: Galileo E1 C/B subframe words

3.10.1.5.2 Galileo E5 bI/bQ

For Galileo E5 bI/bQ signals, 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:

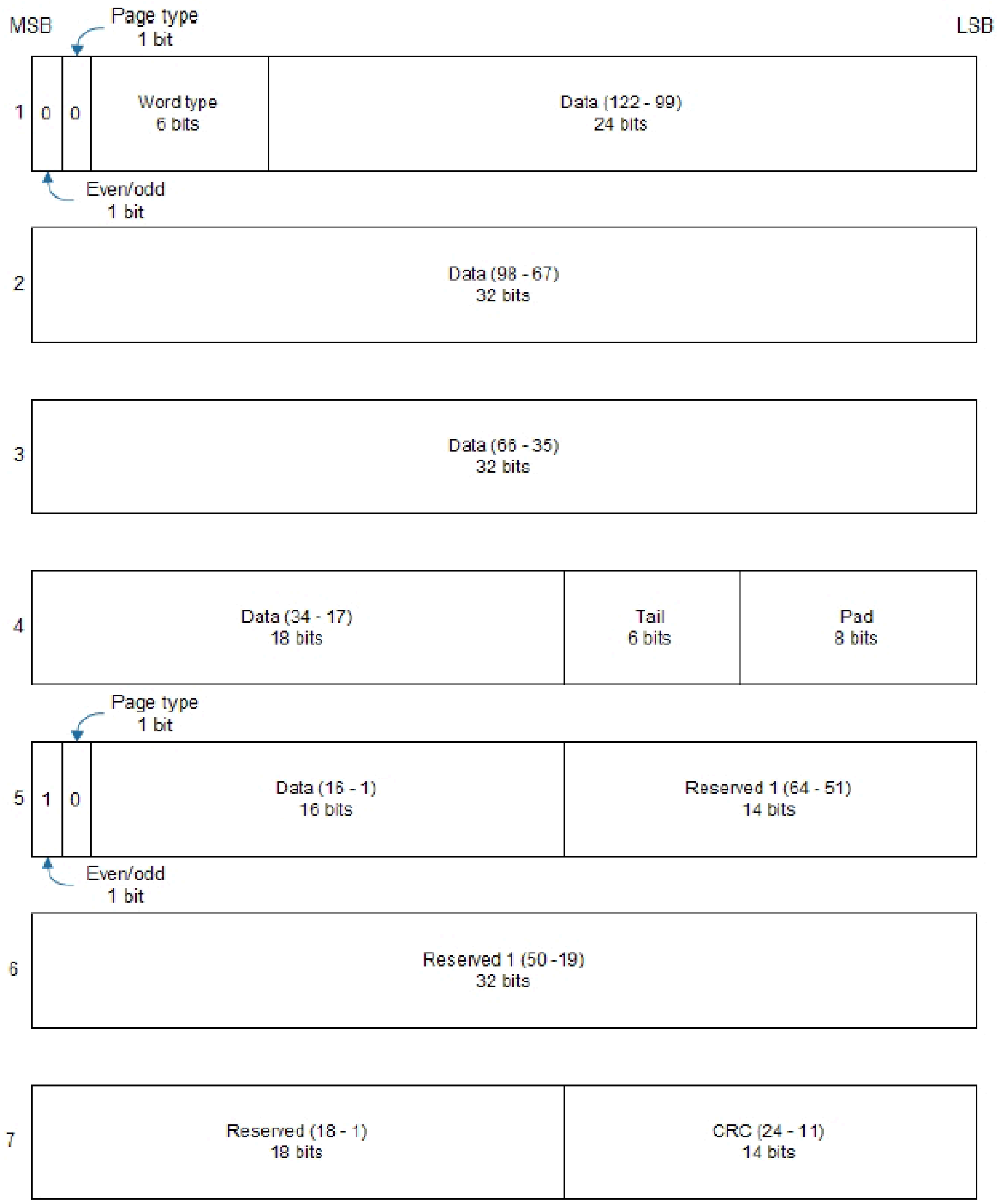


Figure 16: Galileo E5 bI/bQ subframe words

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).

3.10.1.6 SBAS

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

The eight words are arranged as follows:

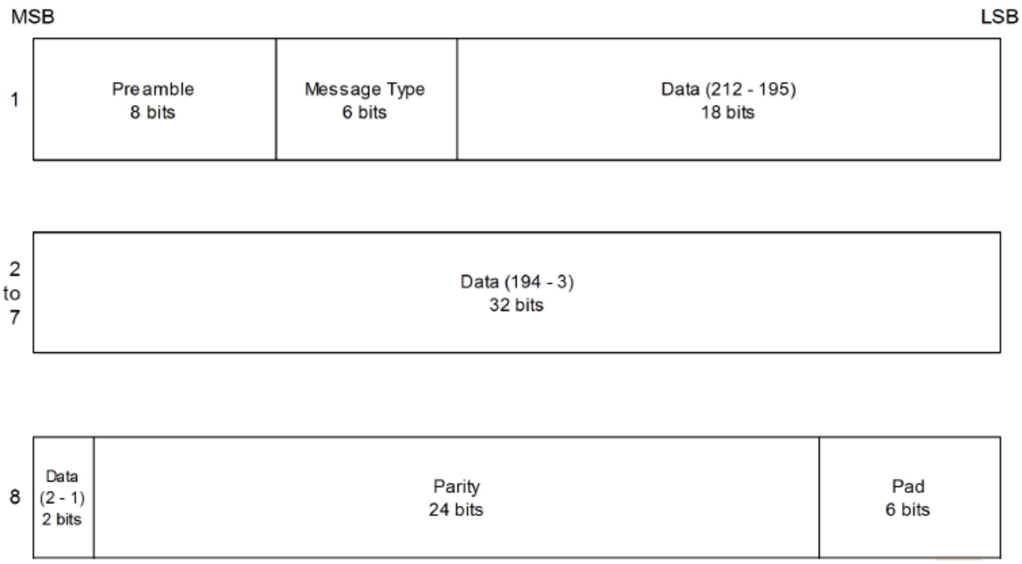


Figure 17: SBAS subframe words

3.10.1.7 QZSS

The structure of the data delivered by QZSS L1C/A signals is effectively identical to that for GPS (L1C/A).

Similarly the QZSS L2C signal is effectively identical to the GPS (L2C).

3.10.1.8 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
SBAS	L1C/A	1	0	8	1s
GPS	L2CL	0	3	10	12s
GPS	L2CM	0	4	10	12s
Galileo	E1 C	2	0	8	2s
Galileo	E1 B	2	1	8	2s
Galileo	E5 bI	2	5	8	2s
Galileo	E5 bQ	2	6	8	2s
BeiDou	B1I D1	3	0	10	6s
BeiDou	B1I D2	3	1	10	0.6s
BeiDou	B2I D1	3	2	10	0.6s
BeiDou	B2I D2	3	3	10	0.6s
QZSS	L1C/A	5	0	10	6s
QZSS	L2CM	5	4	10	12s
QZSS	L2CL	5	5	10	12s
GLONASS	L1OF	6	0	4	2s
GLONASS	L2OF	6	2	4	2s

Table 13: Data message formats reported by UBX-RXM-SFRBX

3.11 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, in order to electrically reset the chip. This is an immediate, asynchronous reset. No Stop events are 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** 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.

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 18. The defined configuration of the PIOs is listed in Table 14.

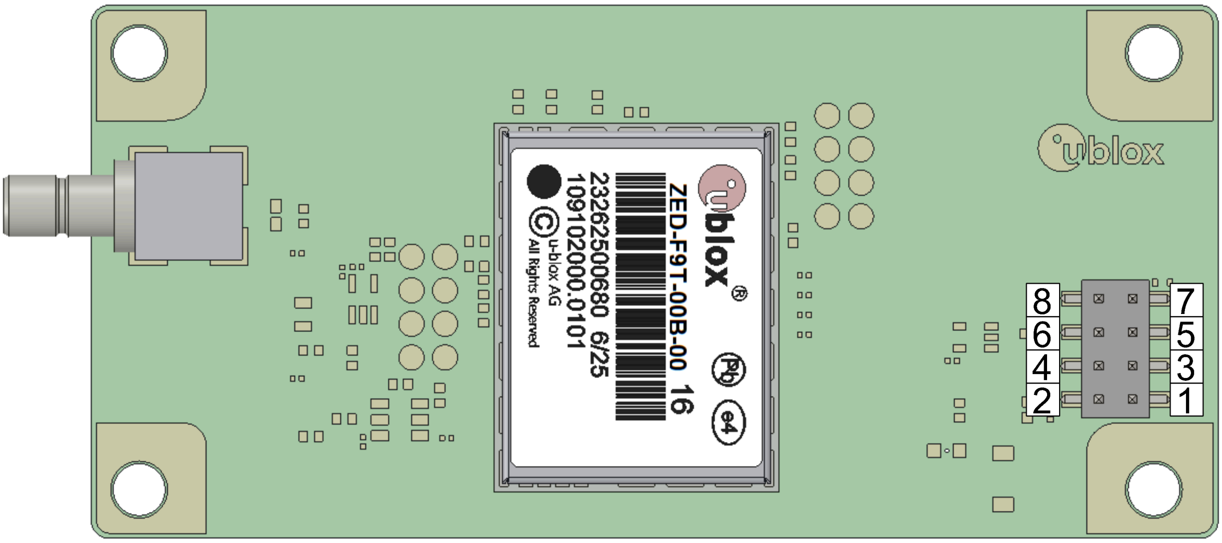


Figure 18: RCB-F9T pin assignment

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 14: RCB-F9T pin assignment

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 RCB-F9T Data sheet [1] for specification).

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

u-blox recommends using an active antenna with RCB-F9T.

If an active antenna needs to be implemented in an application case, it is recommended that an OEM active antenna module be used that meets our specification. To implement the required RF circuitry and source the required components to meet group delay specification is not a simple process compared to previous L1-only implementation.

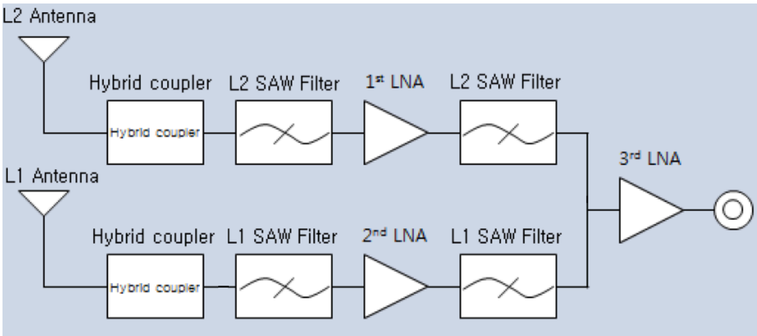


Figure 19: u-blox low cost dual-band antenna internal structure

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

☞ Location of the antenna is critical to reach the stated performance. Unsuitable locations could include, under vehicle dash, rear-view mirror location, etc.

L1 + L2/E5b active antenna required specifications

Parameter	Specification	
Antenna type		Active antenna
Active antenna recommendations	Minimum active antenna gain[1]	17 dB
	Maximum active antenna gain[1]	50 dB
	Noise figure	<4 dB
L1 band antenna gain[2]	1559 - 1606 MHz: 3 dBic typ.	

1 Including passive losses (filters, cables, connectors etc.)

2 Measured with a ground plane d=150 mm

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

Table 15: 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

When integrating GNSS receivers into wireless systems, careful consideration must be given 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 are provided to help in designing robust yet cost-effective solutions.

⚠ 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 u-blox RCB-F9T Data sheet [1].

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

3 Measured with a ground plane d=150 mm

4 GNSS system bandwidths: 1559... 1563 MHz; 1573... 1578 MHz; 1598... 1606 MHz; 1192... 1212 MHz; 1197... 1217 MHz; 1223... 1231 MHz; 1242... 1249 MHz

5 Exception L1 and L2 bands +/- 200 MHz, emphasis on cellular bands

6 GNSS system bandwidths: 1559... 1563 MHz; 1573... 1578 MHz; 1598... 1606 MHz; 1192... 1212 MHz; 1197... 1217 MHz; 1223... 1231 MHz; 1242... 1249 MHz

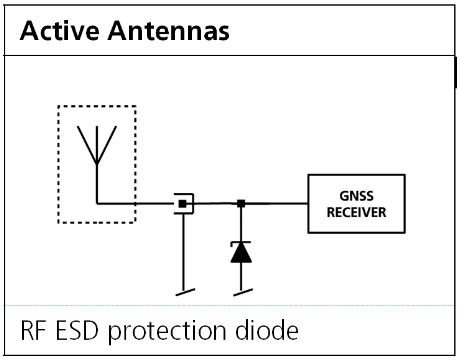


Figure 20: RF ESD precautions

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.

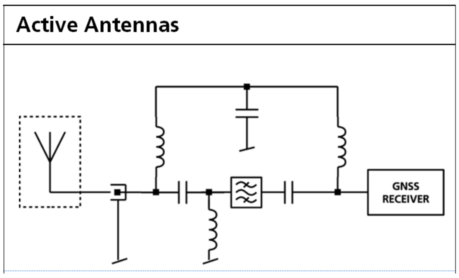


Figure 21: Active antenna EOS protection

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 GNSS 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 preventing the destruction of the receiver from large input signals. Here the GNSS performance under interference conditions is not important and suppression of the GNSS signal is permitted. It is sufficient to just observe the maximum RF power ratings of all the components in the RF input path.
- GNSS performance must be guaranteed even under interference conditions. In that case, not only the maximum power ratings of the components in the receive patch 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.

5 Product handling

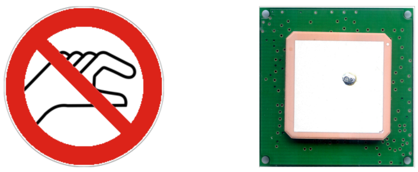
5.1 ESD handling precautions

⚠ RCB-F9T 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!

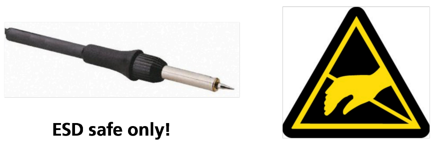
- Unless there is a galvanic coupling between the local GND (i.e. the work table) and the PCB GND, then the first point of contact when handling the PCB must always be between the local GND and PCB GND.
- Before mounting an antenna patch, connect ground of the device.

- 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 16 provides a complete list of the default configuration differences. See the RCB-F9T 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 16: RCB-F9T-specific UART baud rate, antenna supervisor and time pulse 1 default configurations

B Glossary

Abbreviation	Definition
ANSI	American National Standards Institute
ARP	Antenna Reference Point
BeiDou	Chinese navigation satellite system
BBR	Battery-backed RAM
CDMA	Code Division Multiple Access
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOS	Electrical Overstress
EPA	Electrostatic Protective Area
ESD	Electrostatic Discharge
Galileo	European navigation satellite system
GLONASS	Russian navigation satellite system
GND	Ground
GNSS	Global navigation satellite system
GPS	Global Positioning System
GSM	Global system for mobile communications
I2C	Inter-integrated circuit bus
IEC	International Electrotechnical Commission
PCB	Printed Circuit Board
QZSS	Quasi-Zenith Satellite System
RF	Radio frequency

Abbreviation	Definition
SBAS	Satellite-based Augmentation System
SV	Space Vehicle, a satellite
UBX	u-blox
QZSS	Quasi-Zenith Satellite System

Related documents

[1] RCB-F9T Data sheet, doc. no. UBX-18053607
[2] RCB-F9T Interface description, doc. no. UBX-19003606
[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 (http://www.u-blox.com).

Revision history

Revision	Date	Name	Status / comments
R01	19-Mar-2019	tkoi	Advance information
R02	18-Jun-2019	tkoi	Early production information
R03	16-Jan-2020	tkoi	Early production information Updated type number
R04	25-Feb-2020	jhak	Updated minimum and maximum gains in Antenna specifications table.

Contact

For complete contact information visit us at www.u-blox.com.

u-blox Offices

North, Central and South America

u-blox America, Inc.
Phone: +1 703 483 3180
E-mail: info_us@u-blox.com

Regional Office West Coast
Phone: +1 408 573 3640
E-mail: info_us@u-blox.com

Technical Support
Phone: +1 703 483 3185
E-mail: support_us@u-blox.com

Headquarters

Europe, Middle East, Africa

u-blox AG
Phone: +41 44 722 74 44
E-mail: info@u-blox.com
Support: support@u-blox.com

Asia, Australia, Pacific

u-blox Singapore Pte. Ltd.
Phone: +65 6734 3811
E-mail: info_ap@u-blox.com
Support: support_ap@u-blox.com

Regional Office Australia
Phone: +61 2 8448 2016
E-mail: info_anz@u-blox.com
Support: support_ap@u-blox.com

Regional Office China (Beijing)
Phone: +86 10 68 133 545
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Chongqing)
Phone: +86 23 6815 1588
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Shanghai)
Phone: +86 21 6090 4832
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Shenzhen)
Phone: +86 755 8627 1083
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office India
Phone: +91 80 4050 9200
E-mail: info_in@u-blox.com
Support: support_in@u-blox.com

Regional Office Japan (Osaka)
Phone: +81 6 6941 3660
E-mail: info_jp@u-blox.com
Support: support_jp@u-blox.com

Regional Office Japan (Tokyo)
Phone: +81 3 5775 3850
E-mail: info_jp@u-blox.com
Support: support_jp@u-blox.com

Regional Office Korea
Phone: +82 2 542 0861
E-mail: info_kr@u-blox.com
Support: support_kr@u-blox.com

Regional Office Taiwan
Phone: +886 2 2657 1090
E-mail: info_tw@u-blox.com
Support: support_tw@u-blox.com