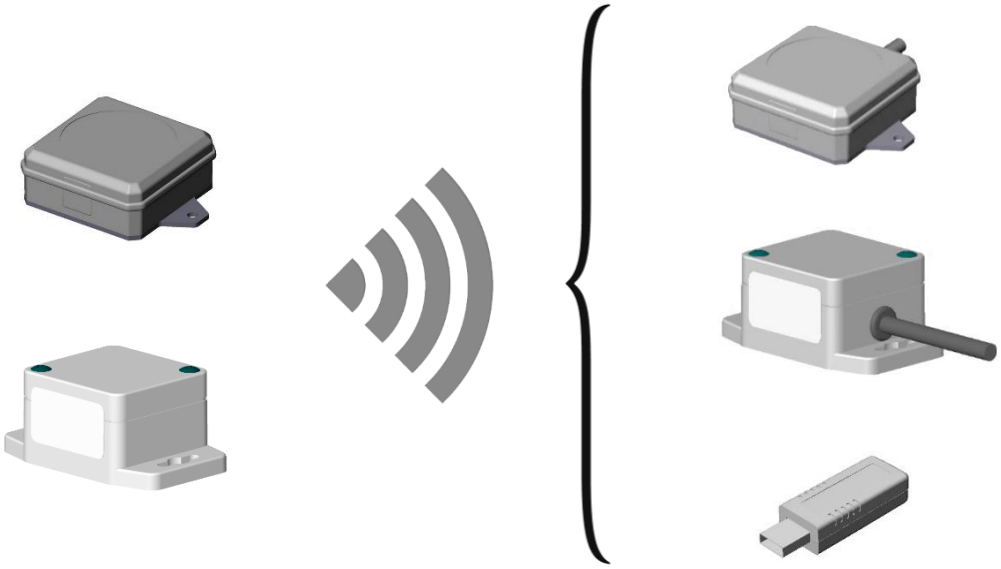


BTI BLE Tilt Angle Sensor

BLE sensor readers

Installation and operating instructions

BTI.000-UA NAME

v.241226

This installation and operating manual is intended to provide users with the information they need to install, operate, and maintain BTI model BLE wireless sensors and BTRx, BR2x, BR4x, BRU2 model BLE sensor .readers

1. Introduction

The BTI model wireless sensor (hereinafter referred to as the "Sensor") is designed to measure and transmit data on angles of deviation relative to the initially fixed position in order to determine the facts of use of the device or equipment or object on which it is installed. The angle sensor can also perform identification functions - the Sensor transmits a unique code (owner ID code) in order to identify the device or equipment on which it is installed.

To transmit information, the Sensor uses the BLE radio interface ("Bluetooth Low Energy" – Bluetooth specification with ultra-low energy consumption). The Sensor can be used together with an external data collection device (GPS monitoring equipment) that supports BLE technology.

To make changes to the Sensor settings during installation or operation, a PC with a built-in or external (for example, in the form of a USB adapter) Bluetooth LE controller or a mobile device based on the Android operating system with a version no lower than Android 8 is used.

The BLE Sensor Reader (hereinafter referred to as the "Reader" or "Readers") is designed to wirelessly receive Sensor data and transmit the read data to an external data collection device (GPS monitoring equipment) via the RS-485 (BTR4/BR4x models) or RS-232 (BTR2/BR2x models) interface. The Reader uses the binary LLS protocol to transmit the read data.

This manual mainly describes the installation and operation of BRx1 model Readers. Installation and operation of BTRx model Readers is performed in a similar manner (for more details, see the "Installation and Operation Instructions" documents for the respective models).

Sensors and Readers can be used on vehicles, agricultural machinery, stationary tanks and other objects to control mounted and trailed equipment, access control, recording the fact of work performed, identification of one's own/another's, identification at checkpoints, control of the position of working tools and mechanisms, etc.

Data transmission by the Sensor (between the Sensor and the Reader) is carried out using a radio channel at frequencies of 2.402 GHz, 2.426 GHz or 2.480 GHz. The Sensor periodically transmits pre-programmed identifiers of belonging to a specific system, as well as measured angles of deviation. The Reader selects Sensors with identifiers of this system and transmits the received data to an external

data collection device. One Reader can simultaneously receive information from 20 Sensors in operation mode, and from 50 Sensors in search mode.

When receiving data from multiple Sensors, the Reader supports the function of calculating the differential angle, for which data from 2 or more identical Sensors is used. For this, the Sensors are configured for two different functions: a base sensor (hereinafter referred to as the “Base Sensor”) and a mobile sensor (hereinafter referred to as the “Mobile Sensor”). The Base Sensor is installed on the base surface, relative to which the differential angle is planned to be measured; only one Sensor can be used as the base. The Mobile Sensor is installed on the surface, the differential angle of which, relative to the base surface, is planned to be measured; from 1 to 19 devices (Sensors) can be used as the mobile sensor. Thus, it is possible to simultaneously measure the differential angle of up to 19 different surfaces relative to one, the base.

If the external data collection device (GPS monitoring equipment) has built-in support for BLE technology and the ability to receive data from the required number of Sensors, and the differential angle calculation function is not required, then using the Reader is not required.

2. Tilt angle sensor and identification

2.1 Sensor Specifications

Table 2.1 – Sensor Specifications

Characteristic name or parameter	Value	Notes
Measurement range, °	- 90...+90(1)	
The given level measurement error, °	± 1	
Dispersion capacity, °	0.02	
Data sending period, sec.	0.1...5	configurable
Reaction time to change position, sec.	0...20	configurable
Bit depth of the measurement results presentation code, bits	16	
Microcontroller temperature estimation range, °C	- 40 ...+85	
Operating mode	continuous	
Continuous battery operation time, years	5(2)	
Internal log capacity, days	1...12(3)	configurable
Operating frequency range, GHz	2,401...2,481	
Radiation power, dBm	0	1 mW
Maximum data reading range, m	20(4)	
Supply voltage (lithium battery), V	3.6	
Operating temperature range, °WITH	– 40 ... + 75	
Degree of protection against dust and moisture ingress	IP67	
Overall dimensions of the product, mm, no more	75 x 56 x 23	

(1)From the default position.

(2)Under a typical usage scenario (1/3 of the time in active mode, 2/3 of the time in sleep mode); continuous operation time may decrease with frequent sensor adjustments and firmware updates;

(3)Depends on the set logging frequency.

(4)The maximum reading range limit is determined in the direct line of sight of the Reader and Sensor, in free space and with such mutual orientation of the Reader and Sensor, at which the maximum level of the received signal is observed. The required reading range limit is limited by software, by default it is set to 25.5 m.

2.2 Description and principle of operation

The Sensor is a wireless device that continuously, at a set interval ("beacon" mode), emits electromagnetic signals containing data such as identifiers (ID codes) of the Sensor and owner, Sensor group identifier, deviation angles relative to the initially fixed position, signal level for calculating the distance to the Reader, battery voltage, and more.

Figure 2.1 – BTI sensor model

The sensors have a plastic rectangular housing with a flange with holes for mounting on the object. The housing houses the electronic module board and the power supply battery. The electronic module board implements the following components: a digital data processing unit, a unit for measuring the Sensor's coordinates in space, and a wireless data exchange device. The wireless data exchange device provides the ability to exchange data with an external device, save and load calibration and configuration data of the Sensor, and remotely update the built-in software using BLE technology. The Sensor is powered by a built-in lithium battery, the charge of which should be sufficient for an operating period of at least 5 years. The internal volume of the housing is filled with compound.

For each Sensor, its own identifier (sensor number in the group), owner identifier, sensor group (sensor group identifier), radio channel number, password for connecting to the sensor and changing its configuration are configured.

Angle measurement is performed by a built-in accelerometer, integrated with the printed circuit board and the Sensor housing (Fig. 2.3). The Sensor independently calculates the angles of deviation of the accelerometer axes from the horizontal. The Reader calculates the differential angle between the axis of the Base Sensor and the Moving Sensor. By default, the Reader uses the X axes of the Sensors to estimate the differential angle. In the Sensor settings, it is possible to “virtually” rotate the accelerometer around the Z axis by 90°, thereby changing the axis of calculating the differential angle to the Y axis (parameter “Device operating orientation” in the Sensor settings).

To determine the differential angle measurement axis, it is necessary to evaluate the possibility of installing the Sensors along their default axes. If it is technically impossible to install the Sensors along their default axes, and

If you need to rotate the Sensor housing by 90°, you should change the “Device operating orientation” parameter.

WARNING!The operating orientation of the device must be the same for Base Sensor and Mobile Sensor.

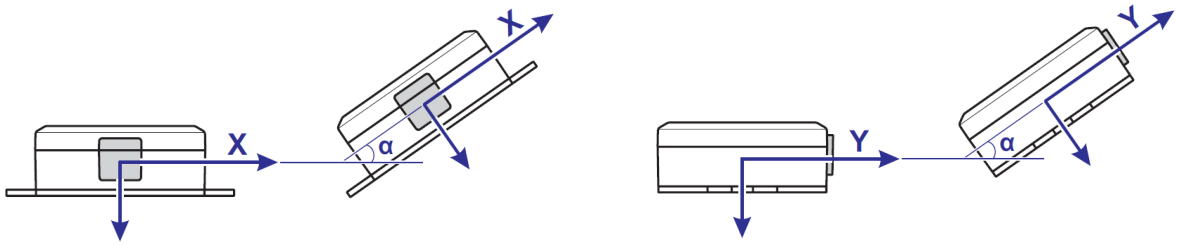


Figure 2.2 – Working orientation of the Base and Mobile sensors during measurement differential angle of inclination

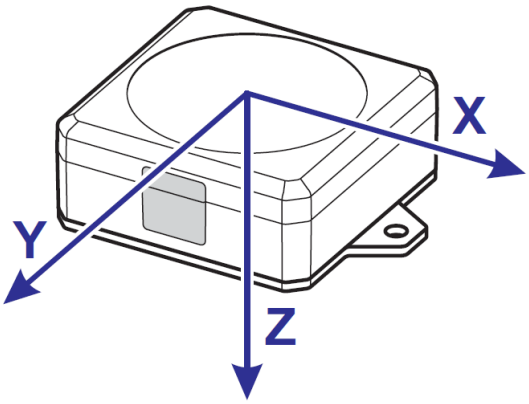


Figure 2.3 – Default sensor axis orientation

The accelerometer is calibrated by the manufacturer at the device manufacturing stage. The horizontal position of the Sensor (hereinafter referred to as “horizontal alignment”) is calibrated by the user, at will, for any working position of the Sensor.

The accelerometer converts the current acceleration of the device in three-dimensional space along three axes into a digital code. The digital data processing circuit controls the accelerometer, provides the required measurement range, compensates for errors of a physical nature during the manufacture of the accelerometer, filters (averages) data, linearly converts acceleration codes into digital codes of the angles of deviation of the X, Y, Z axes from the horizontal level (which, by default, is directed perpendicular to the center of mass of the Earth), and also measures the temperature of the microcontroller.

When left idle for longer than the set time, the sensor goes into sleep mode. In sleep mode, the emission frequency is reduced, thereby increasing the operating time.

The sensor periodically emits signals (beacon mode) with its identifier and data such as owner ID, sensor group ID, battery voltage, signal level to measure the distance to

The reader, temperature and codes of the angles of deviation from the horizontal of the X, Y, Z axes, as well as, directly, acceleration codes along the X, Y, Z axes. Data on the angles of deviation are issued as 8-bit values in sleep mode data packets and as signed 16-bit values in active mode data packets.

The procedure for installing the Sensors on the object is described in the section "Installing the Sensors". The process of setting the Sensor parameters and controlling the horizontal setting procedure is described in the section "Appendix A". The process of updating the firmware, as well as saving and restoring the Sensor configuration data is described in the section "Appendix A. Updating the Sensor Firmware. Saving and Restoring Configuration Data". The description of the Sensor's broadcast package is in the section "Appendix G". The process of configuring the Reader is discussed in the section "Appendix B".

2.3 Designation and ordering

An example of recording the Sensor designation when ordering it and in the documentation of other products in which it can be used:

BLE BTI identification sensor,

where**"Identification sensor"**» – name;
"BLE" –wireless interface based on technologyBLE;
"BTI"– identification sensorBLE in explosion-proof version with tilt angle measurement function.

2.4 Sensor delivery package

Table 2.2 – Basic delivery set

Name	Number	Note
Sensor	1	
Self-drilling screw	2	with a hole for sealing
Indicator seal	1	
Sealing wire	1	length – 30 cm
Passport	1	BTI.000-UA PS

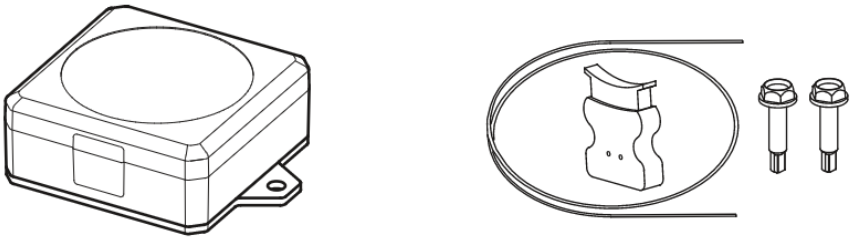


Figure 2.4 – Sensor delivery package

Table 2.3 – Optional accessories and documentation (available upon additional order)

Name	Marking
Installation and operating instructions	BTI.000-UA NAME
User software package	BTI.000 PZ1

2.5 Marking, sealing, packaging

Marking on the sensor housing:

- name and sign for the goods and services of the manufacturing enterprise;
- the inscription "Identification sensor"BLE";
- model designation;
- explosion protection marking;
- serial (factory) number according to the manufacturer's system.

To protect the Sensor from unauthorized interference, a seal is installed after installation to prevent the Sensor from being dismantled. The sealing procedure is described in the section “Installing the Sensor and Reader”.

The sensor is packed in a plastic bag, and the set of components from the main delivery set (see table 2.2) is packed in several sealed plastic bags.

2.6 Explosion protection

Model sensors
explosion protection of the Sensor is as follows:**II 2G Ex ib IIB T4 Gb.**The sensor can be used in explosive zones of classes 1 and 2 in accordance with clause 4 of NPAOP 40.1-1.32 and other regulatory documents regulating the use of electrical equipment in explosive zones.

Safe use of the Sensors is carried out within the operating temperature range: - 40 °C ≤ Ta ≤ + 75 °C.

Explosion safety of the Sensors is ensured by limiting voltage and currents to intrinsically safe values.

The sensor complies with standards**DSTUEN IEC 60079-0:2019, DSTU EN 60079-11:2017.**

The Sensor can be installed in hazardous areas, and the Readers must be installed only in a safe area, as they are not explosion-proof. The areas for installing the Sensor and Reader are shown in Fig. 2.3.

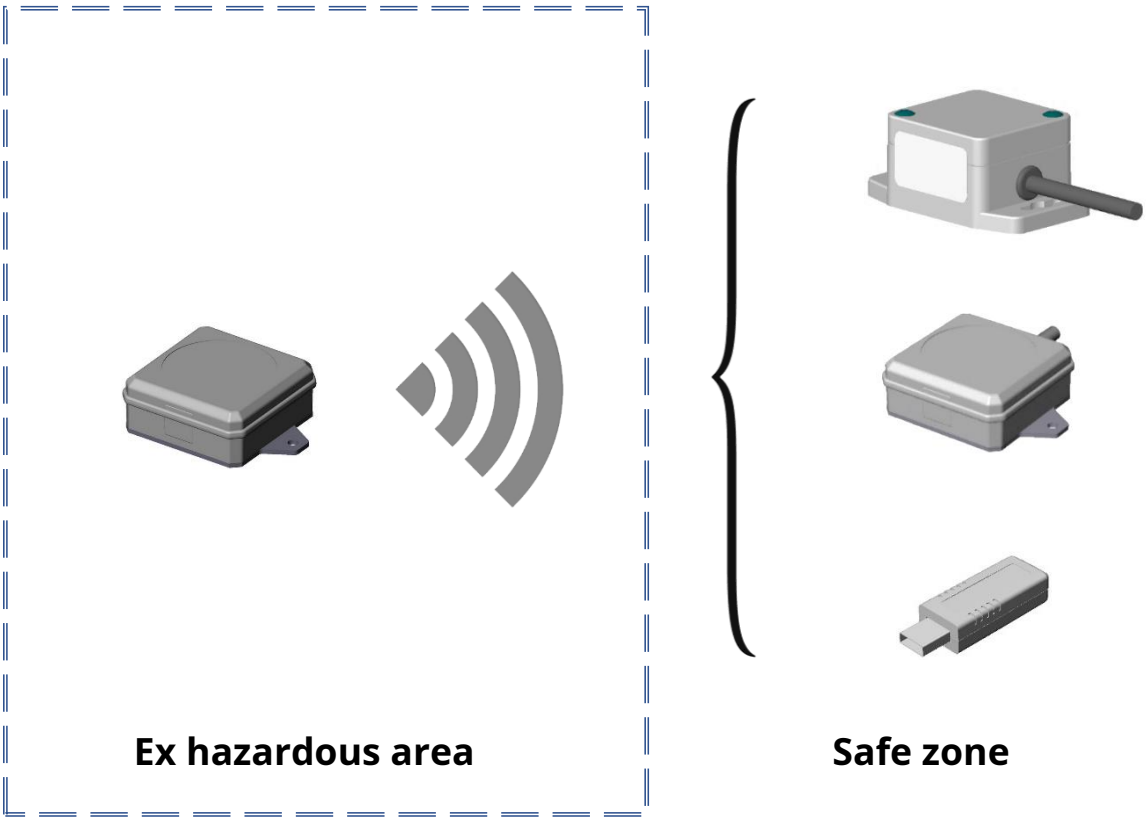


Figure 2.5 – Equipment installation areas

When installing the Sensor in an explosive area, during installation and operation of the equipment, it is necessary to ensure that the Readers and other explosive equipment are located in a safe area.

2.7 Sensor Operating Limitations

When operating the Sensor, the following requirements must be observed:

- it is forbidden to use the device for purposes other than its intended purpose;
- it is forbidden to expose the device to aggressive environments, to allow external actions exceeding the standards for IP67 enclosures according to GOST 14254-96 (IEC 529-89);
- It is forbidden to place sources of strong electromagnetic radiation or heating devices near the Sensor;
- preparation of the product for use is carried out in accordance with the section "Sensor Installation";
- opening the Sensor housing (for example, to replace the battery) is allowed only at the service center.

2.8 Sensor Maintenance The sensor is a maintenance-free product.

2.9 Sensor Malfunctions and Remedial Measures

Only personnel familiar with this installation and operating manual are allowed to troubleshoot the Sensor. Malfunctions that may occur during operation of the Sensor and measures to eliminate them are described in Table 2.4.

Table 2.4 – Malfunctions and measures to eliminate them

No. n/a	Malfunctions that arise	Possible reasons	Troubleshooting measures
1	The sensor transmits data about zero value corners	No connection Sensor with receiver (the receiver can to be, for example, Reader or tracker with BLE support)	Check the ability to connect to the Sensor using the “BTI_User_Tool” program (see “Appendix A”) in close proximity to the Sensor. If the connection is successful, go to point 2 of this table, otherwise go to point 3.
		Sensor or Reader configured incorrectly	Make sure that the Sensor and Reader settings are correct using the “BTI_User_Tool” program (see “Appendix A”). Make sure that the “Owner ID” and “Sensor Group ID” parameters of the Reader and Sensor match correctly. When measuring differential angles, make sure that the “Sensor ID” for the Base Sensor is 0, and for the Mobile Sensors – in the range from 1 to 19.
2	Angle display disappear and are restored through some time	Unstable connection Sensors with receiver (the receiver can speak, for example, Reader or tracker with BLE support)	Using the “BTI_User_Tool” program, connected to the Sensor (see “Appendix A”), or the receiver’s diagnostic tools (for example, the tracker configurator), check the value of the Sensor’s signal strength. If the value is less than -85 dB, improve the communication quality if possible: • orient the Reader by the marker in Sensor direction (Fig.) • ensure direct visibility between Reader and Sensor; • reduce the distance between the Reader and Sensor; • change the radio channel. In the Reader settings, check the maximum distance to the sensor. The value should be three times the required distance if the Reader works with Sensors used as identifiers; in other cases, it should be 25.5m.

3	The sensor is missing in search list “BTI_User_Tool”	Sensor defective	Make sure the receiver is operational. Search for the sensor using the “BTI_User_Tool” program. Change the configuration if necessary. If detection is not possible, replace the Sensor.
4	Connecting to Sensor fails	Installed password on connection to Sensor	If you lose your password, contact the service center.
5	During the change Movable position Sensor value differential angle not changes	Wrong working arrangement Sensor: selected axes Basic Sensor and Mobile The sensor is not coincide	Using the “BTI_User_Tool” program, connect to the Base Sensor and the Mobile Sensor in turn: make sure that the “Device Operating Orientation” parameter is the same for both Sensors. Make sure that this parameter is set appropriately for the physical location of the Sensors.

2.10 Sensor Replacement Procedure

The sensor is a non-repairable product and maintains stability of its parameters during the warranty period. In case of failure of the sensor, it must be replaced.

Sensor replacement is performed in the following sequence:

- unscrew the mounting screws, dismantle the Sensor;
- load the configuration data of the previous Sensor into the new Sensor (see "Appendix A. Saving and Restoring Configuration Data");
- install the new Sensor in place (if necessary, before installation or after, perform the horizontal installation operation, and, if necessary, seal the Sensor in accordance with the requirements set out in the section "Installation of the Sensor and Reader")
- if configuration data is missing, it is necessary to perform Sensor configuration operations described in the "Sensor and Reader Installation" section.

2.11 Transportation and storage

Transportation of the Sensor in the manufacturer's transport packaging is allowed by all types of closed land and sea transport (in railway cars, containers, closed cars, holds, etc.). Transportation in sealed heated compartments of aircraft is allowed. Transportation and storage must be carried out in conditions that comply with storage conditions in accordance with GOST 15150-69.

2.12 Assembly drawings

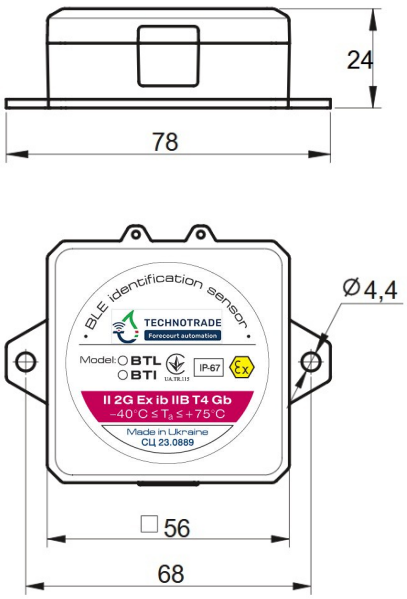


Figure 2.6 – Dimensional drawing and connection dimensions

3. BLE sensor readers

3.1 Functionality Notes

Importantly!Readers have the ability to work with several types wireless sensors with support for BLE technology manufactured by RCS. Accordingly, the Reader's firmware (software) has several versions with different functionality. Depending on the equipment with which the Reader is planned to be used, it is necessary to use one or another version of the software. The correspondence of the Reader's software versions to the type of equipment is given in Table 3.1.

The Reader software update/replacement process is performed using the “RCS_AppLoader” loader program, the process description is in the “Appendix B” section.

Table 3.1 – Technical specifications of Readers

Equipment with which the Reader is used	Software version Reader
BLE identification sensors of BTT/BTL models	1.xx
BLE identification sensors with tilt angle measurement function BTI model	2.xx
Fuel level sensors model ER-BLE	3.xx
Fuel level sensors model ER2-BLE	4.xx

3.2 Technical characteristics of Readers

Table 3.2 – Technical specifications of Readers

Characteristic name or parameter	Value
Supply voltage range, V	+ 9 ... +36 (models BTRx, BR2x, BR4x) + 5 from USB (model BRU2)
Current consumption, mA, no more	25
Operating frequency range, GHz	2,400 ... 2,485
Radiation power (only in Sensor setup mode), dBm	0
Reader Sensitivity, dBm	- 85
Maximum reading range, m	0 ...20*

Reaction time to the appearance and disappearance of the Sensor (software version 1.xx), sec.	5
Reaction time to the appearance and disappearance of the Sensor (software version 2.xx), sec.	15
Sensor data retention time in the absence of communication with the Sensor (software version 3.xx and 4.xx), sec.	5
Data transmission interface	RS-485 (model BTR4) RS-232 (model BTR2) USB (model BRU2)
The number of Sensors that the Reader can simultaneously receive (software version 1.xx), no more than	50
The number of Sensors that the Reader can simultaneously receive (software version 2.xx, 3.xx and 4.xx), no more than	20 (in working mode) 50 (in search mode)
Degree of protection	IP67
Operating temperature range, °C	- 40 ...+75
Overall dimensions (without cable), mm, no more	81 x 51 x 37 (BTRx) 78 x 68 x 24 (BR21/BR41) 48 x 20 x 13 (BR22/BR42) 66 x 20 x 13 (BRU2)
* The maximum limit reading range is determined in the direct line of sight of the Reader and Sensor, in free space and with such mutual orientation of the Reader and Sensor, at which the maximum signal level is observed (see Fig. 4.1). The required limit reading range is set software, by default it is set to 8 m (software version 1.xx) or 25.5 m (software version 2.xx, 3.xx, 4.xx, see Table 3.1)	

3.3 Description and principle of operation

The reader is a transceiver capable of receiving electromagnetic signals from sensors, decoding the received data, performing additional calculations, and transmitting the data to an external device using the binary LLS protocol.

BTRx BRhu BRU2

Figure 3.1 – BLE sensor reader models

The Reader receives and transmits data (receives and emits electromagnetic signals) only in the Sensor setup mode, the rest of the time (working mode) the Reader only receives data from the Sensors, while the Reader transmitter is turned off.

In the operating mode, the Reader is able to receive radio frequency signals only from Sensors that are within its range. The range can be changed when configuring the Reader by changing the limit distance to the Sensor. In the operating mode, when using the Sensor as an identifier, it is recommended to use a value three times the required distance for the limit distance (see subsection 4.1 of the section “Installing the Sensor and Reader”), for the BTI model the default value (25.5 m).

For the Reader (as for the Sensor), the owner (enterprise) ID, sensor groups (IDs) for reception, password for sensor reception, radio channel number are configured. The Reader is able to output received data upon request or in automatic mode to an external device via the interfaces: RS-485 (BTR4/BR4x models), RS-232 (BTR2/BR2x models) and USB (BRU2 model). The Reader outputs data of a specific Sensor (allowed) to an external device provided that the sensor identification parameters (owner ID, sensor group ID, password for reception and radio channel number) match the similar parameters of the Reader.

Thus, Sensors of different owners and different groups will not interfere with data transmission to their Readers. One Reader can be configured to receive data from 16 groups of Sensors (software version 1.xx) or simultaneously receive information from 20 Sensors (software versions 2.xx, 3.xx and 4.xx).

The Reader receives Sensor data only if its group is enabled in the Reader settings. The reaction time to the appearance and disappearance of the nearest Sensor (software version 1.xx) is 5 seconds. – for filtering Sensors that accidentally fall into the reader's reception zone. The retention time of the latest Sensor data in the absence of communication with the Sensor (software version 3.xx and 4.xx) is 5 seconds, and 15 seconds (software version 2.xx).

The Reader should be installed as close as possible to the Sensor, within direct line of sight at a distance of no more than 20 m. The Reader has the ability to calculate the distance to the Sensor based on the signal level. This distance is indicative, since the Sensor signal level depends on the installation locations of both the Sensor and the Reader, the presence of nearby sources of electromagnetic radiation and metal structures, as well as the mutual orientation of the Sensor and the Reader. The maximum Sensor signal level is observed when the marks (markers of the maximum of the directional pattern) on the Sensor and Reader housings are directed towards each other (see Fig. 4.1).

The reader (software version 1.xx) transmits the following data of the nearest permitted Sensor to the external device: received signal level, minimum distance to the Sensor, sensor identifier and Sensor supply voltage.

The reader (software version 2.xx) transmits the following data of the allowed Sensors to the external device: received signal level, minimum distance to the Sensor, sensor identifier (sensor number in the group), Sensor supply voltage, differential angle of inclination between the Base and Mobile Sensors, angle of deviation from the horizontal of the Mobile Sensor.

The reader (software version 3.xx and 4.xx) transmits the following data of the allowed Sensors to the external device: received signal level, minimum distance to the Sensor, sensor identifier (sensor number in the group), Sensor supply voltage, temperature, fuel level code.

The Reader installation procedure is described in the section “Installing the Sensor and Reader”. Configuring the Reader parameters is described in the section “Appendix B”. The process of updating the firmware, as well as saving and restoring the Reader configuration data is described in the section “Appendix E”. A description of the Reader data exchange protocol with external devices is found in the section “Appendix G”.

3.4 Designation and ordering of the Reader

An example of recording the Reader designation when ordering it and in the documentation of other products in which it can be used:

BLE sensor reader. Model BRxy, where**«BLE sensor reader »** – name; **"BR"**– «Bluetooth Reader";

"x"– Interface:

"2" – RS-232;
"4" – RS-485;
"U" – USB.

"y"– Execution:

"1" – external IP67 (BR21/BR41); "2" – internal IP20 (BR22/BR42/BRU2);

or

BLE sensor reader. Model BTRx, where**«BLE sensor reader » –**name;

"x"– Interface:

"2" – RS-232;
"4" – RS-485.

3.5 Readers delivery package

Table 3.3 – Delivery set of the BRxy/BTRx Reader (except BRU2)

Name	Number	Notes
Reader with attached cable	1	cable length ~ 3 m
Fuse holder with wire (loop)	1	5x20 mm, with wire
Glass fuse, 0.1 A	1	glass, 5x20 mm
Indicator seal	1	
Sealing cable	1	length – 30 cm
Self-drilling screw	2	
Passport	1	BR.000-UA PS/BTR.000-UA PS
Installation and operating instructions	-	BT.000-UA NAME Available upon request

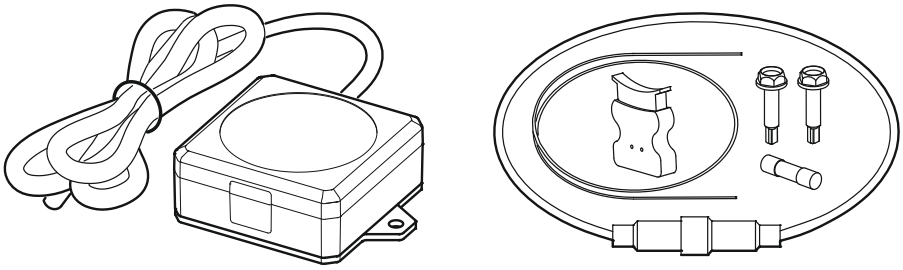


Figure 3.2 – Delivery package of the BR21/BR41 Reader model

3.6 Reader Operating Limitations

When operating the Readers, it is prohibited to:
- place Readers near sources of strong electromagnetic radiation or heating devices;
- use the Readers for purposes other than their intended purpose;
- connect Readers to devices with interfaces other than specified in this manual;
- apply power voltages to the Reader that exceed those specified in Table 3.2;
- allow the impact of pulse voltage on power supply circuits;
- allow external influences that exceed the norms for shellsIP according to table 3.2 and exposure to aggressive environments;
- open the Readers' case, this operation is allowed only in service center.

3.7 Reader Maintenance The readers do not require maintenance.

3.8 Reader Repair

Reader repairs are carried out at the manufacturer's service center.

3.9 Transporting and storing Readers

Transportation of Readers in the manufacturer's transport packaging is allowed by all types of closed land and sea transport (in railway cars, containers, closed cars, holds, etc.). Transportation in sealed heated compartments of aircraft is allowed. Transportation and storage must be carried out in conditions that meet storage conditions 3 according to GOST 15150-69.

3.10 Installation drawings and marking of Reader terminals

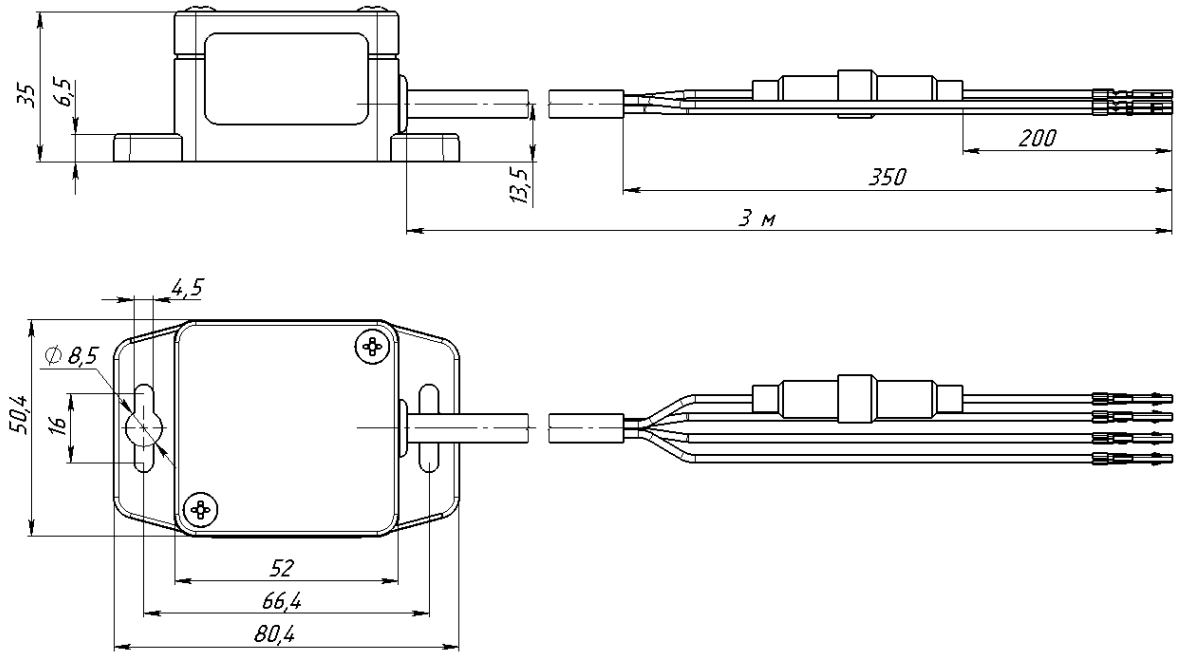


Figure 3.3 – Dimensional drawing and connection dimensions of the Reader BTRx models (with fuse holder)

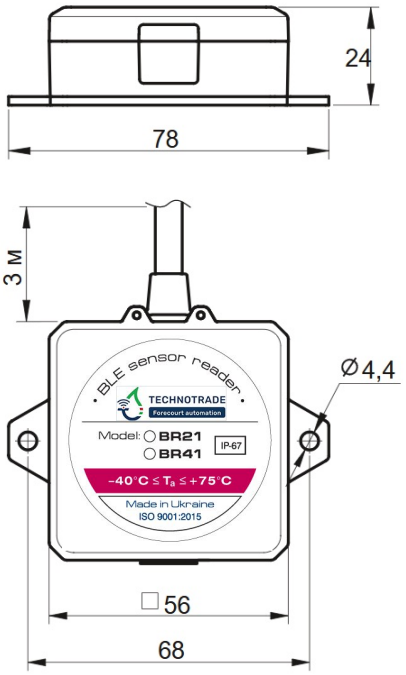


Figure 3.4 – Dimensional drawing and connection dimensions of the Reader BR21/BR41 models

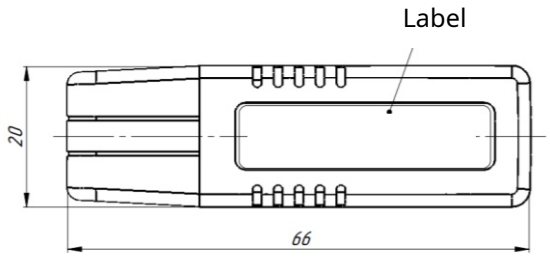


Figure 3.5 – Dimensional drawing of the BRU2 model Reader (thickness 12.5mm)

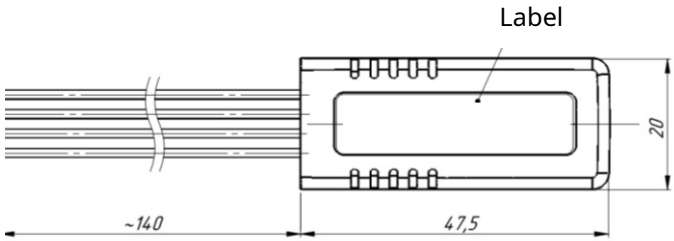


Figure 3.6 – Dimensional drawing of the BRU22/BRU42 Reader model (thickness 12.5mm)

Table 3.4 – Purpose and marking of the cable wires of the Reader models BTRx/ BR2x/BR4x

Marking	Appointment	Wire color
U+	On-board network (+)	Brown
U–	General (–)	Black
TX (A)	RS-232 (RS-485) interface	Yellow
RX (B)	RS-232 (RS-485) interface	Blue

4. Installing the Reader and Sensors

4.1 Reader and Sensor Settings

For the successful operation of the Reader and Sensors, it is very important to correctly orient them on the controlled objects.!

Typically, the Reader is mounted on the object being monitored, and the Sensors are mounted on the monitored surfaces in such a way that the maximum directional pattern markers (dot or square protrusion) on the device housings are directed towards each other, as shown in Fig. 4.1:

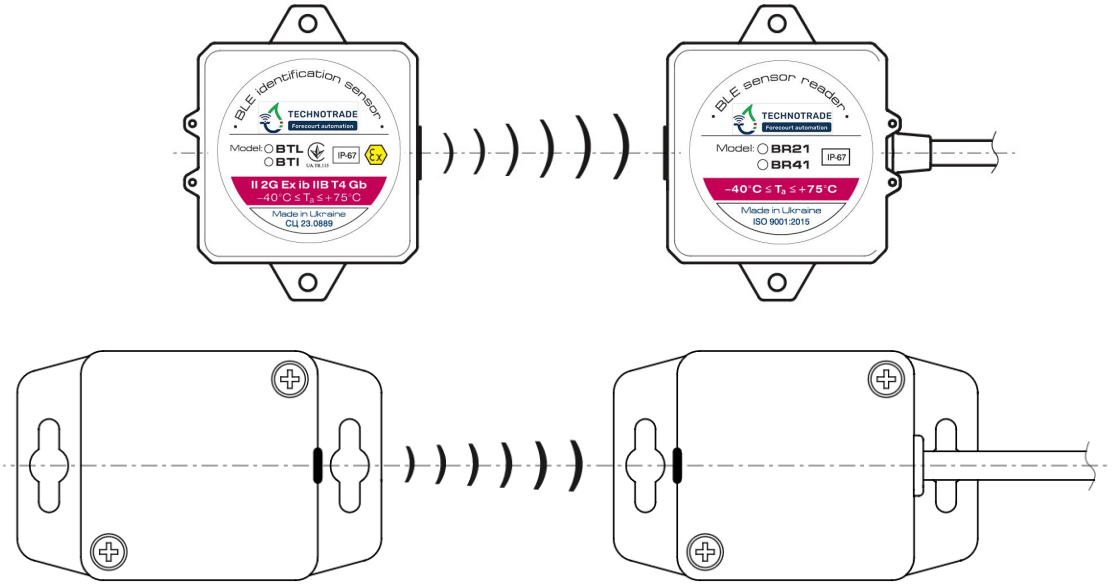


Figure 4.1 – Optimal mutual orientation of the Reader and Sensor

In this case, the signal power received by the Reader will be maximum. Each Sensor is calibrated during the production process to link the signal power to the distance. The Reader determines (calculates) the distance to the Sensors and transmits data from the closest (allowed) one to an external device (for example, an on-board controller).

The Reader in the operating mode is able to receive radio frequency signals only from Sensors located in its coverage area. The coverage area can be changed when configuring the Reader by changing the maximum distance to the Sensor. The boundaries of the zones in which the allowed Sensors will be reachable are shown in Fig. 4.2.

The Reader receives Sensor data only if the group to which the Sensor belongs is allowed (registered) in the Reader settings. The reaction time to the appearance and disappearance of the nearest Sensor is 5 seconds - to filter Sensors that accidentally fall into the Reader's reception zone.

An example of when the Reader receives data from Sensors of allowed groups 1 and 3 is shown in Fig. 4.3.

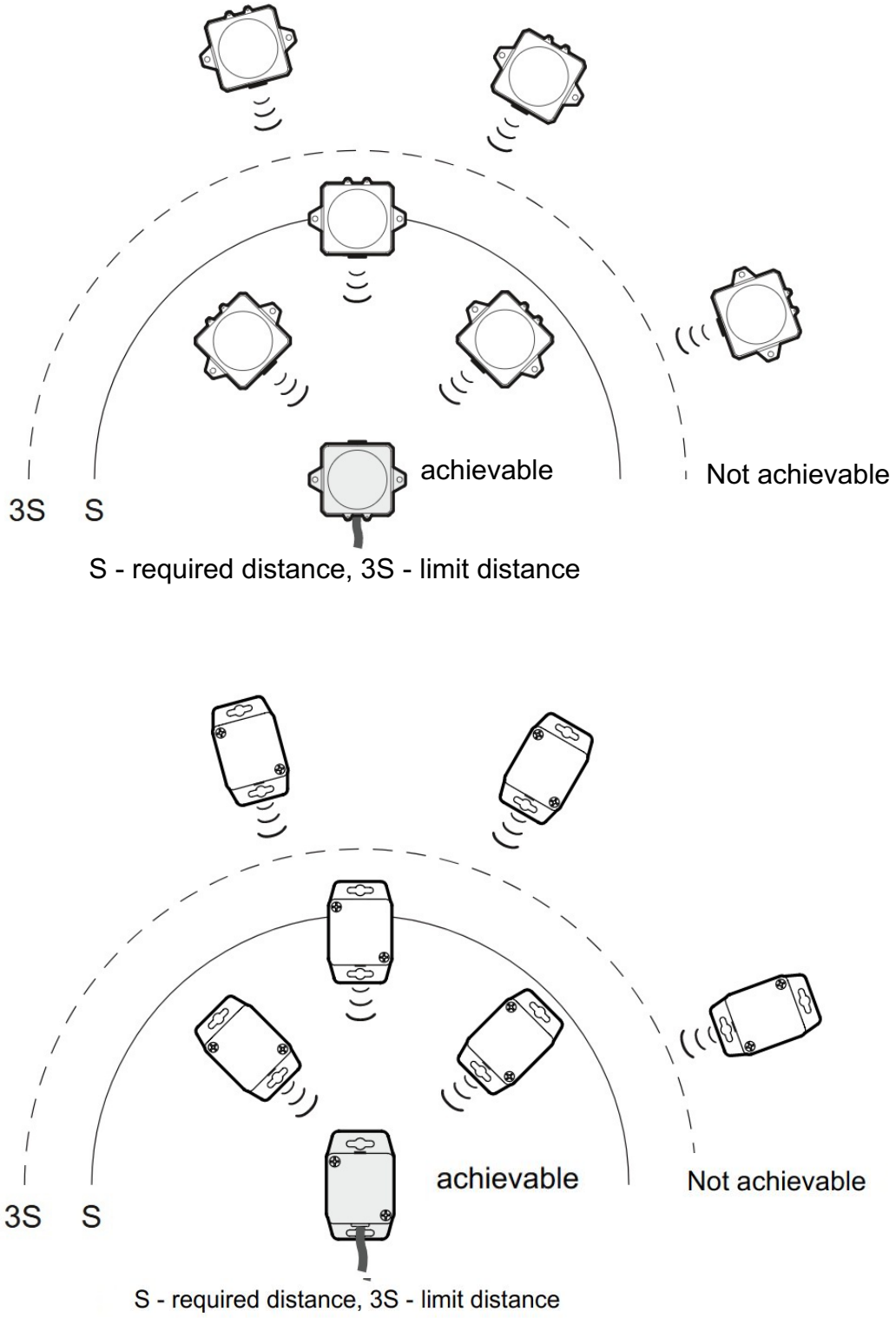


Figure 4.2 – Sensors' reach zones (hereinafter: S – required distance read)

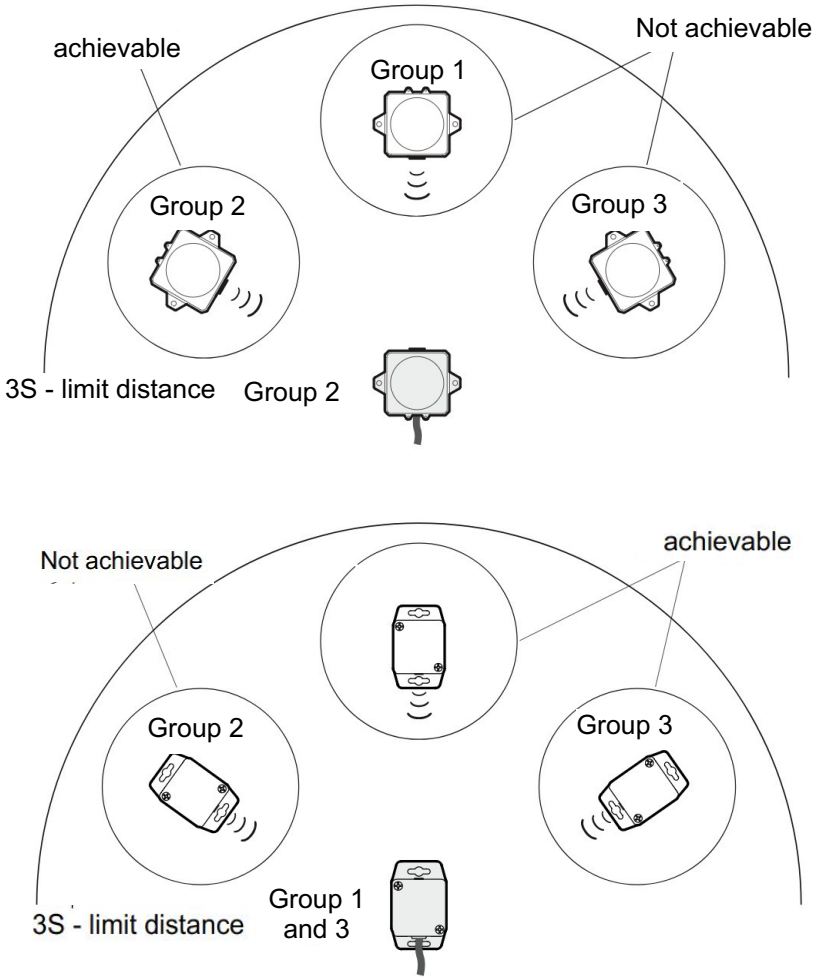


Figure 4.3 – Receiving data from allowed Sensor groups

The distance to the Sensors determined by the Reader is indicative, since the Sensor signal level depends on the installation locations of both the Sensor and the Reader, the presence of nearby sources of electromagnetic radiation and metal structures, as well as the mutual orientation of the Sensor and the Reader. The maximum Sensor signal level is observed when the marks markers of the maximum of the directional pattern) on the Sensor and Reader(.)housings are directed towards each other (Fig. 4.1

If the Sensor is directed at an angle to the Reader, it may turn out that the determined distance to it will be greater than to the Sensor, which will be .located opposite the Reader at the same distance, as shown in Fig. 4.4

If the mutual orientation of the Reader and Sensor does not correspond to the maximum signal level, or if there are metal structures in the Sensor signal reception area, the distance calculated by the Reader to the Sensor will be greater than the .actual distance

Therefore, for the Reader that works with BTT/BTL model Sensors (Reader software version 1.xx), it is recommended to use the maximum reception distance of the Sensors in the operating mode.***three times more than necessary***, as shown in .Fig. 4.5

For the Reader that works with BTI model Sensors (Reader software version 2.xx), in operating mode it is recommended to use the default (maximum) reception distance limit.

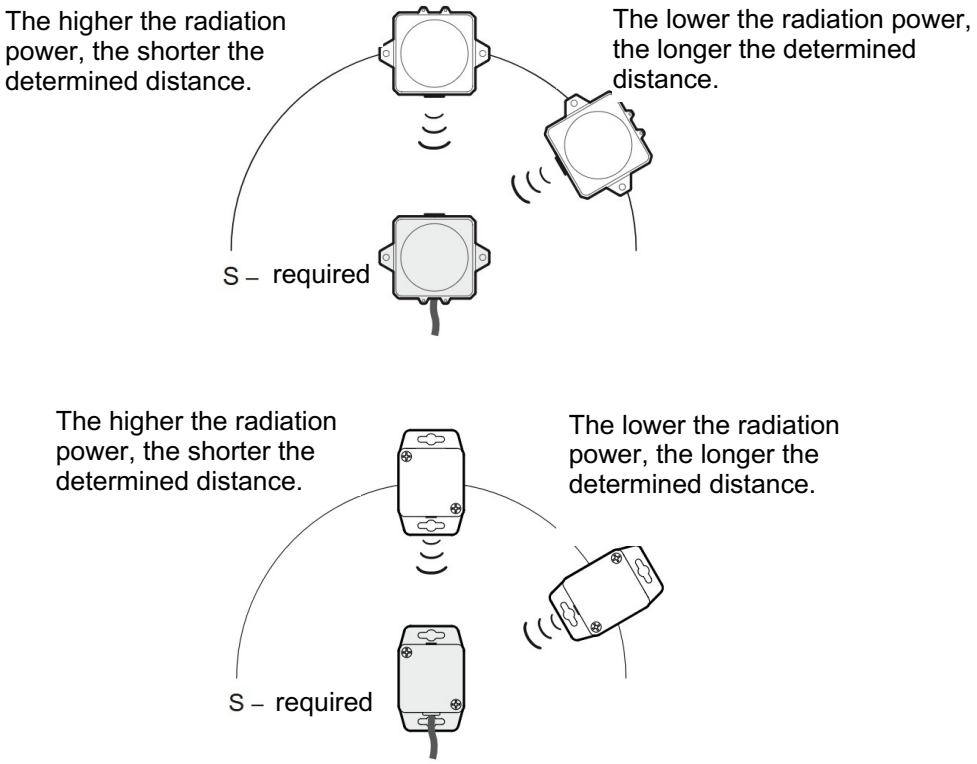


Figure 4.4 – Distance determination by the Reader

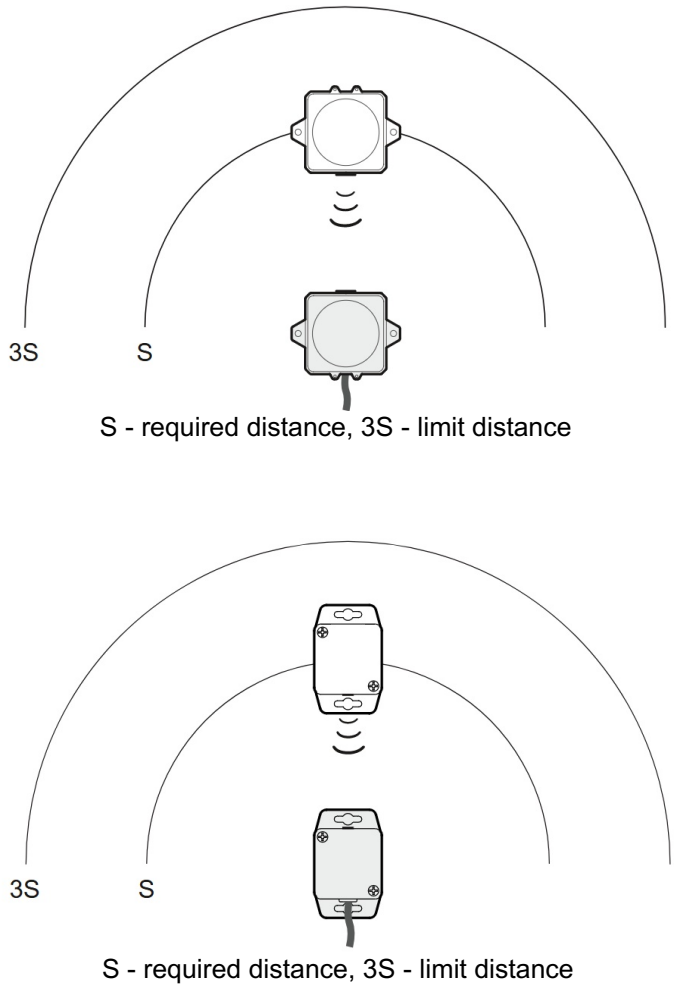


Figure 4.5 – Maximum reception distance

Examples of correct and incorrect mutual arrangement of the Sensor and Reader are shown in Fig. 4.6 and 4.7, respectively.

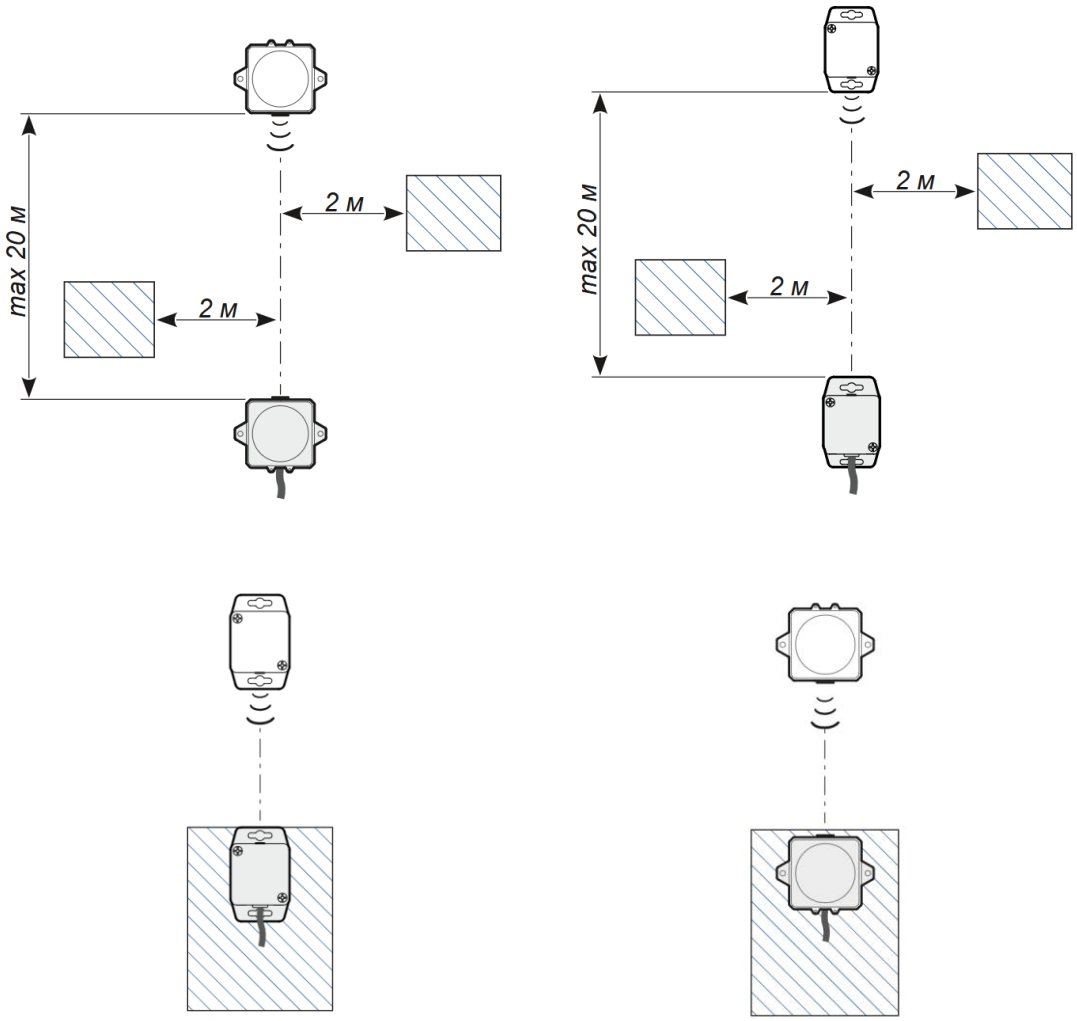


Figure 4.6 – Examples ***correct*** Sensor and Reader location during installation

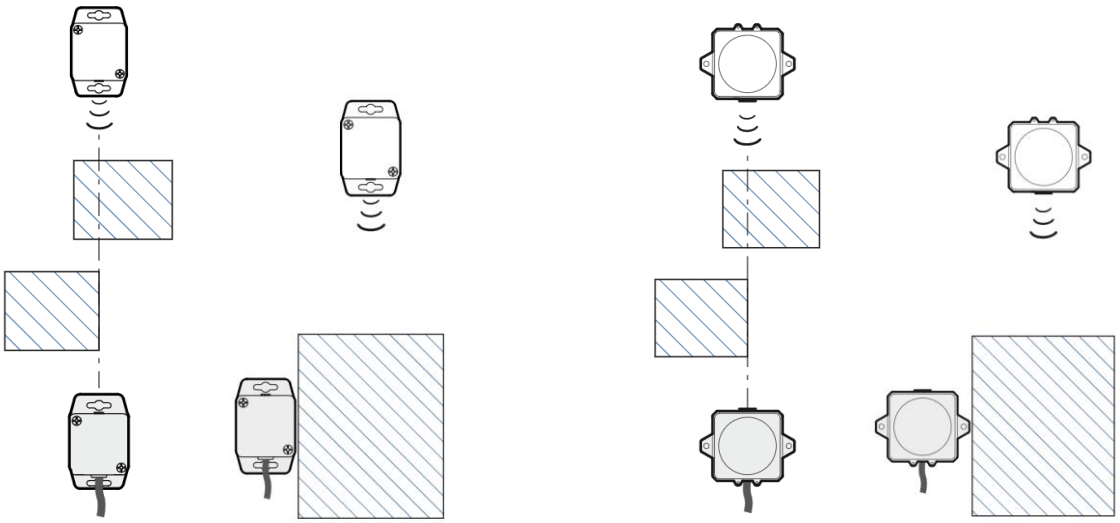


Figure 4.7 – Examples ***wrong*** Sensor location and Reader during installation

4.2 Preparation for installation

Preparation for installation is as follows:

- Unpack the Sensor and/or Reader assembly and accessories;
- Check the Sensor configuration according to the table2.2;
- Check the Reader configuration according to the table3.3;
- Prepare documentation and relevant software (SW) according to table 4.1.

Table 4.1 – Documentation and Software

Name	Marking	Note
Instructions for installation and operation	BT.000-UA NAME	
Software package user (supplied for request)		Composition: • program “BTI_User_tool” for configuring the Sensor and Reader; • Reader loader “RCS_AppLoader”.

- Prepare the necessary equipment, tools and consumables according to table 4.2:

Table 4.2 – Equipment, tools and consumables

Name	Number
Cordless drill/screwdriver with a 7 mm end head (depending on the material of the installation site and its thickness, metal drill bits Ø3.2 ... 3.5 mm may be required)	1 pc.
Laptop (PC), minimum requirements: Pentium 500 MHz, 1 GB RAM, MS Windows 7/8/10/11, MS Office, at least 20MB of free hard disk space, mouse, free USB port	1 pc.
Transformer USB/Serial (only for Reader models BTRx/BR2x/BR4x). It is recommended to use MOXA UPort 1110 (USB/RS-232) or MOXA UPort 1130 (USB/RS-485) converters	1 pc.

Typically, the Reader is mounted on the object being monitored, and the Sensors are mounted on the objects that need to be monitored.

For correct operation of the Sensor and Reader***it is extremely important to be correct to position and orient them*** (see subsection 4.1 of this section).

It is recommended to follow these rules:

- Place the Sensor and Reader at the installation site (for example, vehicle (Vehicle)) in such a way that during interaction they are as close as possible to each other, within direct visibility at a distance of no more than 20 m. The Sensor and Reader must be oriented in such a way that the maximum markers of the directional pattern on their housings are directed towards each other (Fig. 4.1);

- Fasten the Sensor and Reader with self-drilling screws with of the delivery set in accordance with Fig. 2.6, 3.3, 3.4. Another method is also allowed, ensuring reliable fastening and maintaining the orientation of the devices during operation.;
- It is advisable to perform fastenings with the possibility of subsequent dismantling in in case of unsuccessful device placement;
- When laying the cable, it is necessary to ensure that it is protected from possible external mechanical influences from parts and components of equipment and random objects;
- Cables can be attached to existing strong structural elements and communications (for example, hydraulic system pipelines). Where possible, lay cables together with standard electrical or hydraulic wiring through existing cable channels;
- When laying and fixing the cable, exclude mechanical load on the cable, bends and twists with a radius of less than 5 cable diameters, in a free area the bending radius must be at least 10 cable diameters;
- Do not place the Sensor and Reader near sources of strong electromagnetic radiation and heating devices!

4.4 Sensor Settings

The Sensor is configured before commissioning using a PC with the Windows 10 / Windows 11 operating system installed or using a mobile device based on Android OS version no lower than Android 8.

To configure the Sensor, the “BTI_User_Tool” program (Windows or Android version depending on the environment) is used (see “Appendix A” for the Windows version, “Appendix B” for the Android version). Preparing the Sensor for

The use consists of recording the following mandatory and optional (specified) data into it:

- Radio channel number;
- Owner (enterprise) ID;
- Sensor group identifier (installation object, for example, vehicle);
- Sensor ID (sensor number in the group);
- Password for connecting to the sensor (recommended);
- Using a journal (optional);
- Horizontal (optional).

A detailed description of the above parameters and the procedures for viewing or changing them is contained in the "Appendix A" section.

After making all necessary changes to the settings, it is strongly recommended to save the Sensor configuration (see “Appendix A. Updating the Sensor Firmware. Saving and Restoring Configuration Data”). A similar procedure is recommended before making changes to the settings of a previously configured Sensor.

4.5 Reader Settings

The use of the Reader consists in receiving from it by an external device (for example, an on-board controller or other GPS monitoring equipment) information transmitted by the Sensors. All data from the Reader can be received by an external device using the user command interface. For compatibility with equipment (on-board processors, control systems, trackers) already on the market, the Reader supports the binary LLS protocol (see "Appendix D").

For operation, the Reader must be configured in advance. The configuration is carried out using the “BTI_User_Tool” Windows version program (see “Appendix B”). Preparing the Reader for use consists of writing the following mandatory data to it:

- Owner ID;
- Sensor group identifier;
- Radio channel number;
- Number of sensors simulated

The number of simulated sensors determines the number of Sensors for which the Reader will output data to an external device. For more information about this parameter and its settings, see “Appendix B. Configuring the Reader and Viewing its Parameters” and “Appendix D. One- time Data Reading (Command 06h)”.

After making all necessary changes to the settings, it is recommended to save the Reader configuration using the “RCS_AppLoader” program (see “Appendix D”). A similar procedure is recommended before making changes to the settings of a previously configured Reader.

4.6 Connecting to an external device

If the external data collection device (GPS monitoring equipment) has built-in support for BLE technology and the ability to receive data from the required number of Sensors, and there is no need to calculate the differential angle (for the BTI model Sensor) directly before transmitting data to the external device, then the Sensor can be used without an intermediate link in the form of a Reader. Instructions for connecting the Sensor to various equipment are in the "Appendix K" section of this manual.

The Reader is connected to an external device (GPS monitoring equipment) according to the marking and assignment of the cable wires (table 3.4). The Reader is controlled by an external device via an interface cable and does not require any additional operator intervention. All data from the Reader can be received by an external device using the user command interface. For compatibility with equipment (on-board processors, control systems, trackers) already on the market, the Reader supports the binary LLS protocol (see "Appendix D").

It is important to ensure that the external device transmits data without modification (for example, averaging of received data must be disabled).

4.7 Sealing

To protect against unauthorized interference, BTL/BTI model sensors and BR21/BR41 model readers can be sealed. To do this, you must:

- push the wire through the screw hole for sealing and the eyelet for sealing on the Sensor/Reader body;
- insert the ends of the wire into the seal (when using the SILTEC seal, the ends wires must enter through the seal holes on the side opposite the marking);
- pick up the slack in the wire and close the seal.

Appendix A – Configuration program “BTI_User_Tool” (Windows version) (mandatory)

Getting started with the program

The configuration program "BTI_User_Tool" (hereinafter referred to as the "program") is intended to provide the configuration procedure for the wireless tilt angle sensor of the BTI BLE model (hereinafter referred to as the "Sensor").

To install on a personal computer (PC), simply copy the program files to the desired directory. If you are using a PC without a built-in BLE adapter, you must connect an external USB BLE adapter to the PC.

WARNING! *If used Windows 10 versions below 1703, to connect to the Sensor, it is necessary to create a pair through the standard mechanism for adding a new device in the system. If this is not done, the system allows searching for BLE devices, but blocks the connection attempt. That is, the "BTI_User_Tool" program will display the found Sensors, but will not be able to connect to the Sensor.*

After launching the program, you can select the interface language from the "Language" list (see Fig. A.1).

The “Connection” tab is used to search for Sensors and connect to the selected Sensor. The “Reader” tab is used to configure the reader. The “Device Log” tab is used to view the previously read log from the Sensor. For more details about the log and working with it, see the section “Downloading the log. Interpreting the content”

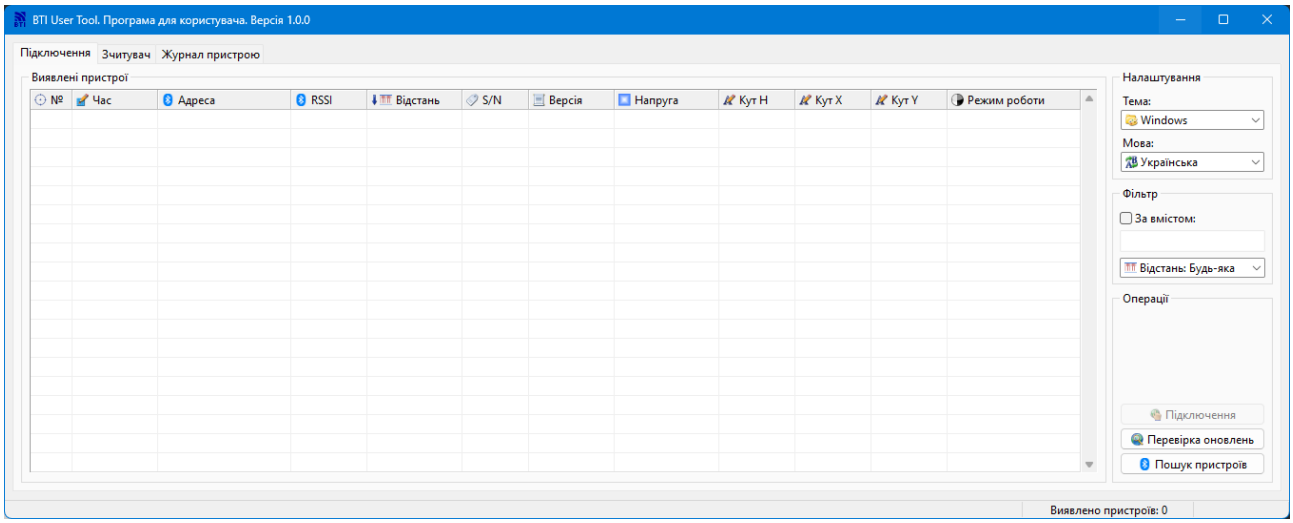


Figure A.1 – Main window of the “BTI_User_Tool” program

The "Filter" block allows you to hide from the list of detected devices Sensors with parameters that do not meet the filter criteria. To use the filter, you should check the "By content" box and enter the filtering text in the field. In this case, detected devices that contain the filter substring in their MAC address or serial number will be considered as those that meet the criteria.

For example, a device with serial number 100 and MAC address 01:02:03:04:05:06 and a device with serial number 150 and MAC address 99:88:77:66:55:04 are detected. If you enter "1" in the "Filter" field, then both devices will be displayed in the list, since the character "1" occurs in the serial number and MAC address of the first device and the MAC address of the second. If you enter "15" in the "Filter" field, then only the second device will be displayed in the list, since only it contains the substring "15" in its serial number value. If you enter "405", the first device will be displayed, since the sequence "405" is contained in the MAC address of the first device (for filtering the MAC address, a comparison is performed both with and without a colon, therefore, the possible forms of writing the filter string for filtering by MAC address are both with and without a colon, for example "05:06" or "0506" - in both cases, the first device will be displayed in the list). If you enter "50" in the filter field, both devices will be displayed in the list, since the text "50" is found in the serial number and MAC address of the first device and the MAC address of the second.

The "Distance" list allows you to filter Sensors by distance to them. It is recommended to set "Distance: Any" to ensure that the Sensor is displayed in the list.

Devices that have passed the filtering (by the "Filter" and "Distance" blocks) are added to the device list, and the list is sorted according to the selected parameter and sorting direction. To select a sorting parameter

just click on the column header of the list with the parameter name. To select the sorting direction, click on the selected column header of the list – each subsequent click changes the sorting direction, as indicated by the direction of the sorting arrow. As an example, see Fig. A.1 – sorting by RSSI parameter is selected, the sorting direction – as the signal strength decreases.

Sensor Search and Connection

The normal operating mode of the Sensor is the “Beacon” mode. In this mode, the Sensor emits 2 types of packets into the air: an information packet (containing data on battery voltage, etc.) and a sensor packet (containing data on the configuration of the Sensor itself, as well as the results of measuring its orientation in space).

To increase battery life, data transmission is implemented in two modes – “Active mode” and “Sleep mode”.

In active mode, the sensor emits every 300ms in this case, for every 6 data packets, a sensor packet is emitted 5 times, and an information packet is emitted 1 time.

In sleep mode, the Sensor emits an information packet every 2.5 seconds; there is no sensor packet on the air.

The transition from active mode to sleep mode occurs automatically when the Sensor is in a stationary position (where the measured angles do not change by more than 0.1°) for more than a user-specified time period. The transition from sleep mode to active mode occurs automatically when the measured angles change by more than 0.1°.

Therefore, to find the Sensor in the program faster and establish a connection to it, it is recommended to manually change the position of the Sensor in space, thereby bringing it out of sleep mode.

To view the current data that is being broadcast, simply activate the search for BLE devices and in the list of detected devices, find the desired Sensor and view its value (see Fig. A.2).

To change and/or view the general settings of the Sensor, you must search for BLE devices and set BLE disconnection to the Sensor.

The "Connection" tab is used to search for and connect to the Sensor (see Fig. A.1). Reading the log is also performed after connecting to the sensor.

To search for Sensors – click the “Search for devices” button. After that, the program switches to continuous air scanning mode. As new Sensors are detected (or new information is received from a previously detected and added Sensor to the list), the program updates the list of detected devices according to the rules described above.

Thus, the list of detected devices constantly displays the most up-to-date information from all emitting Sensors within the signal reception radius.

The following information is displayed for each Sensor in the list:

1. “No.” – ordinal number in the list;

2. “Time” – the time of Sensor detection (or the time of receiving the next packet from sensor): indicates the relevance of the information package from the Sensor;

3. "Address" - MAC address of the Sensor;

4. “RSSI” – signal strength from the Sensor, measured by the receiver PC (built-in BLE controller or external USB BLE controller).

5. “Distance” – the calculated value of the distance to the Sensor. For The calculation uses the calibrated value of ibCblRssi from the received Sensor information packet (see "Appendix G"). Accordingly, the calculated distance value may differ significantly from the actual distance to the current BLE controller used to detect this Sensor, and is only a relative estimate of the distance to the Sensor. To obtain accurate distance values, it is necessary to calibrate *ibCblRssi* directly for use with BLE receiver sensor. The manufacturer performs calibration *ibCblRssi* for the receiver used in typical Readers.

6. “S/N” – Sensor serial number (possible value “N/A” in case of receiving a sensor data packet; after receiving the information packet, the value will be updated)

7. “Version” – the version of the Sensor firmware. In case the Sensor is in service mode, or if the information packet has not yet been received, this parameter is unavailable and has the value "N/A"

8. “Voltage” – battery voltage measured by the Sensor. In case, if the Sensor is in service mode, or if the information packet has not yet been received, this parameter is unavailable and has the value "N/A"

9. “Angle X” – the angle of deviation of the X axis of the microcircuit measured by the Sensor accelerometer from the horizontal. If the Sensor is in service mode, or if the sensor packet has not yet been received, this parameter is unavailable and has the value "N/A"

10. “Y Angle” – the angle of deviation of the Y axis of the microcircuit measured by the Sensor accelerometer from the horizontal. If the Sensor is in service mode, or if the sensor packet has not yet been received, this parameter is unavailable and has the value "N/A"

11. “Z Angle” – the angle of deviation of the Z axis of the microcircuit measured by the Sensor accelerometer from the horizontal. If the Sensor is in service mode, or if the sensor packet has not yet been received, this parameter is unavailable and has the value "N/A"

12. “Operating mode” – Sensor operating mode:

12.1 Operating mode – “Beacon” mode. The main operating mode of the Sensor, in which measurements are performed and results are emitted: when operating in active mode, information and sensor packets are emitted into the air; when operating in sleep mode, only the information packet is emitted into the air.

12.2 Service mode – a special mode that the Sensor enters in the absence of the main firmware or at the user’s request to perform service functions. In this mode, control is transferred to the sensor’s bootloader code. The Sensor is waiting for connection. If there is an undamaged firmware, after a period of 1 minute, the bootloader automatically transfers control to the main firmware, thereby transferring the Sensor from service mode to operating mode. If the Sensor’s firmware is damaged or missing, the device is constantly in service mode and will not be detected by the Reader or GPS monitoring equipment that supports BLE technology. Updating the Sensor’s firmware is discussed in the “Sensor Firmware Update” section.

To connect to the Sensor, you must stop the search using the "Stop Search" button, select the Sensor from the list of detected devices, and click the "Connect" button (or double-click with the mouse) (see Fig. A.2).

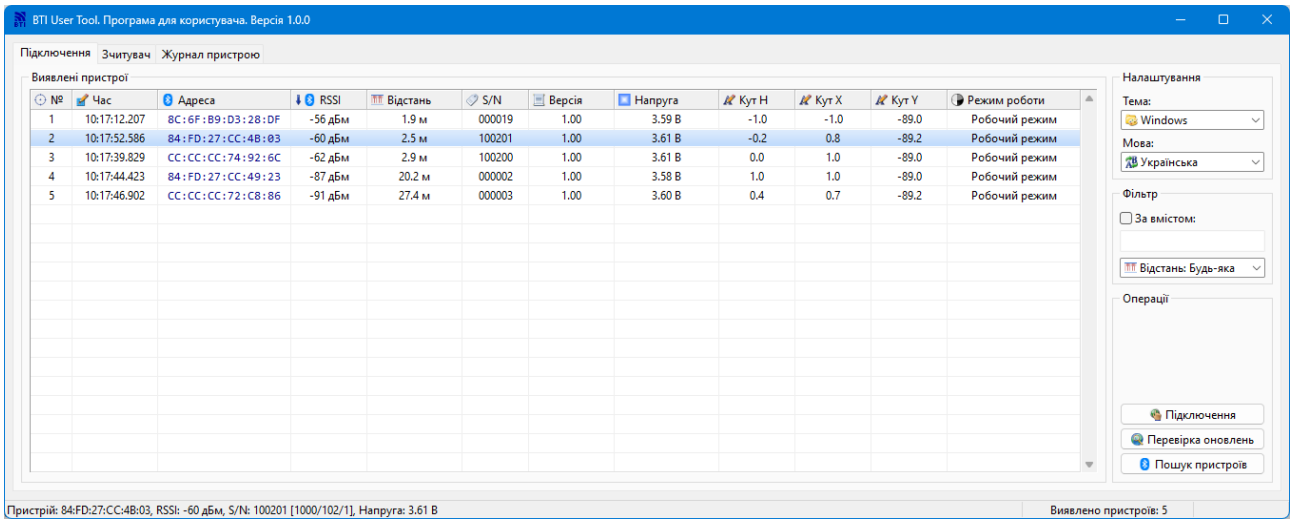


Figure A.2 – Sensor with serial number 100201 is selected.

After that, a password request window should be displayed (see Fig. A.3), if a password is not set - click the "Connect" button (leave the password field empty). The connection will be established and the device operation window will be displayed (see Fig. A.4).

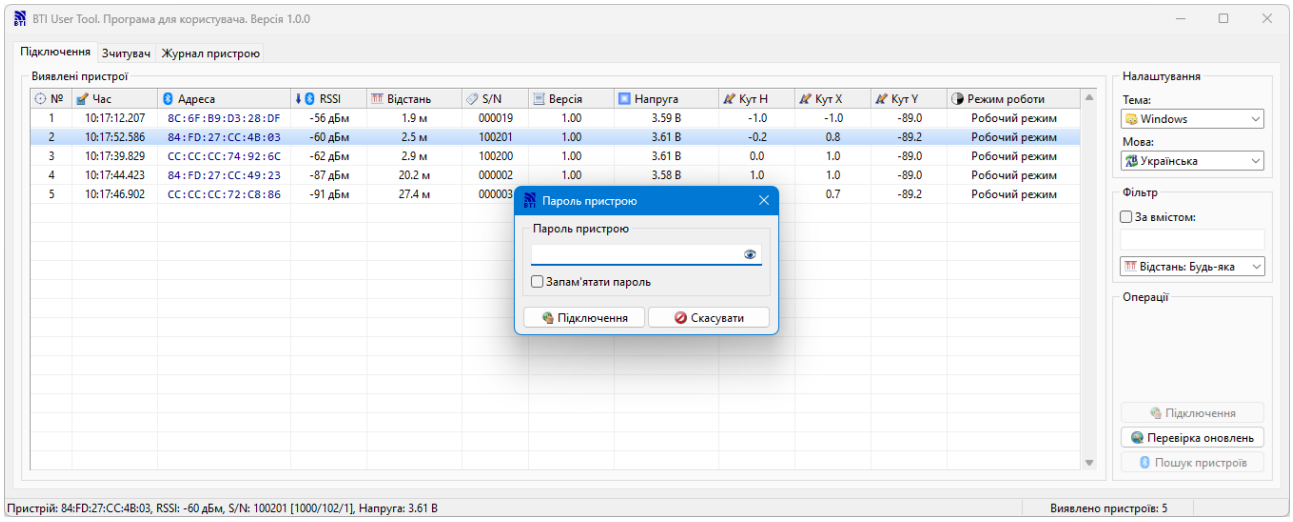


Figure A.3 – Password request to connect to the Sensor.

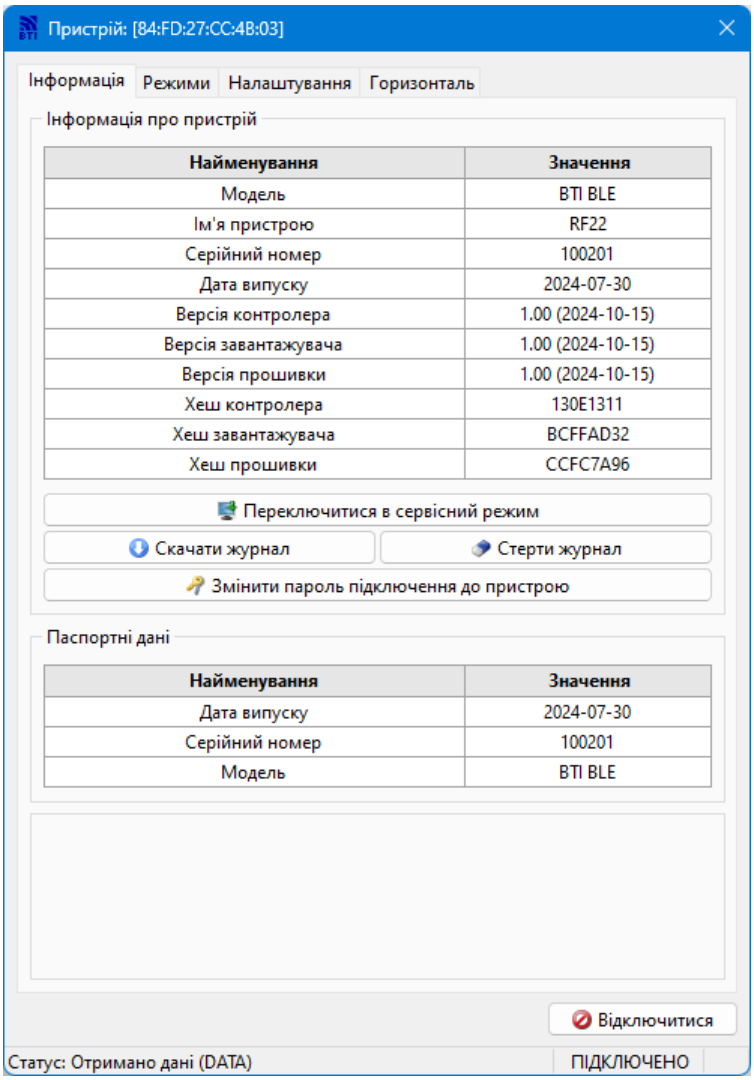


Figure A.4 – Window for working with a connected device. “Information” tab.

After successful connection to the Sensor, the window for working with the connected device will be displayed and all the Sensor parameters necessary for displaying will be read. Until the parameter has been read, its field contains the text "*waiting for value...*»

In the Sensor connection mode, the program continuously exchanges data with the Sensor – sends requests to read the necessary parameters and receives responses to requests. After each successful response to the request, a green indicator is displayed in the lower right corner of the window for working with the connected device. The display time of this indicator is 300*ms*, after which the indicator disappears.

Upon loss of connection, sudden program shutdown, or other unforeseen events, after 5 seconds of inactivity, the Sensor automatically returns to the "Beacon" operating mode and after 10 seconds, if in a stationary position, it switches to sleep emission mode.

The BLE connection mode allows you to view information about the Sensor, configure certain parameters, set the horizontal, read the log, update the Sensor firmware, and save and restore calibration and configuration information.

WARNING!In preset modeBLE connection increases the current consumption of the Sensor by 7-10 times. To save the Sensor's battery, it is not recommended to maintain the connection with it longer than is objectively necessary.

If the user has connected to the sensor and left the program unattended, after 5 minutes of inactivity the program will automatically disconnect from the Sensor.

The connected device window contains the following tabs:

1. Information tab

2. Modes tab

3. Settings tab

4. "Horizontal" tab

Information tab

The “Information” tab (see Figure A.4) contains the following data:

1) The "Device Information" group contains basic information about the device:

• "Model" is a modelBTI BLE;

• “Device Name” – displays the Sensor type: “RF22";

• “Bootloader version” – the version of the embedded bootloader code;

• “Loader Date” – the date the embedded code was compiled bootloader;

• “Bootloader hash” – a checksum of the embedded code bootloader;

• “Firmware version” – version of the embedded firmware code;

• “Firmware date” – the date of compilation of the embedded firmware code;

• “Firmware hash” – checksum of the embedded firmware code;

2) The “Passport data” group contains information set by the manufacturer:

• “Release Date” – the date of release (manufacturing) of the Sensor;

• “Serial number” – the serial number of the Sensor;

• "Model" – model of the Sensor.

It is strongly recommended to change the connection password at the Sensor setup stage. To do this, after connecting to the Sensor, click the “Change device connection password” button (see Fig. A.4) and, following the program prompts, set a new password. The range of valid password values is from 0 to 9999 9999 9999 9999. The password consists only of numeric characters from “0” to “9”. The Sensor interprets the password in text form, i.e., for example, password values such as “0” and “000000” are two different passwords. An empty field can also be entered as a new password.

The new password will be requested upon subsequent connections to the Sensor. If an incorrect password is entered, the program displays an error message (see Figure A.5).

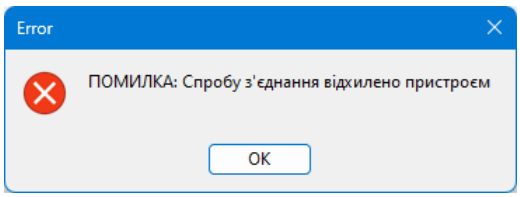


Figure A.5 – Incorrect password for connecting to the Sensor.

It is recommended to set a single password within the enterprise.

In case of password loss (or accidental user error when entering the password), after an unsuccessful attempt to connect to the Sensor, the next time the program attempts to connect, the program displays a modified password request window (see Fig. A.6). The user, as before, has the opportunity to try to enter the password again and complete the connection.

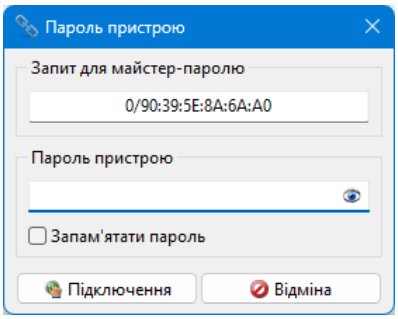


Figure A.6 – Password entry window after Sensor installation failure connection due to entering an incorrect password.

To reset the password to the factory settings, contact the service center with the information from the “Request for master password” field (see Fig. A.6). The one-time master password received from the service center should be entered into the “Device password” field in the same way as it is done in a normal situation when establishing a connection. After a successful connection to the Sensor, the one-time password is automatically deactivated and the password is reset. For the next connection to the Sensor, leave the password field empty, or immediately, without disconnecting from the Sensor, change the password using the “Change device connection password” button.

Modes tab

The “Modes” tab (see Figure A.7) contains the following data:

1) Group "Special operating mode" - contains settings special operating modes. By default, the device operates in the mode of outputting data necessary for calculating the angle of inclination. To expand the functionality of the Sensor, additional, special operating modes have been implemented:

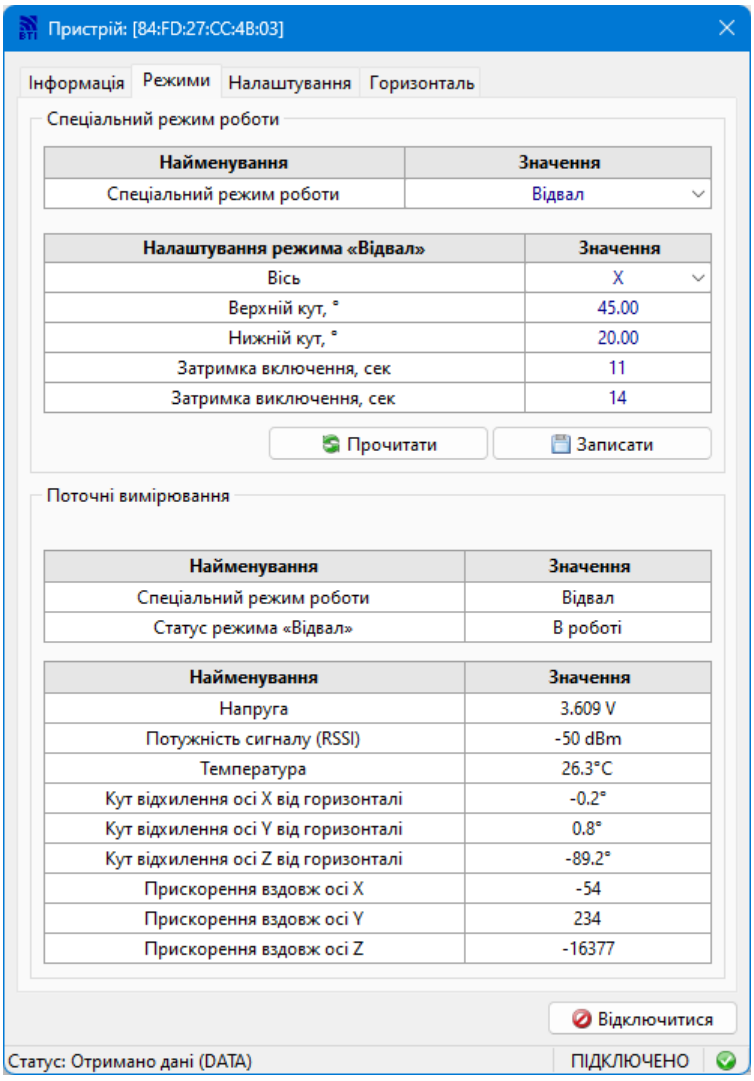


Figure A.7 – “Modes” tab.

- “Rotation” – in this mode the Sensor additionally performs continuous analysis of changes in the angles of inclination of its axes and provides information on whether the current time of rotation of the Sensor around the selected axis is recorded; depending on the situation, the Sensor provides the status "No rotation", "Rotation to the left" and "Rotation to the right";
- “Angle control” – in this mode the Sensor performs continuous monitoring the tilt angle of the selected axis; if the axis tilt angle exceeds the parameter "Upper angle limit", the status "Angle exceeded" will be displayed, if the axis tilt angle becomes less than the value of the parameter "Lower angle limit", the status "Angle not exceeded" will be displayed. The pair of parameters "Upper limit" and "Lower limit" makes it possible to implement hysteresis of status changes;
- “Bucket” – the mode can be used to control the bucket operating time excavator. In this mode, the Sensor analyzes the deviation of the angle of inclination of the selected axis: the current angle value is read, then, after the time period "On Delay" the angle difference is calculated. If the difference exceeds the value of the parameter "Delta", the sensor will be triggered, and the Sensor will start to display the status "In operation". If, after some time, the next calculated angle difference becomes less by the value "Delta", the timer "Off Delay" will be started, after which, if the angle difference, as before, is less than "Delta", the Sensor will start to display the status "Inactivity";
- “Digger” – the mode can be used to control work, for example, snowplows or bulldozers. When the blade is operating, its angle of inclination changes. If the angle of inclination becomes less than the value of the “Lower angle” parameter, the “On delay” timer starts – after the timer expires, if the angle of inclination is still less than the “Lower angle” value, the sensor starts to give the “In operation” status. After the angle of inclination becomes greater than the “Lower angle” value, the “Off delay” timer starts, after which, if the angle of inclination is still greater than the “Lower angle” value, the activation is canceled and the sensor starts to give the “*Inactivity” status. If the angle of the selected axis of the sensor exceeds the value of the “Upper angle” parameter, the activation is immediately canceled (without using the off delay), and the sensor gives the “Inactivity” status.

2) The "Current Measurements" group contains a constantly updated information regarding the current values of angles, accelerations, type of special mode, corresponding status, etc., as well as the value of the signal strength from the Sensor, which is measured by the receiver. Allows convenient settings

special mode parameters and immediately monitor the results of the settings:

• “Special operating mode” – displays the activated special operating mode;

• "Mode status..." – displays the status of the activated operating mode. For example, if the "Rotation" mode is activated, the status displays information about whether rotation was recorded, and in which direction;

• “Voltage” – battery voltage measured by the Sensor. In mode connection, consumption increases by 7-10 times and, accordingly, there is a slight decrease in the battery voltage compared to the values in the “Beacon” mode (see Fig. A.2, “Voltage” column);

• “Signal strength (RSSI)” – the signal strength from the Sensor, measured by the receiver (BLE controller of the PC). In the connection mode, the packet exchange rate between the Sensor and the receiver increases (the exchange period changes from 1200 ms to 150 ms), accordingly, the RSSI value in this field also increases compared to the “Beacon” mode;

• “Temperature” – the temperature of the microcontroller measured by the Sensor;

• "Axis deviation angle"X from horizontal" – the angle of deviation of the X axis of the accelerometer chip from the horizontal measured by the Sensor;

• "Axis deviation angle"Y from horizontal" – the angle of deviation of the Y axis of the accelerometer chip from the horizontal measured by the Sensor;

• "Axis deviation angle"Z from horizontal" – the angle of deviation of the Z axis of the accelerometer chip from the horizontal measured by the Sensor;

• "Acceleration along the axis"X" – the value of the accelerometer acceleration in the direction of its X axis;

• "Acceleration along the axis"Y" – the value of the accelerometer acceleration in the direction of its Y axis;

• "Acceleration along the axis"Z" – the value of the accelerometer acceleration in the direction of its Z axis;

Settings tab

The “Settings” tab (see Figure A.8) contains the following data:

1) Group "Device Settings" - contains basic settings device and information about the device's immutable parameters:

• “Owner ID” – Owner (enterprise) ID;

• “Sensor group ID” – Sensor group ID (installation object, for example, vehicle);

• “Sensor ID” – Sensor ID in the specified group (a group can be, for example, a vehicle with several Sensors);

• "Radio Channel"Bluetooth” – Bluetooth advertising channel number;

• “Radio channel activity in active mode” – the frequency with which Sensor data packets are emitted in the "Beacon" mode in active mode. The manufacturer sets the value to 300*ms*The ability to change this parameter is blocked for the user;

• “Radio channel activity in sleep mode” – the frequency with which Sensor data packets are emitted in the "Beacon" mode in sleep mode. The manufacturer sets the value to 1200*ms*The ability to change this parameter is blocked for the user;

• “Sleep mode transition” – the period of time during which, if the measured angles have not changed by more than 0.1°, the sensor goes into sleep mode of data emission.

WARNING: this parameter is ignored immediately after the firmware is launched (initial device power-on, firmware reboot due to transitions to service mode and back, emergency reboot due to communication failure in connection mode); in these cases, the Sensor goes into data emission sleep mode 10 seconds after the firmware starts (of course, if it is in a stationary position).

• “Filtration depth” – configuring the built-in filter; the higher the value, the more stable the Sensor readings, but the slower the Sensor responds to changes in its position in space;

• “Logging frequency” – the frequency of recording current measured temperature values and angles of deviation of the X, Y, Z axes in the log;

• “Log capacity” – indicates the period of time during which It is possible to record the position of the Sensor in space in the measurement log without overwriting previous values.

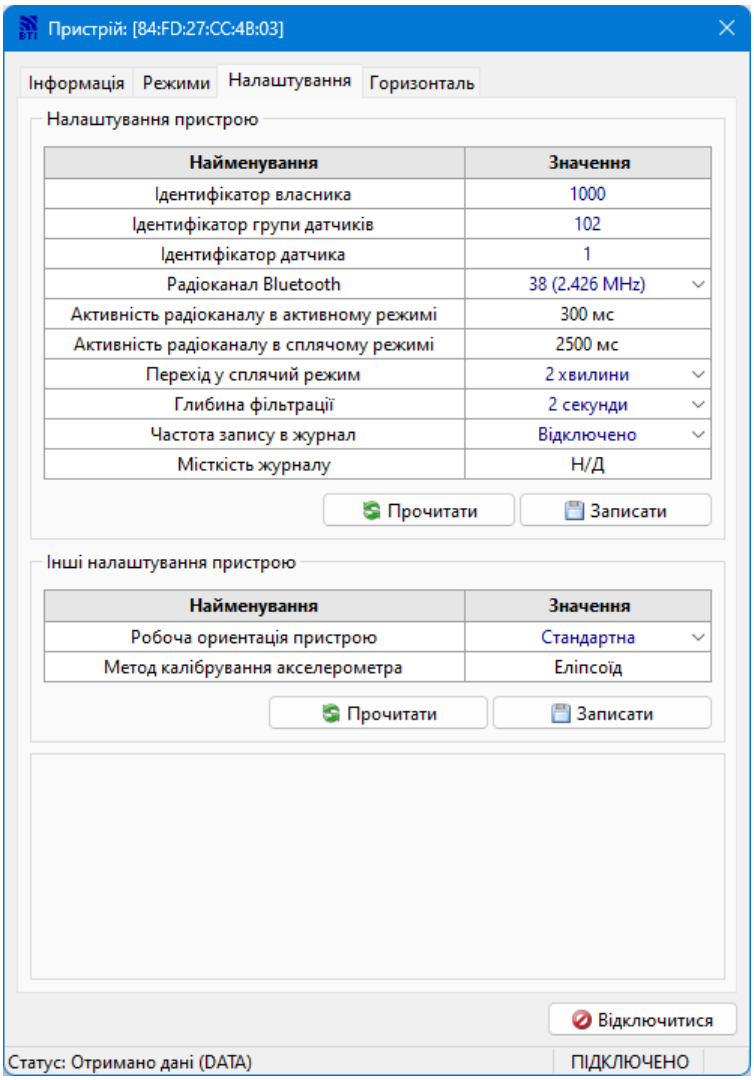


Figure A.8 – Window for working with a connected device. Tab "Settings".

2) Group “Other device settings” – contains operating system settings sensor position and display of accelerometer calibration method:

- “Device working orientation” – orientation of the Sensor body axis, along which directly calculates the tilt angle; if it is physically impossible to install the Sensor in the default direction (due to physical limitations of the installation location), this setting allows the Sensor body to be turned 90° and the tilt angle to be measured along another axis;
- “Accelerometer calibration method” – set by the company by the manufacturer during the device calibration phase

Device settings

In this group it is possible to set the necessary parameters of the Sensor, for this you should change the required parameter and click the "Save" button. For

To read the current Sensor parameters, click the "Read" button. A more detailed value of the parameters of this group is given below.

The “Owner ID” field is a Sensor parameter that specifies the owner ID of the enterprise. It is set to the same for all Readers and Sensors of the enterprise. It is used to ensure that Readers work with Sensors from only one owner. Sensors with an owner ID value that differs from the similar Reader parameter will be ignored by the Reader. The permissible value is in the range of 0...65535. The default value is 1. The owner ID can be selected randomly from the range of permissible values.

The "Sensor Group Identifier" field is used to divide Sensors into groups according to their intended use within one enterprise (example of use is vehicle identifier). In total, Sensors can be divided into 65536 groups. The Reader will accept Sensor data only if the Sensor is in the group specified in the Reader. The default value is 1.

The "Sensor ID" field is a Sensor parameter used to identify the Sensor in a group (example of use is the Sensor number on a specific vehicle). The permissible value is in the range from 0 to 20.

To measure the differential angle of inclination, it is necessary to designate one of the Sensors as the base, for which the “Sensor Group ID” for it must be set to 0 (“Base Sensor”). For the remaining Sensors (from 1 to 19), the value of the “Sensor Group ID” parameter must be from 1 to 19 (“Moving Sensor”).

The reader considers the received data packet in which the value of "Sensor ID" is 0 as a data packet from the Base Sensor. All other data packets with a value of "Sensor ID" other than 0 are considered as data from Mobile Sensors (i.e., for which it is necessary to calculate the differential angle of inclination relative to the Base Sensor).

That is, in general, to determine the tilt angle of an arbitrary Mobile Sensor N, the Reader needs 2 data packets - from the Base Sensor and from Mobile Sensor N.

WARNING! *It is strictly not recommended in the "Identifier" fields "Owner" and "Sensor Group Identifier" (for both Sensors and Readers) should be left at their default values, and the same values should be used for different companies and vehicles. Each company (or group of companies with the same owner) should have its own identifier, different from the default value. Each object,*

defined as the "Sensor Group Identifier" within the enterprise must have a unique identifier (for example, a state number). Failure to comply with this requirement may result in "mixing" of data from Sensors that have the same identifiers and, as a result, incorrect information being received.

The “Bluetooth Radio Channel” list is used to select the radio channel on which the Sensor emits data packets in “Beacon” mode. You can choose from three radio channels: 37th (2.402 GHz), 38th (2.426 GHz), or 39th (2.480 GHz). Changing the radio channel may be necessary in case of electromagnetic interference on the current radio channel. The 38th channel is selected by default.

Other device settings

In case it is not possible to install the Base Sensor and the Mobile Differential Angle Sensors in the default position (for example, due to physical limitations of the installation location), setting the Sensor's working orientation allows you to rotate the differential angle measurement axis by 90° (thereby, the Sensor body will also be rotated by 90°, which makes it possible to "squeeze" the body into the given installation location).

To set the working orientation of the Sensor, after connecting to the Sensor, go to the "Settings" tab (see Fig. A.8) and select the required value from the list. Then, click the "Save" button.

Setting the Sensor Horizontal

The sensor has the ability to set a zero level ("Horizontal"), which will consider the user-defined position of the sensor body as perfectly horizontal.

To set and/or view the current horizontal settings of the Sensor, after connecting to the Sensor, go to the “Horizontal” tab (see Fig. A.9).

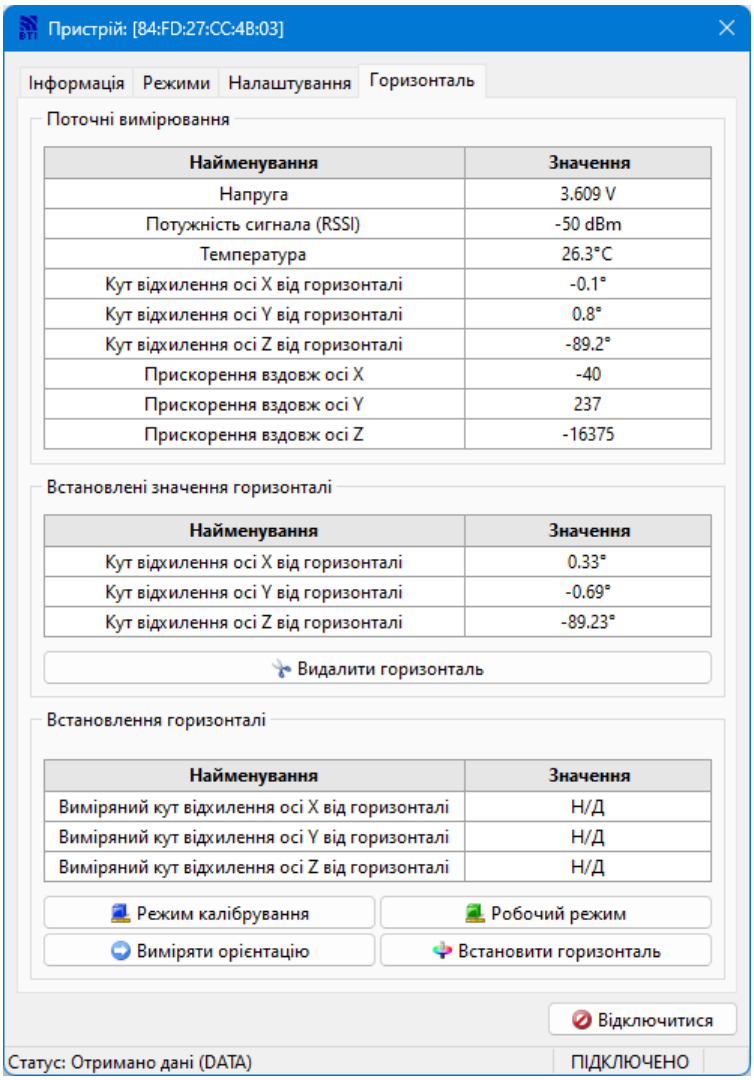


Figure A.9 – "Horizontal" tab

The "Current measurements" group displays the current values of the Sensor's position in space, taking into account the calibration parameters. The "Set horizontal values" group displays the horizontal calibration values, i.e. the measured values of the Sensor's position in space, which are taken into account as the ideal horizontal position.

To set the horizontal, you should install the Sensor on a plane that the user wants to consider a horizontal surface. Click on the "Calibration Mode" button. The Sensor will switch to the mode of issuing uncalibrated angles of deviation of the axes. Make sure that the surface on which the Sensor is located, and the Sensor itself, are in a stationary, motionless position. Click on the "Measure Orientation" button. The Sensor's position in space will be measured. To set the measured values as the horizontal value, click on the "Set Horizontal" button. The measured values will be written to the Sensor's non-volatile memory, and the Sensor will automatically return to the mode of issuing calibrated angles of deviation. That is, the angles of deviation in the "Current Measurements" group should approach the ideal values of 0°, 0° and -90° (respectively for the X, Y and Z axes).

The same surface can be used to set the horizontal of all Sensors – that is, for both the Base Sensor and the Mobile Sensors.

If it is necessary to consider the initial positions of the Mobile Sensors as such, at which the differential angle with the Base Sensor is equal to 0° (or, if another position is currently impossible due to the structural features of the measured surfaces and places available for the placement of the Sensors), it is convenient to set the horizontal of each sensor for the position in which it is located - thus, the initial differential angle between the Base Sensor and the Mobile Sensors will be set to 0°.

Reading a magazine. Viewing and interpreting the content.

Throughout the device's life cycle, the sensor's firmware continuously logs events. The sensor distinguishes between the following events:

- “Configuration” – an event that is added to the log with each change current Sensor settings, such as log recording frequency and radio channel activity;
- «"BLE Connection" – an event added to the log upon successful connection to the Sensor using the service software;
- «"BLE Disconnection" – an event that is added to the log after the connection session to the Sensor is completed;
- “Firmware restart” – an event that is added to the log before performing a firmware restart. Such an event is possible when the user puts the Sensor into service mode, or in the event of an accidental loss of communication with the service software during an established connection);
- “Device restart” – an event that is added to the log when unexpected device restart (for example, when restoring the system after a power outage);
- “Log erased” – an event that is added to the log after the user clicked the "Clear log" button and all log entries were successfully deleted;
- “Sensor” – this event is automatically generated by the built-in Sensor software after a specified period of time (set on the "Settings" tab in the "Logging frequency" field (see Fig. A.8). At the same time, the current values of the inclination angle measurements are added to the log.
- "Sensors" – a sequence of "Sensor" events combined into a single event "Sensors"

The log is kept in a "cyclical" manner, namely: when the memory allocated for storing log events is completely full, the oldest block of events is deleted, and the most "fresh" block of events is written in its place. Events in the log are combined into blocks - the smallest inseparable sequence of events stored in the non-volatile memory of the device. For the BTI Sensor, the block size is 2048 bytes. The maximum number of events of the "Sensor" type that can fit in one block is 290 (i.e. 290 records of measurements of the angles of deviation of the X, Y, Z axes from the horizontal). This determines the time interval (with the "Log entry frequency" settings set) that is inseparable when reading the log, as well as the total capacity of the log.

For example, with a log recording frequency of 120 seconds (i.e., current measurements of the angles of deviation of the X, Y, Z axes from the horizontal are stored every 120 seconds), it is possible to store up to 9 days and 16 hours of information about such changes with a discreteness of 2 minutes.

WARNING!"Sensor" events are recorded in the log only during the stay device in active data emission mode.

To read the log from the Sensor memory, you need to establish a connection to the Sensor, then, on the "Information" tab, click the "Download log" button. The program will display a dialog box for selecting the time period for which you want to receive the log (see Fig. A.10). The time period is always counted from the current moment back into the past. When choosing a range, you should take into account the fact that the longer the time period specified by the user, the greater the amount of data, and, accordingly, the longer the time period required to transfer information from the Sensor to the PC.

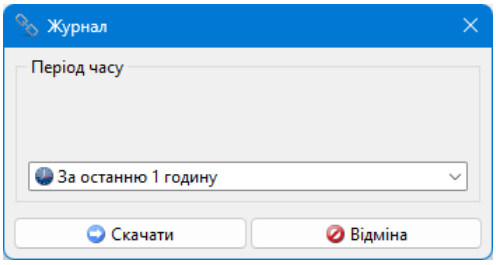


Figure A.10 – Time range selection dialog box

After clicking the “Download” button (see Fig. A.10), the data transfer progress will be displayed (see Fig. A.11)

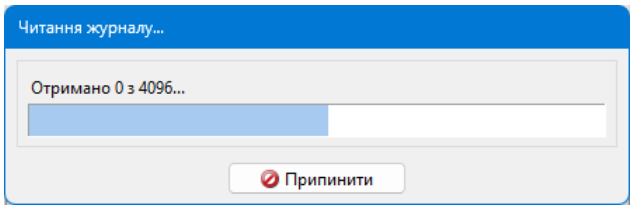


Figure A.11 – Progress of transferring log data from Sensor to PC

Upon completion, a message will be displayed stating that the log data download process was successful (see Figure A.12)

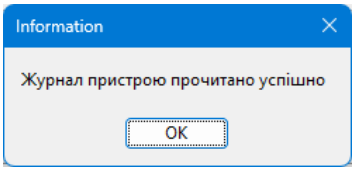


Figure A.12 – Log data download success message

The log data file is automatically saved in the “DeviceLog” folder, which is located in the program folder. The log file is given a name of the format: “snNNNNNN_RRRRMMDD_YYYY.rf22lg”, where NNNNNN is the serial number of the current Sensor, padded with zeros up to 6 characters, YYYYMMDD_YYYY is the current local time (year-month-day hours-minutes-seconds).

To view the log file, you must disconnect from the Sensor, close the window for working with the connected device. In the main program window, go to the “Device Log” tab. The program will automatically create a request to open the newly downloaded log (see Fig. A.13).

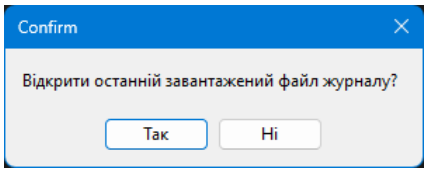


Figure A.13 – Request to open a newly downloaded journal

If desired, you can answer yes, in which case the newly downloaded log will be opened. Or refuse and manually select the desired file by clicking the "Select log" button.

After opening the log, its contents will be displayed. Figure A.14 shows an example of a log downloaded from a Sensor for the “Entire log” time period. By default, the program displays only “Sensors” events. All other events are not displayed.

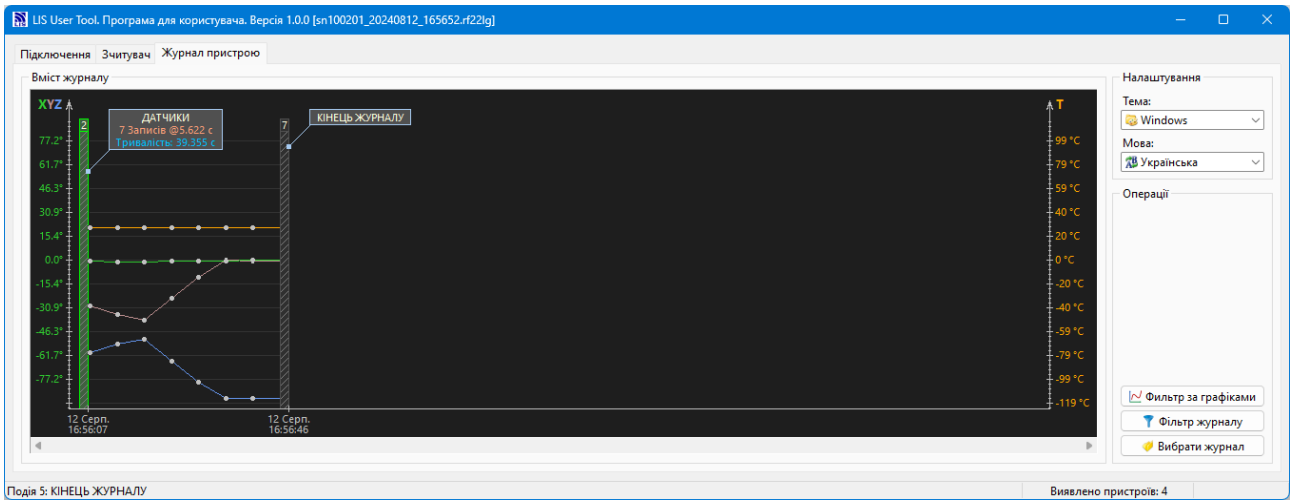


Figure A.14 – Example of log content

The axis on the left displays three graphs at once - for the angles of deviation of the X, Y, and Z axes. The name of the axis itself contains three multi-colored letters "XYZ", where the color of each letter matches the color of the corresponding graph curve.

To select the events to display, click the "Log Filter" button and in the dialog box, select the events to display (see Fig. A.15).

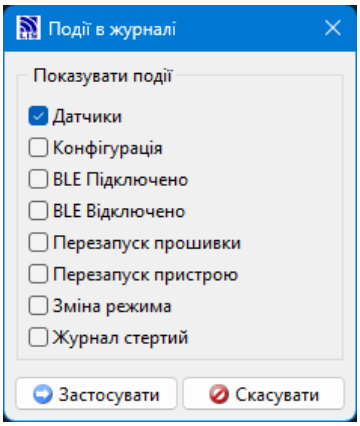


Figure A.15 – Dialog box for selecting events to display

"Sensor" events that follow each other are grouped into a continuous sequence and displayed as a single "Sensors" event with the corresponding number of discrete temperature and angle values. When displayed on a graph, such a sequence will be broken only by other events (for example, "Configuration" and others).

All "adjacent" events "Sensors" when displayed are conditionally combined into a single event "Sensors". That is, for example: if the log sequentially records event #1 "Sensors" with 100 records, event #2 "Configuration" and event #3 "Sensors" with 1000 records, then if the log filter is set, in which "Configuration" events are not displayed, event #2 will be perceived

program as non-existent, events #1 and #3 will become "adjacent" and will be combined into a single event "Sensors" with 1000+100=1100 records.

Figure A.16 shows a case where all possible events were selected as the event filter for display. After displaying the log, you can see that on August 12 at 16:55:40 the log was erased, then at 16:56:01 the connection was broken, and the Sensor returned to the normal “Beacon” operating mode. Accordingly, the “Configuration” event was created and after 6 seconds (at 16:56:07) the first “Sensor” record was added to the “Sensors” event. For 39 seconds (from 16:56:07 to 16:56:46) the Sensor was in operating mode and added another record with current measurements to the log at a given frequency (6 seconds). As you can see, 7 records were added during this time period. After that, at 16:56:46 the connection to the Sensor was made (event “BLE Connected”).

To view the entire time period, you can use the horizontal scroll bar, or by pressing the right mouse button, move the display left/right.

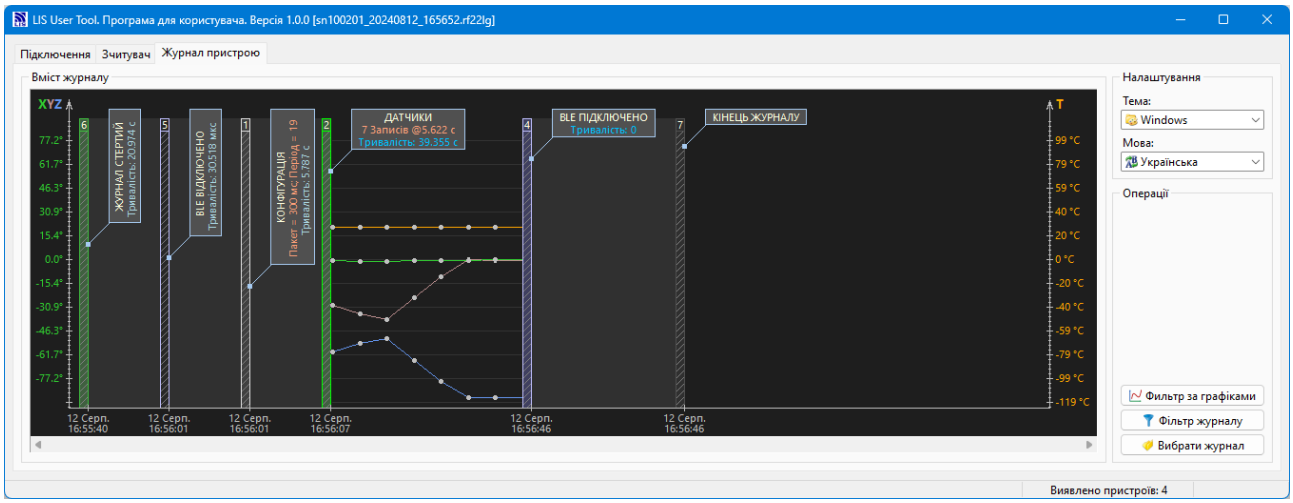


Figure A.16 – Displaying all log events.

You can use the mouse wheel to zoom in on the current event display - to do this, place the mouse pointer inside the event to zoom in, and rotate the mouse wheel to increase (decrease) the zoom.

When horizontally scaling the "Sensors" event, the graph displaying the measurements of the angles of deviation of the axes from the horizontal is scaled in the time dimension. To scale the temperature graph or the graph of the angles of deviation of the axes from the horizontal in the vertical direction (measurement of values), move the mouse pointer to the appropriate scale (XYZ or temperature) and rotate the mouse wheel to perform vertical scaling of the graph.

While horizontal scaling applies only to the time interval within the selected event, vertical scaling applies to all Sensors events without exception.

To vertically scale the temperature graph without moving the mouse pointer to the temperature scale, press the "SHIFT" button on the keyboard and rotate the mouse wheel. To vertically scale the graph of the angles of deviation of the axes from the horizontal without moving the mouse pointer to the fuel level scale, press the "CTRL" button on the keyboard and rotate the mouse wheel.

When a sufficiently large magnification of the graph is achieved over time, drawing small dots on the graph is added, thereby providing the opportunity to visually distinguish between two adjacent discrete measurements.

When you move the mouse pointer inside the "Sensors" event graph, the cursor is displayed as a vertical line that corresponds to the measurement closest to the mouse pointer. On the temperature and axis deviation angles graphs, the current measurement is highlighted with a bold line, and at the bottom of the graph area, directly for this measurement, you can see the digital values of temperature, axis deviation angles, and time.

To move the temperature graph or the angles of deviation of the axes from the horizontal in the vertical direction, you need to move the mouse pointer to the area of the corresponding scale (on the left - the scale of the angles of deviation of the axes from the horizontal, on the right - the scale of temperature values) and press the left mouse button to move the graph. It is also possible not to move the mouse pointer to the corresponding scale of the graph, but only to point the mouse pointer to the part of the graph line that you want to move, and press the left mouse button to move the graph vertically.

Firmware update provision.
Saving and restoring Sensor configuration data. software Sensor

To update the firmware of the BTI BLE wireless tilt angle sensor, as well as save and restore configuration data from a file, you must put the Sensor into service mode.

To do this, click the "Switch to service mode" button. The Sensor will be put into service mode by disconnecting the current connection, transferring control to the bootloader, and connecting to the activated Sensor bootloader. After successfully putting the device into service mode, the window for working with the connected sensor will look like the one shown in Figure A.17.

Click the “Select data file” button. In the displayed dialog box (see Fig. A.18), specify the firmware file to download and click the “Open” button.

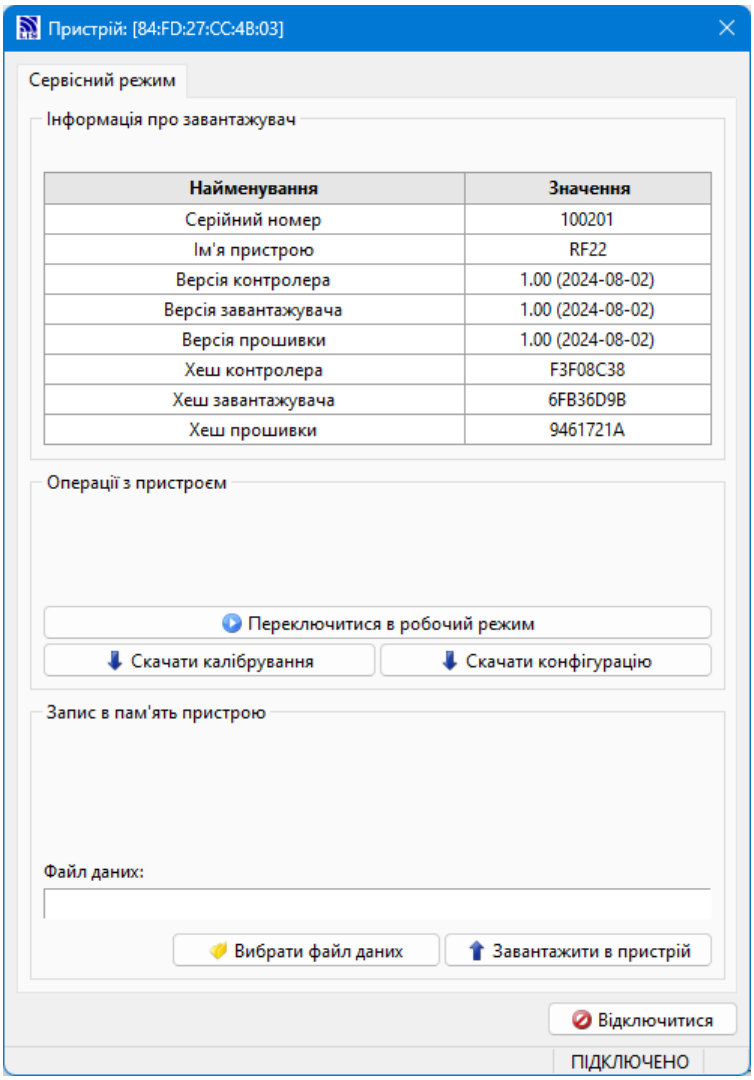


Figure A.17 – Window for working with the sensor in service mode

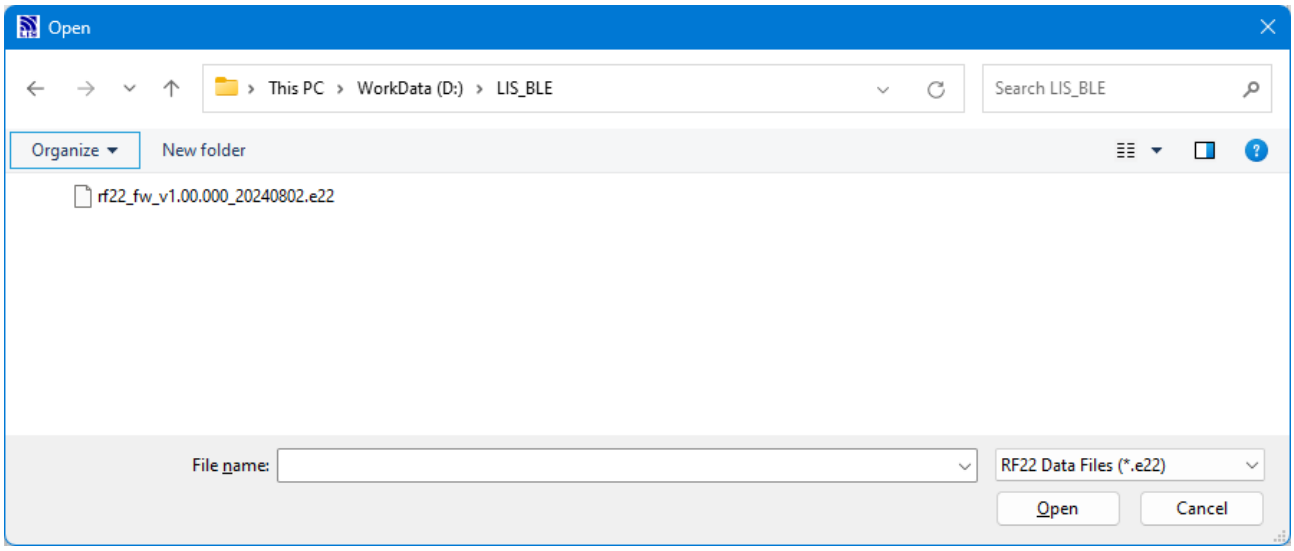


Figure A.18 – Selecting a firmware file

After selecting the firmware file, click the “Download to device” button. The file download process will be accompanied by a progress indicator (see Fig. A.19).

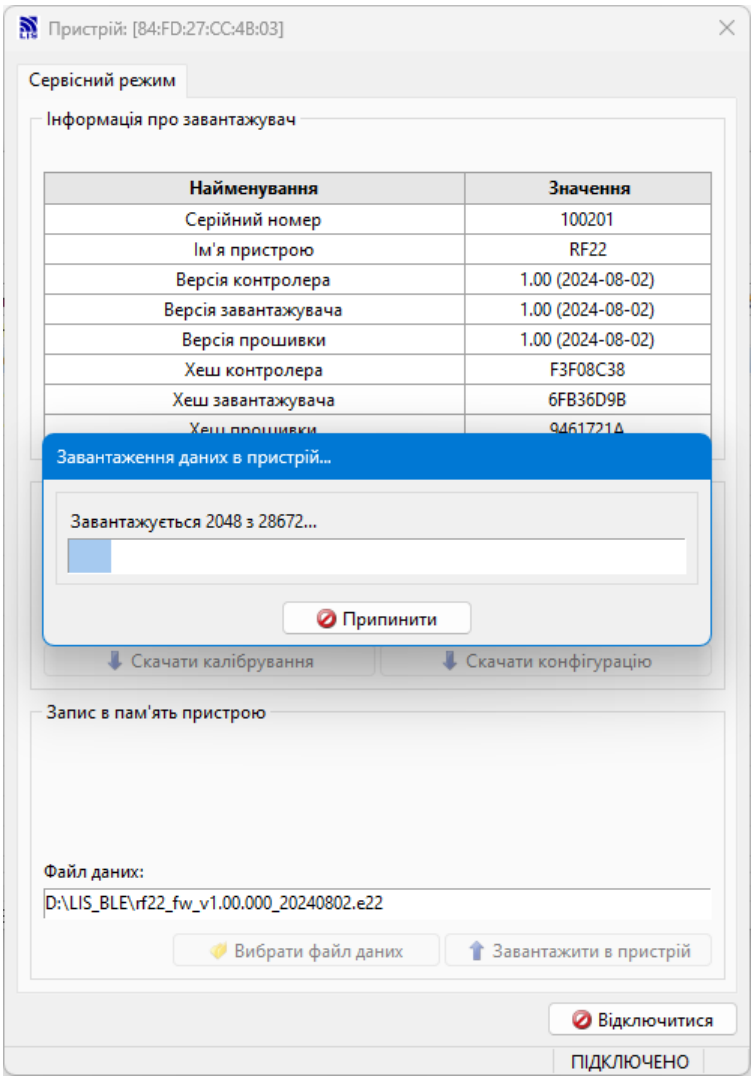


Figure A.19 – Process of uploading a file to the device

After successfully uploading a file to the Sensor, a status dialog box will be displayed, stating "Data block uploaded to device successfully", otherwise a message will be displayed about a file upload error - in this case, you must repeat the file upload operation.

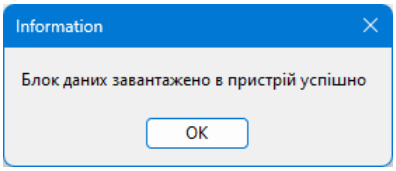


Figure A.20 – Success message

After successfully downloading the firmware file, the “Firmware Version” field (see Figure A.17) will display information about the new firmware.

To save the Sensor configuration to a file, click the "Download configuration" button, after which the Sensor configuration will be read and a dialog box for saving the configuration file will be displayed.

(see Fig. A.21). By default, the program offers to save a file with a name like “rf22_snX_var_cfg.e22”, where X is the Sensor serial number.

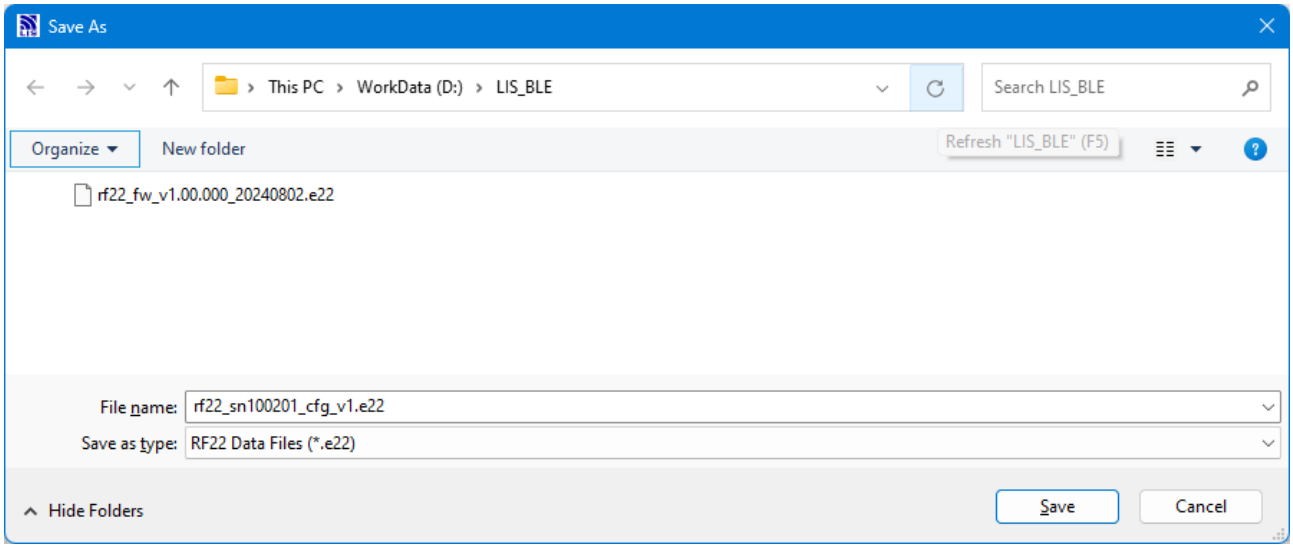


Figure A.21 – Configuration File Save Dialog Box

Restoration configuration data is being done similarly loading the firmware, with the difference that instead of the firmware file, you need to select a configuration file.

After everything necessary in the service mode has been completed, you should press the “Switch to operating mode” button to switch the Sensor to normal operating mode (“Beacon” operating mode). Similarly to switching from normal operating mode to service mode, the device will be switched to normal operating mode and the connected device operation window will return to the view shown in Figure A.4.

After you finish working with the Sensor, click the "Disconnect" button.

If the Sensor is in service mode and the user presses the “Disconnect” button (see Fig. A.17), the Sensor goes into connection standby mode, remaining in service mode. After 1 minute, it will automatically return to normal operation mode.

If the user has not completed the firmware update (the update was interrupted, an error occurred during the process, or the process was not completed) and clicks the "Disconnect" button, the Sensor will go into connection standby mode, remaining in service mode. With damaged firmware, the Sensor will remain in service mode until the user reconnects to the Sensor and successfully completes the firmware update process.

When switching from service to normal operation mode, if the Sensor is in a stationary position, i.e., does not move, after 10 seconds

The device enters sleep mode regardless of the set sleep mode time.

Appendix B – Configuration program “BTI_User_Tool” (Android version)

(mandatory)

This appendix will discuss the functional features of the Android version of the program compared to the Windows version. A full description and explanation of the purpose of the Sensor settings is provided in the Windows version of the program (see Appendix A).

Getting started with the program

To install on a mobile device, you need to copy the "apk" file of the program to the device's memory (for example, to the Download folder) and use the standard file manager to install the "apk" program.

After installing the program, a program with the name BTI BLEu and an icon as in Fig. B.1 will appear in the list of installed programs.

Figure B.1 – Program icon

After launching the program, the main program screen will be displayed (see Fig. B.2) and the operating system will also display requests for the user to grant specialized Bluetooth permissions (see Fig. B.3).

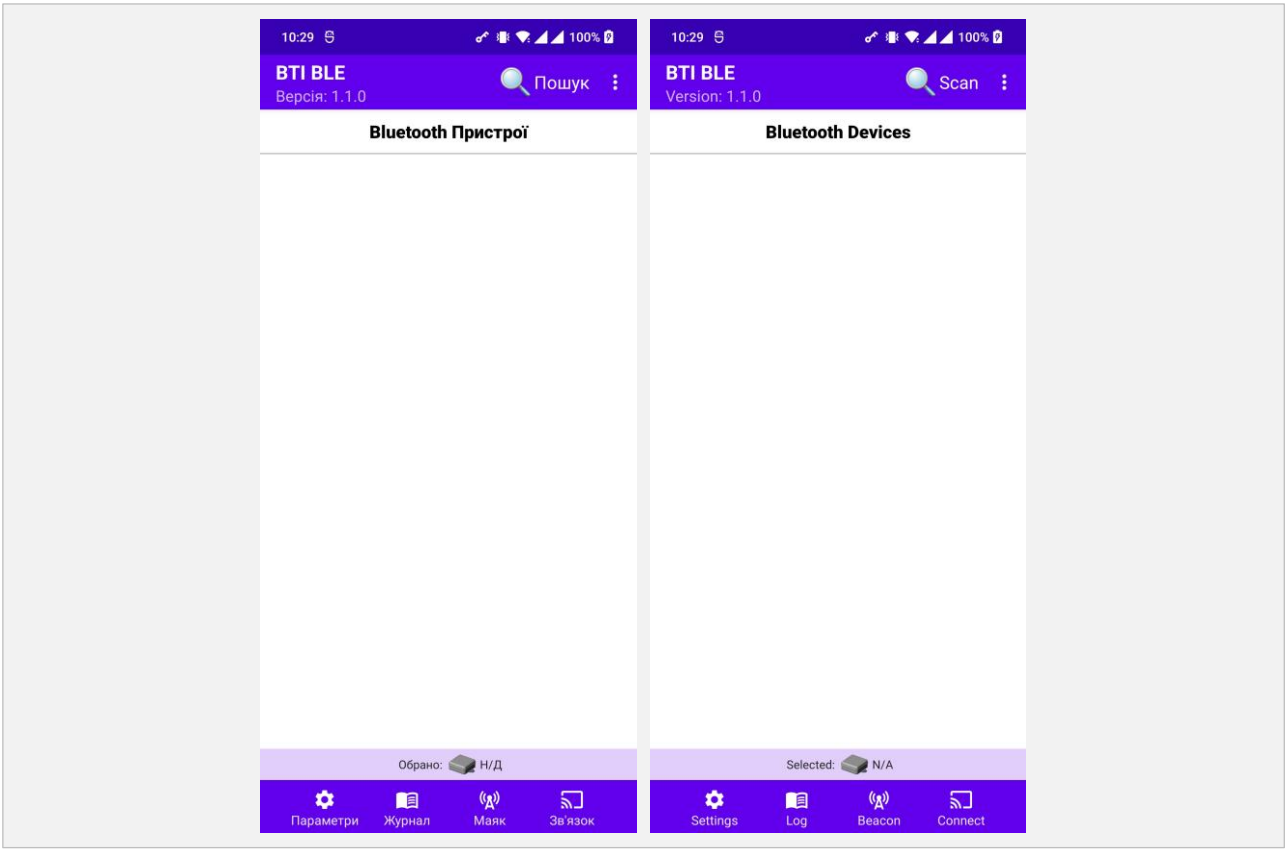


Figure B.2 – Main screen of the program in Ukrainian (left) and English (right) localizations

According to the official documentation of the Android operating system, the request for permission to access the precise location of the device (see Fig. B.3, left) was introduced by Google as necessary, since scanning for Bluetooth devices can potentially be used to collect information about the user's location. Therefore, in Android 11 and higher, any application that intends to use scanning to search for Bluetooth devices must explicitly request the user to grant such permission. The "BTI_User_Tool" application does not collect information about the user's location, and issues such a request only out of necessity, in order to obtain permission from the operating system to search for BLE devices (BTI BLE Sensors).

Another, combined request for permission to “find nearby devices, connect to them, and determine their relative location” (see Figure B.3, right) must be provided in order for the operating system to allow the “BTI_User_Tool” program to perform BLE connections to Sensors.

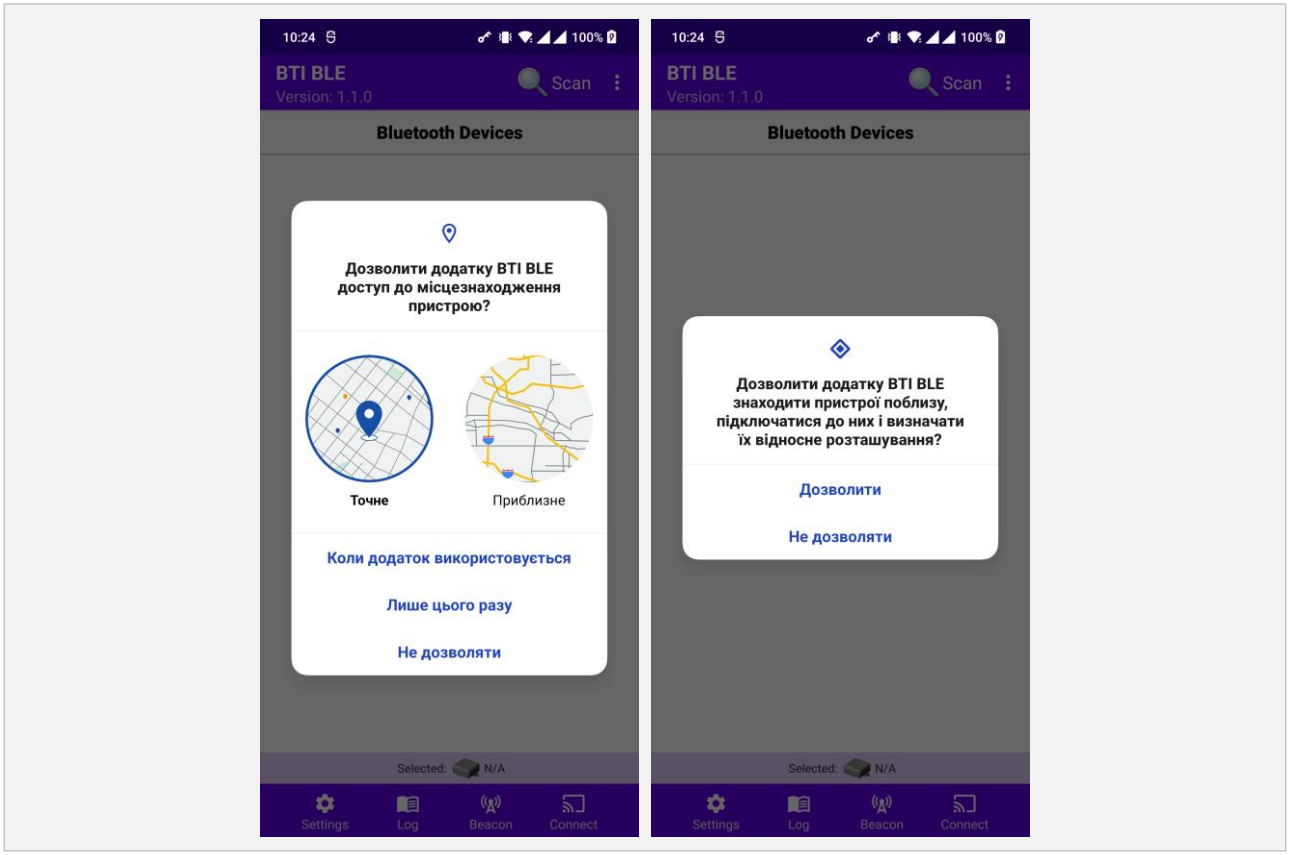


Figure B.3 – Operating system request for permissions (location – left, device scan – right)

Before launching the program for the first time, you must use the built-in file manager (or any other installed on the mobile device), at the user's discretion, to create a folder in a predetermined location that will be used by the program as the main one. This folder will be used by the program to save files that will be downloaded from the Sensor (for example, configuration files, calibration, log), and vice versa, read files that will be used by the program (for example, firmware update files, configuration or calibration files for uploading to the Sensor, or log files, etc.).

For example, in the Download folder, create a BTI_BLE folder.

After the first launch, you need to perform the initial program settings. To do this, on the main program screen, tap the “Parameters” menu button (or, “Settings” if the first program start occurs on a system with English localization). A dialog box for changing program settings will be displayed (see Fig. B.4). Select the program interface language from the list.

For the program to work, you must explicitly allow access to the data folder. This is a necessary requirement of the Android operating system. To do this, in the program settings dialog box, tap the "File folder" area. The operating system will display the standard folder selection screen (see Fig. B.5,

on the left). Select the previously created folder (in this example, go to the Download folder and select the BTI_BLE folder (see Fig. B.5, left).

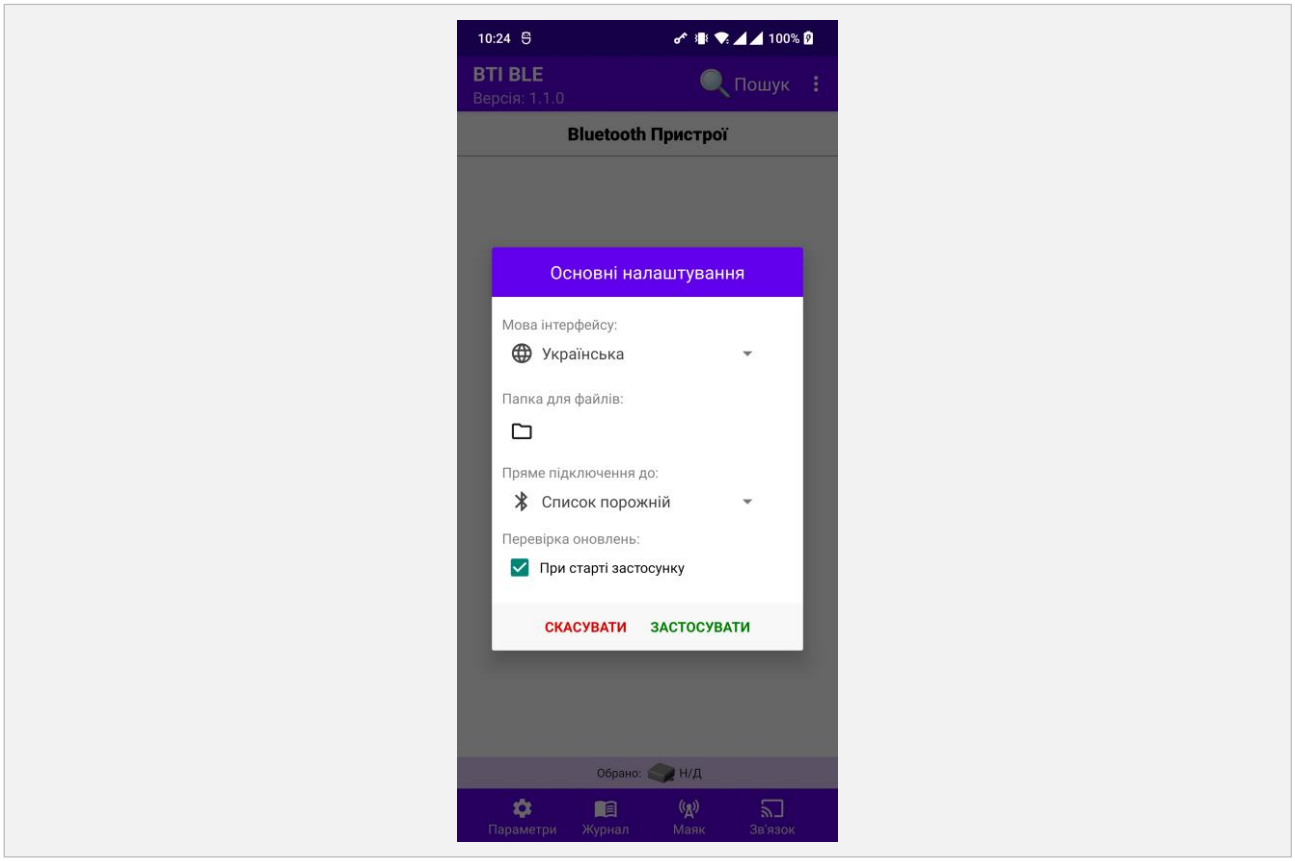


Figure B.4 – Program settings dialog box

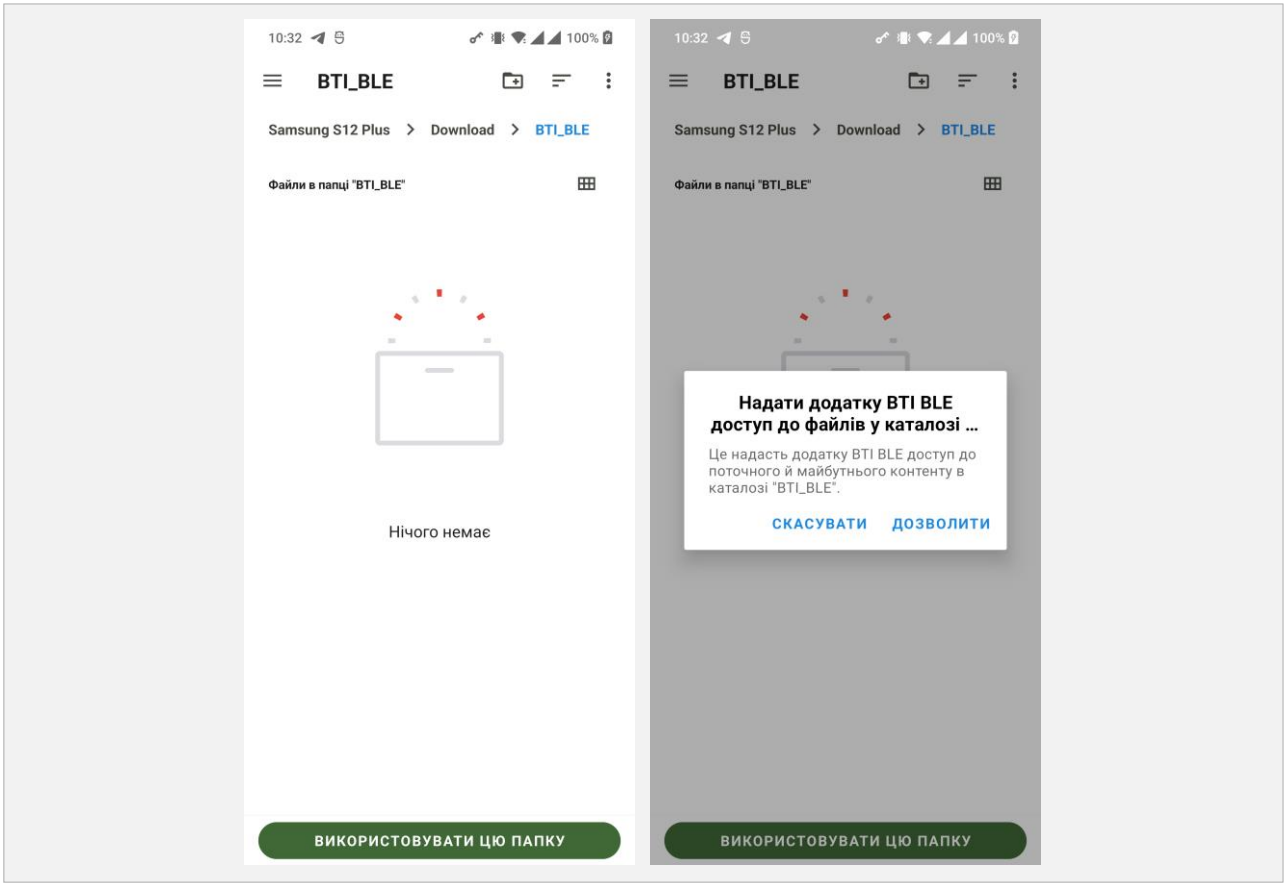


Figure B.5 – Example from Android 12 operating system: Selecting the root folder (left) and the system prompts you to grant permission to access the selected folder

To select a folder – touch the button ☰ in the upper left corner folder selection screen, and performing standard folder selection actions, first tap the “Download” folder in the list, and then the “BTI_BLE” folder. Then, tap the “Use this folder” button (see Fig. B.5, left). The operating system will display a request to grant permission to the program to perform read and write operations in this folder (see Fig. B.5, right). You must click “Allow”. You will be returned to the program settings dialog box (see Fig. B.6).

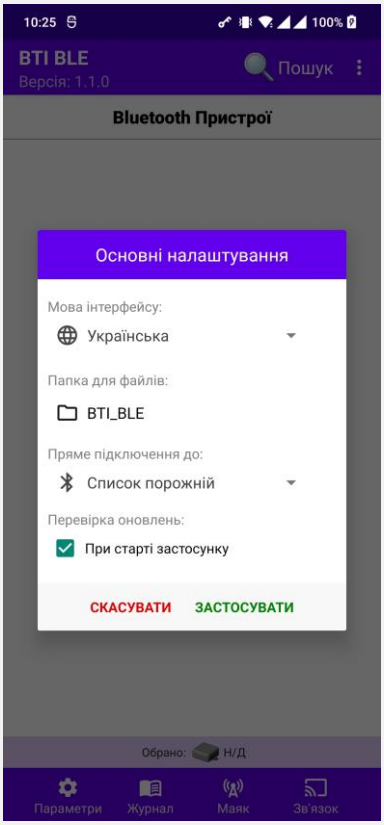


Figure B.6 – Program settings dialog box with selected folder "BTI_BLE"

Tap the Apply button. The initial setup of the app is complete.

Working with the program

To search for devices, the “Search” button is used (in the upper right corner of the screen, Fig. B.3). Touching this button activates the device search. At the same time, the button changes its name to “Stop” and an animated circular indicator is displayed, indicating that the search process is activated. Touching the “Stop” button stops the search.

WARNING!O perating systemAndroid blocks the search for BLE devices if the geolocation service is not enabled. If the geolocation service is disabled, the application will display a notification to the user asking them to enable geolocation.

The main menu (three vertical dots in the upper right corner of the screen) allows you to access sorting and filter settings, see Fig. B.7).

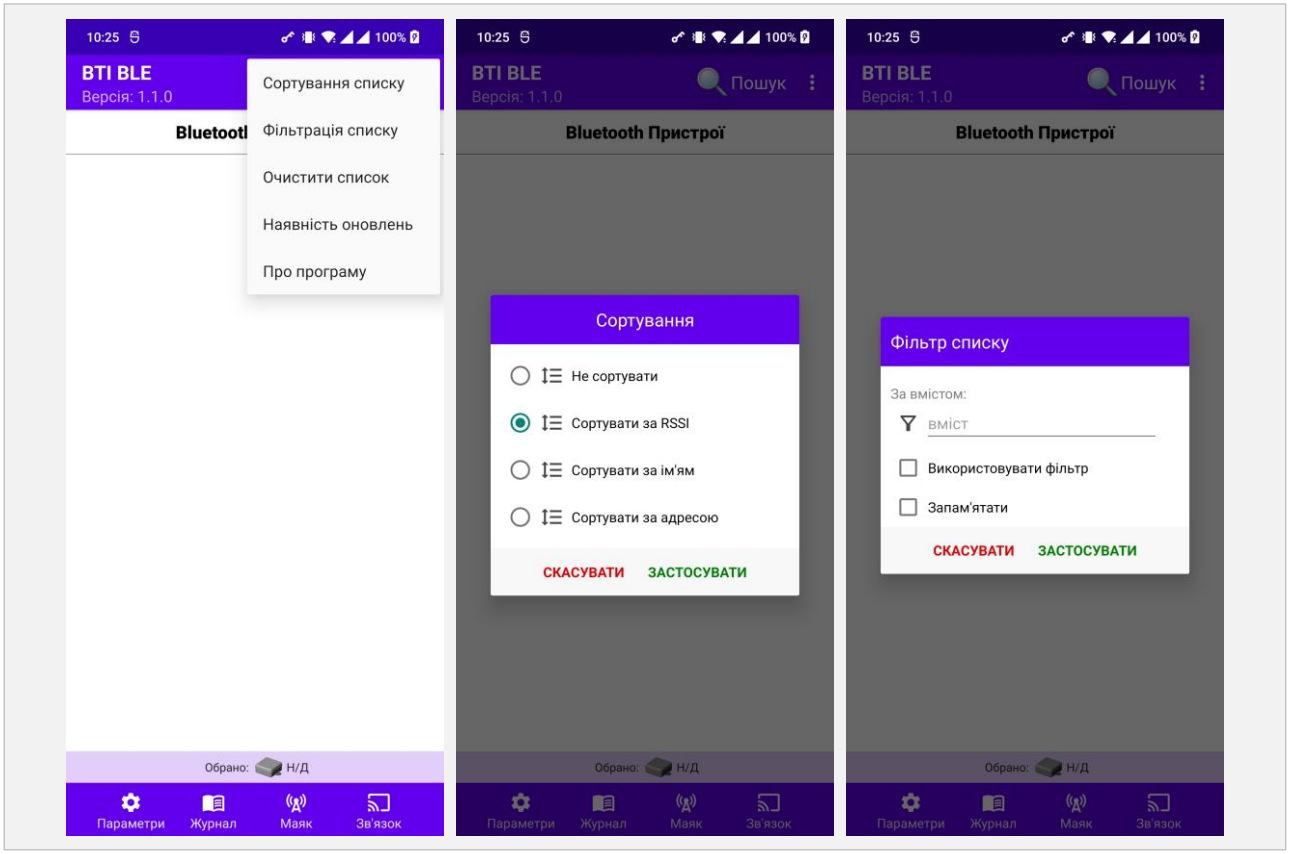


Figure B.7 – Main menu (left), Sort list (center) and List filtering (right)

Similar to the Windows version of the program, it is possible to choose how to sort the list of detected devices, as well as filter the list (see Fig. B.7 – Sorting the list, Filtering the list).

The "Remember" option in the filter settings dialog box is designed to save the enabled "Use filter" value for subsequent program launches. If the "Remember" option is disabled, then the set "Use filter" value will be used only for the current program session - the next time the program is launched, "Use filter" will be automatically disabled.

According to the set sorting and filtering mode, the program displays a list of detected Sensors (see Fig. B.8). When device search is activated, the program adds a new detected device to the list or updates the data of an existing one. Data update is indicated by a short-term lighting of the “flashlight” icon (see Fig. B.8, right).

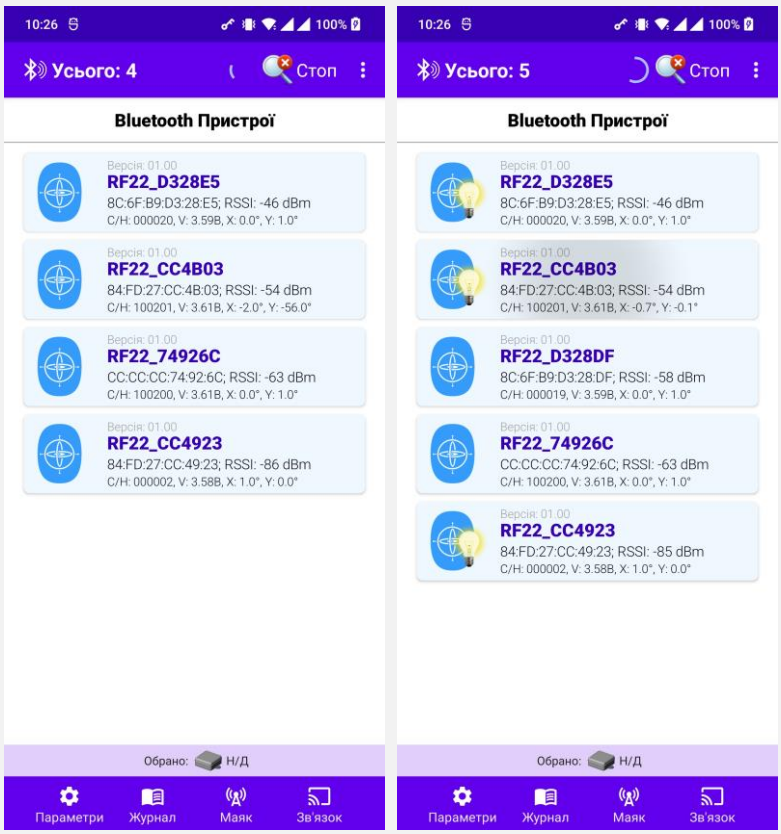


Figure B.8 – List of detected Sensors

To select a Sensor, stop the search by pressing the “Stop” button and tap the desired Sensor in the list of detected devices. The context menu for Sensor operations will be displayed (see Fig. B.9, left).

The program has implemented a separate screen for displaying “Beacon” data. To view the “Beacon” data of the Sensor, select the “Beacon data” context menu item. A screen will be displayed in which the airwaves will be continuously scanned only from the selected Sensor and information will be updated from the received data packets from it (see Fig. B.9, right).

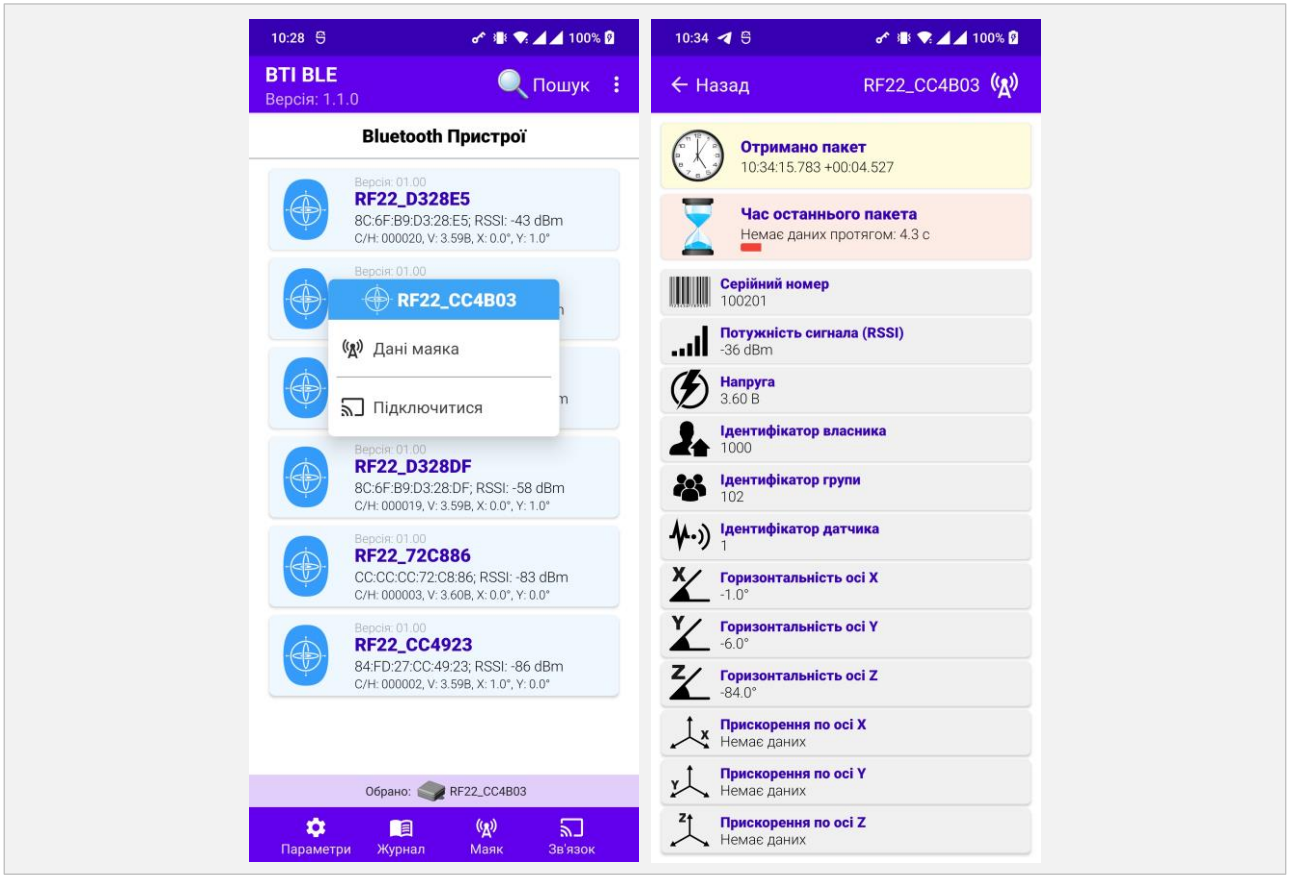


Figure B.9 – Selected Sensor (left) and data from the selected Sensor in mode "Lighthouse" (right)

To connect to the Sensor, select the "Connect" context menu item. After connecting, the device operation screen will be displayed (see Fig. B.10). When actively connected to the Sensor, the program displays a white background, when the connection is lost, the program displays a red background. The current value of the Z-axis deviation from the horizontal is displayed in the upper left corner of the screen. The current measured battery voltage is displayed in the upper right corner of the screen.

To quickly connect to a specific Sensor, or view the “Beacon” data of a specific Sensor, the “Connect” and “Beacon” buttons are provided. After any operation with a Sensor selected via the context menu (see Fig. B.9, left), the program automatically adds this Sensor to the list of known devices, and also sets this Sensor as a selected one (at the bottom of the screen you can see “Selected: RF22_XXXXXX”; in the example in Fig. B.9 – “Selected: RF22_CC4B03”). If you click the “Connect” or “Beacon” button, the corresponding operation will be performed directly with the selected Sensor. There is no need to search for devices in this case. The list of known devices is stored in the program, and it is possible to select a Sensor from the list (menu “Options”, list “Direct connection to”). The last selected Sensor will remain so even after restarting the program.

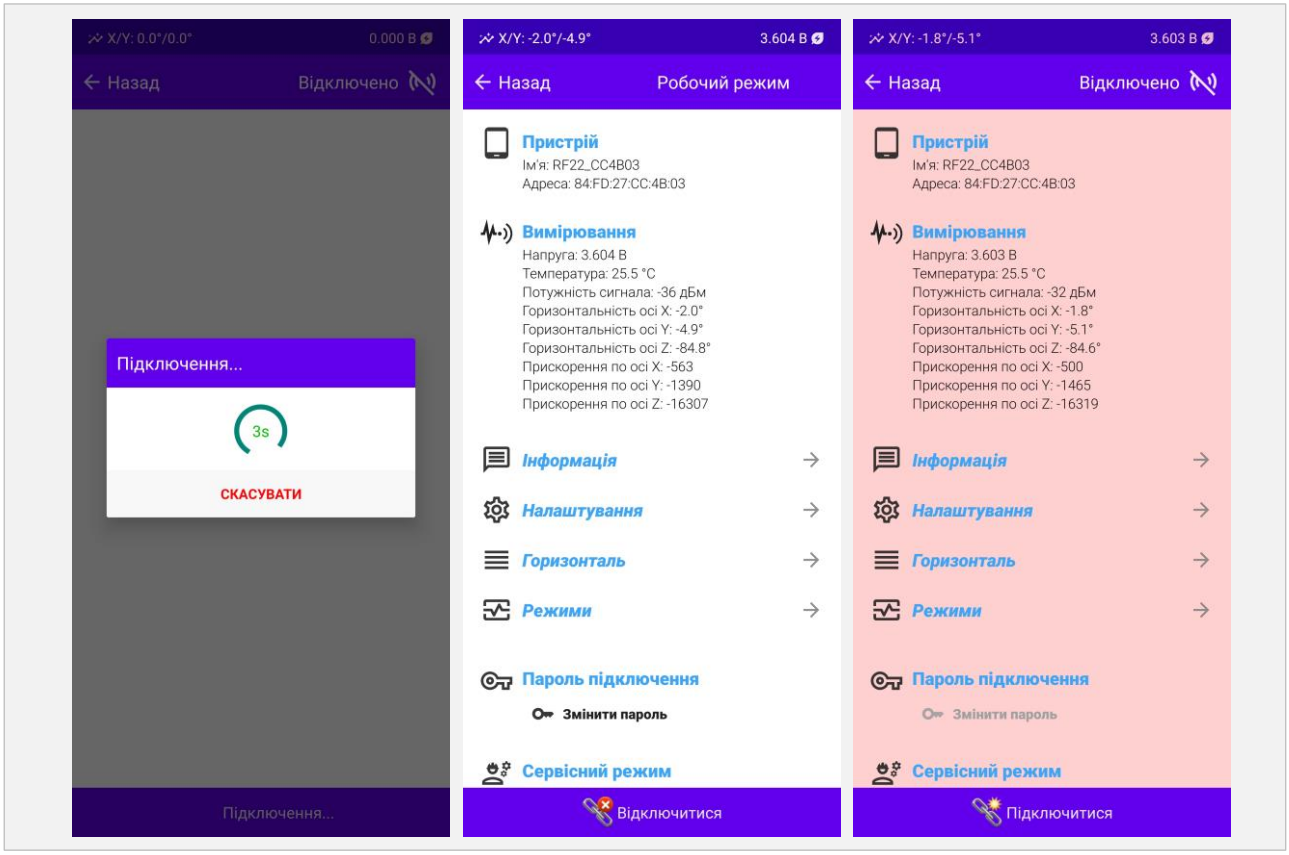


Figure B.10 – Connection to the Sensor (left), active connection to Sensor (inside) and Sensor connection broken (right)

Similar to the Windows version of the program, the Sensor settings are combined into groups "Information", "Settings", "Horizontal" (see Fig. B.11) and "Modes" (see Fig. B.12, left)

The Sensor parameters in each group are combined into subgroups. In each subgroup, if necessary, it is possible to re-read data from the Sensor and write the subgroup data to the Sensor (the "Read" and "Write" buttons).

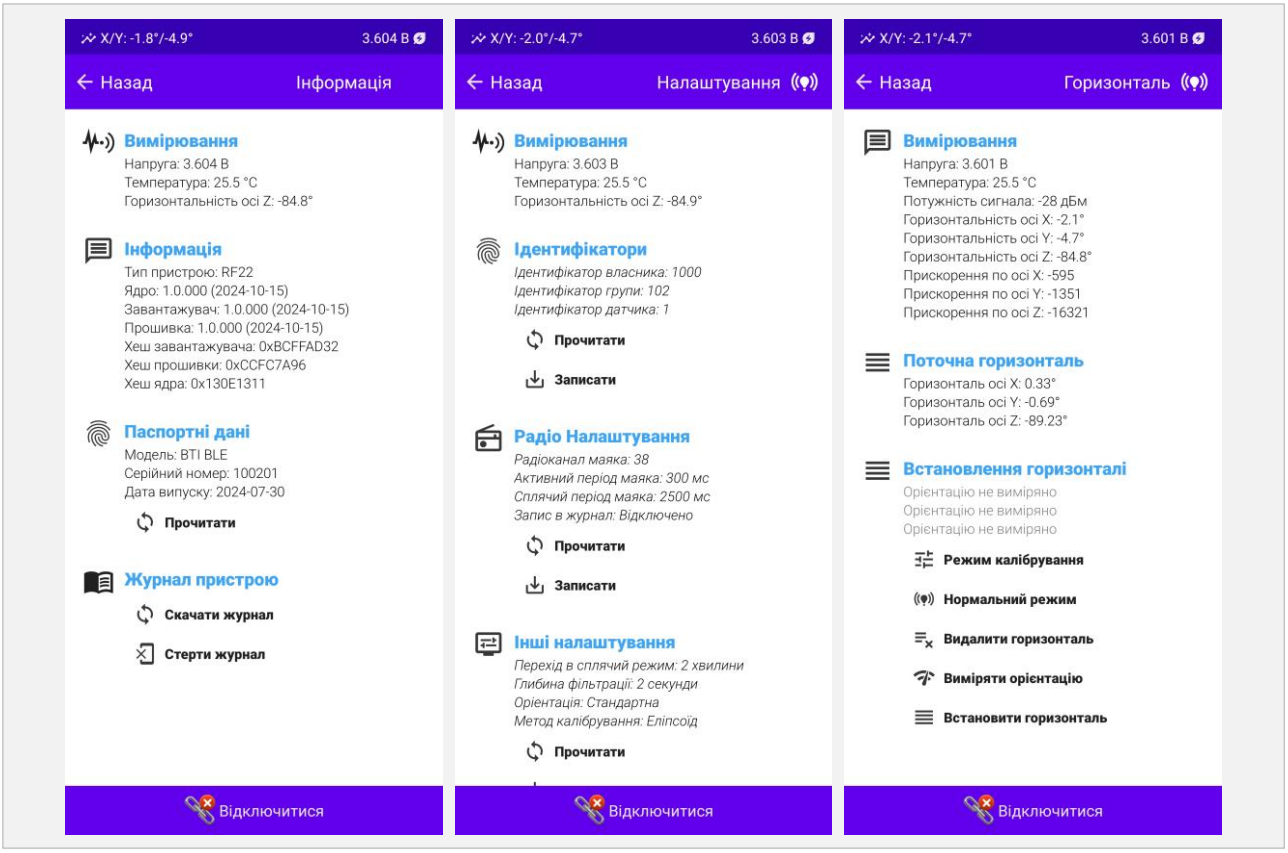


Figure B.11 – Groups “Information”, “Settings”, “Horizontal”

To facilitate intuitive orientation in the settings, subgroups of data that can be configured are displayed in italics, those that cannot be configured are displayed in regular font. To change the data that is configured, simply touch the area of this subgroup. The dialog box for configuring the parameter values of this subgroup will be displayed. As an example, Fig. B.12 shows the dialog box for configuring the subgroup “Identifiers” from the “Settings” group.

In the dialog box, you can click "Cancel" - in this case, the changes made by the user to the values of the subgroup parameters will be lost. When you select "Apply", the corresponding changes will be displayed in the subgroup, but not written to the Sensor memory. To write the values of the subgroup parameters to the Sensor memory, you must touch the "Write" button of the corresponding subgroup (in this example, the "Write" button of the "Identifiers" subgroup).

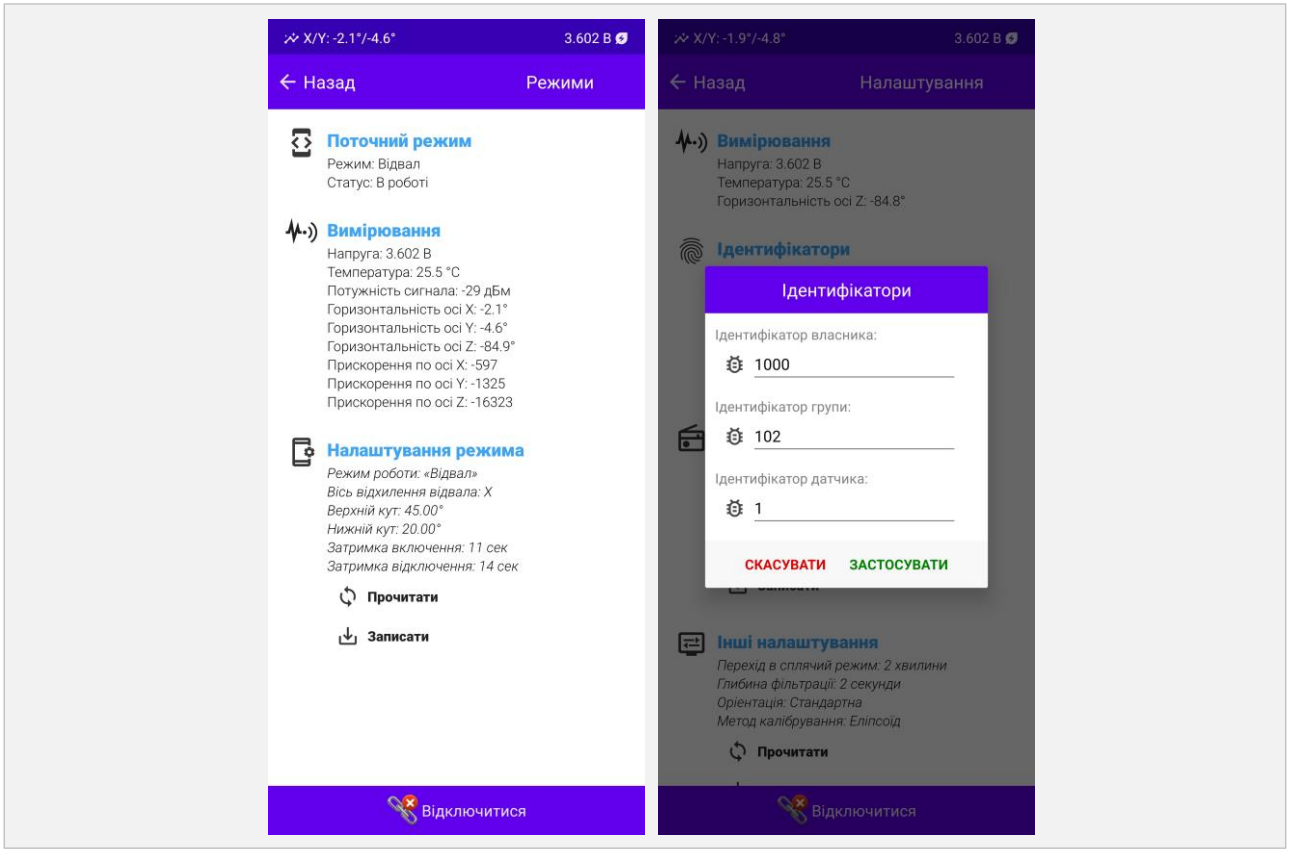


Figure B.12 – “Modes” group (left) and settings dialog box "Information" group, "Identifiers" subgroup (on the right)

The rest of the functionality – switching to service mode, changing the connection password, setting the horizontal, downloading the log, viewing the log, etc. – is discussed in detail in the description of the Windows version of the program (see Appendix A).

Appendix B – Reader Settings

(mandatory)

If the external device (GPS monitoring equipment) that is planned to be used together with the BTI BLE fuel level sensor (hereinafter referred to as the “Sensor”) does not support BLE, you must use an intermediate link in the form of a BLE sensor reader (hereinafter referred to as the “Reader”).

This section contains information about the Windows version of the "BTI_User_Tool" program, namely, the part that is designed to provide the Reader setup procedure.

Getting started

Before starting to work with the program, it is necessary to connect the Reader to the USB/RS-485 (for the BTR4/BR4x model) or USB/RS-232 (for the BTR2/ BR2x model) interface converter, observing the polarity of the interface and power wires, and to provide power to the Reader from the vehicle's on-board network or from an external source (set the power supply parameters in accordance with the technical characteristics specified in Table 3.2). The connection diagram is presented in the section "Appendix E". It is enough to connect the BRU2 model reader (USB adapter) to a free USB port of the PC (the driver of the built-in converter based on Silicon Labs CP2102 is usually installed automatically).

After launching the “BTI_User_Tool” program, go to the “Reader” tab (see Fig. B.1).

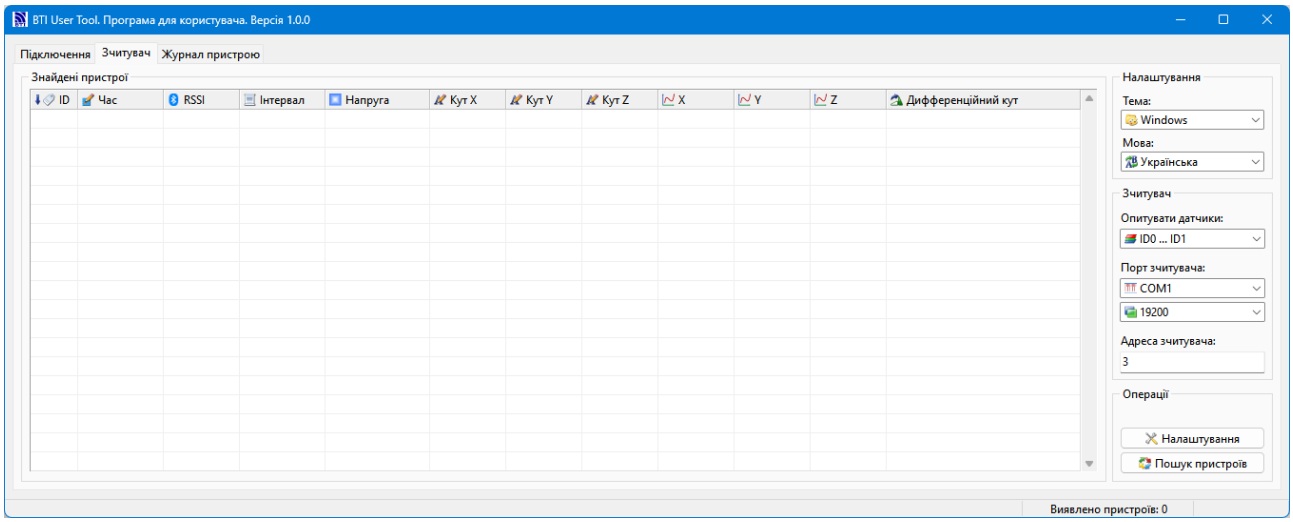


Figure B.1 – Reader Tab

In the "Reader" group on the settings panel (on the right), you need to select the desired COM port that corresponds to the connected USB/RS-485 or USB/RS-232 interface converter. Updating the list of available COM ports

ports occurs automatically when new ones appear or existing ones disappear in the system. You can find out the availability and numbers of ports on your PC here: *"Computer\Properties\Device Manager\Ports (COM and LPT)".*

After selecting the COM port to connect to the Reader, select the baud rate of 19200 bps and the device address of 3 (factory default settings). Then click the "Settings" button.

After connecting to the Reader, the Reader operation window will open (similar to connecting to Sensors), which corresponds to Fig. B.2.

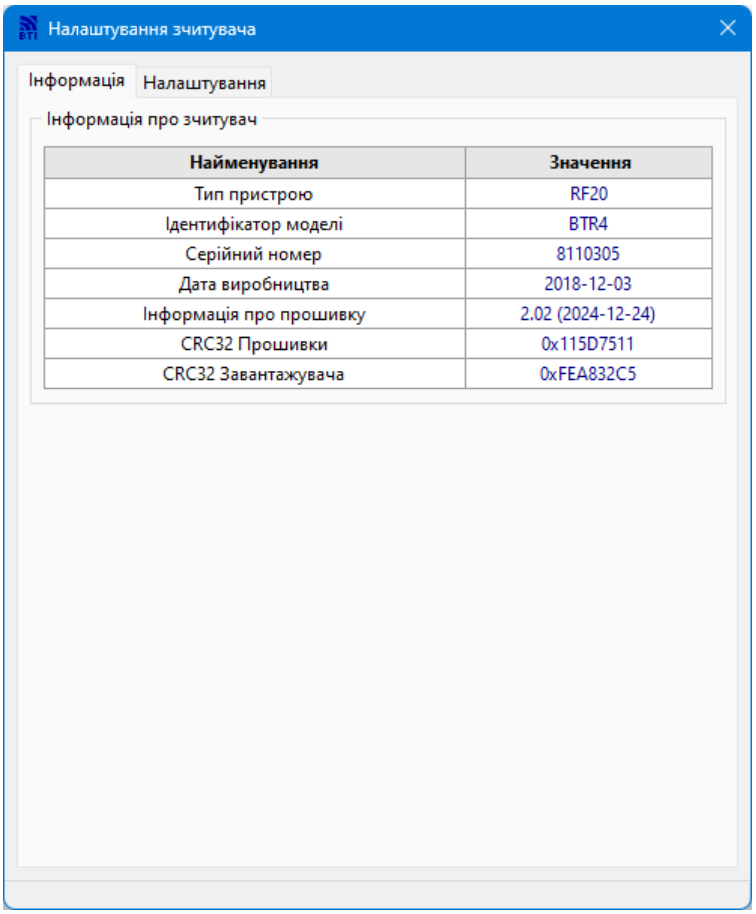


Figure B.2 – Connecting to the Reader, “Information” tab

If you cannot connect to the Reader (Fig. B.3), you need to check the port number, as well as the correct connection of the interface and power cables (for the BRU2 Reader, make sure that the driver is installed in the device manager) and then search for the device.

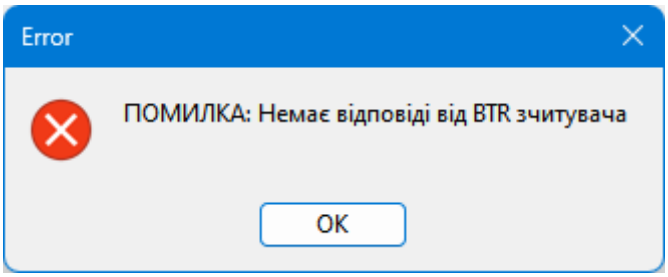


Figure B.3 – Connection to Reader failed

The "Information" tab is used to display information about the Reader (Fig. B.2). The "Settings" tab is used to configure the Reader parameters (Fig. B.4).

Reader Information

After connecting to the Reader, the program displays the Reader work window and automatically switches to the "Information" tab (Fig. B.2). It displays the following data about the Reader.

The "Reader Information" group contains information set by the manufacturer:

- “Device type” – for example, “RF20»
- “Serial number” – the serial number of the Reader;
- “Model ID” – internal model identifier
- “Date of manufacture” – the date of manufacture of the Reader;
- “Firmware Information” – the version of the Reader application’s firmware as well as the date of development of the Reader application firmware;
- «CRC32 Firmware” – 32-bit checksum of the main Reader firmware.

- «"Loader CRC32" – 32-bit checksum of the Reader's built-in loader.

Reader Settings

To configure the Reader and view its parameters, go to the "Settings" tab of the Reader window (see Fig. B.4).

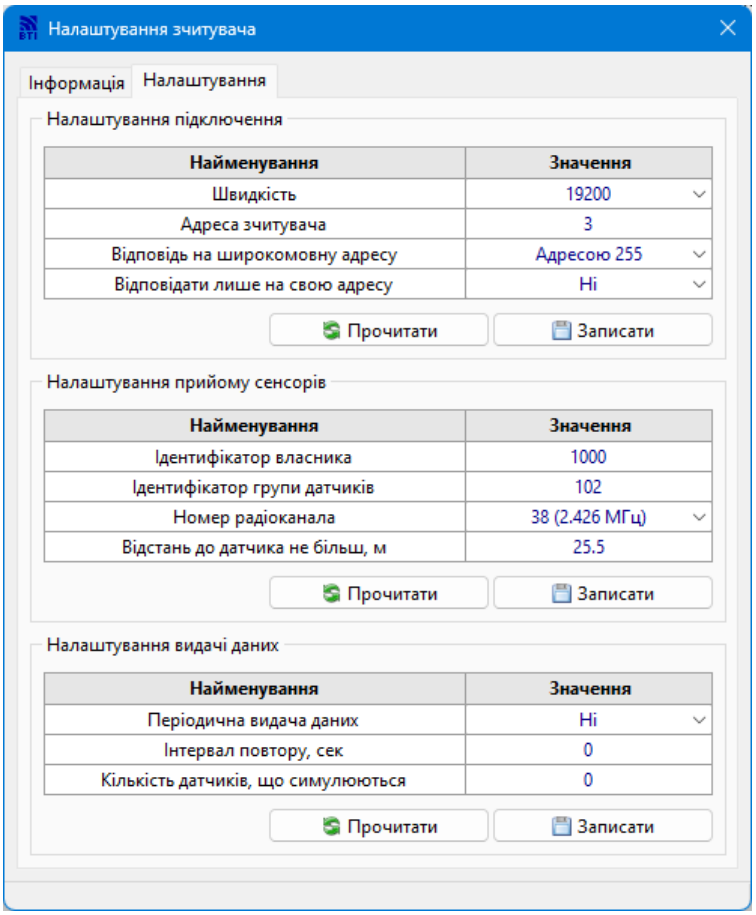


Figure B.4 – Reader Settings

On this subtab, you can set the Reader parameters. To do this, change the desired parameter and click the "Write" button.

To read the current Reader settings, click the "Read" button. When connecting to the Reader, the Reader settings are automatically read and all fields in the "Settings" tab are updated.

If errors occur while reading or setting parameters, check the connection of the interface and power cables, re-open the corresponding COM port, and repeat the necessary operation.

The "Settings" tab of the Reader window contains the following groups of fields and Reader parameters: "Connection settings", "Sensor reception settings", "Data output settings".

Connection Settings Group

The "Speed" list allows you to set one of the seven proposed port exchange speeds, bit/s: 2400; 4800; 9600; 19200; 38400; 57600; 115200. The default is 19200 bit/s.

The "Reader Address" field can take values from 0 to 255. It defines the network address of the Reader. The default is 3. If up to one

If several devices are connected to the RS-485 interface, they must have unique addresses, each of which must be registered individually for each device.

The “Broadcast Address Response” field defines the address with which the Reader responds to a request with a broadcast address (255): “Address 255” or “Own address”. By default, “Address 255”.

The “Reply only to own address” field – determines the Reader’s response to a request with a broadcast address (255). When set to “Yes”, the value of the “Reply to broadcast address” field discussed above is considered to be set to “Own address” regardless of the current value.

Sensor reception settings group

The “Owner ID” field is a parameter that defines the owner ID of the enterprise. It is set to the value of the owner ID of the Sensor from which information is planned to be received by this Reader. Sensors with an owner ID value that differs from the similar parameter recorded in the Reader will be ignored by the Reader. The permissible value is in the range 0...65535.

The "Sensor Group Identifier" field is used to divide Sensors into groups according to their intended use within one enterprise (example of use is vehicle identifier). In total, Sensors can be divided into 65536 groups. The Reader will accept Sensor data only if the Sensor is in the group specified in the Reader.

The "Radio Channel Number" field is used to select the radio channel on which the Reader will work with the Sensors. A Sensor that transmits a signal on a different radio channel will not be visible to the Reader. There are three radio channels to choose from: 37, 38, and 39. Changing the radio channel may be necessary in case of electromagnetic interference on the current radio channel.

The field "Distance to the sensor no more than, m" is the maximum distance to the Sensor, measured by the Reader, beyond which the Sensor will not be visible to the Reader. The distance is determined by the Reader based on the signal strength from the Sensor. The value of the required distance at which the Reader confidently receives should be THREE times less than the maximum - in order to compensate for the non-optimal orientation of the Reader and Sensor, as well as to take into account various obstacles in their area of operation. For example, if the required distance for confident reception of the Reader is 3 meters, then the maximum distance value should be set to 9 meters. The range of permissible values is 0 ... 25.5 m. The default value is 25.5 m.

WARNING!It is recommended to use the default value.

Data Output Parameters Group

Field "Periodic data output" - activates periodic data output (takes effect when you click the "Write" button and restart the Reader by power reset). Not activated by default.

The "Repeat interval, sec" field defines the repeat interval for periodic output in seconds. The default is 0 (the value 0 corresponds to an interval of 0.5 seconds).

The “Number of simulated sensors” field is intended for use with GPS monitoring equipment that does not support BLE. The field determines the number of wireless sensors for which the Reader will output data according to the “Single data reading” command (command 06h, see “Appendix D. Data exchange protocol”). Each Sensor is allocated 2 addresses, starting from the Reader address specified in the “Reader address” field of the “Connection settings” group. For example, with a Reader address of 3 and a number of simulated sensors of 1, the Reader will output data at addresses 3 and 4. With a number of simulated sensors of 2 – at addresses 3, 4, 5, 6. With a number of 3 – at addresses 3, 4, 5, 6, 7, 8, etc. The default value is 0, in this case the Reader does not output data to additional addresses. The maximum possible value is 20. The format of the output data is described in the section "Appendix D. Data exchange protocol".

Appendix D – Data Exchange Protocol (mandatory)

D.1 General provisions

This document describes the data exchange protocol of the BLE sensor reader (hereinafter referred to as the “Reader”) of the BTR2/BR2x, BTR4/BR4x and BRU2 models with external devices (hereinafter referred to as the “ED”).

D.2 Physical level

Communication with the PLC is carried out using RS-232 or RS-485 interfaces. The exchange rate is selected from the following range: 2400, 4800, 9600, 19200 (default), 38400, 57600, 115200 bps;
Data bit depth – 8 bits;
Parity – none;
Stop bit – 1; Flow control – none.

D.3 Logical level

The device implements the binary LLS protocol. The text protocol is not supported.

The following is a description of the binary protocol.

Data exchange is carried out in packets according to the "Request-Response" principle. The Master (initiator of exchange) is the Reader. Each Reader is assigned a network address. The default range of valid addresses is 0x00 – 0xFE. If the value of the number of simulated sensors (see below) is different from 0, the maximum value of the range of valid addresses is reduced by the value of the number of simulated sensors multiplied by 2). Default address – 0x03.

The protocol uses the following packet types:

– “Request” packet. The packet contains a command, the RS transmits the packet to the Reader;

– “Response” packet. The packet contains the response to the command and is transmitted by the Reader.

Request package format

Prefix	Network address device	Team code	Parameters	CRC
0x31	0x00..0xFF	see description commands	see description commands	Calculated according to Application Note 27 from Dallas

Response packet format

Prefix	Network address device	Team code	Respond device	CRC
0x3E	0x00..0xFF	see description commands	see command description	Calculated according to Application Note 27 from Dallas

Multibyte command parameters are passed in order from least significant byte to most significant byte (Little endian).

D.4 Description of commands

D.4.1 One-time data reading (command 06h)

The command is intended for reading the current data of the Sensor. The number of addresses to which the Reader will respond to the 06h command is determined by the value in the field “Number of simulated sensors” (hereinafter referred to as “Sensors”) in the Reader settings (see “Appendix B”, Fig. B.4). Each Sensor is allocated 2 addresses – with an even and odd offset relative to the Reader’s network address. Accordingly, the Reader can respond either to its network address (with a SENSOR of 0) or to 40 addresses, starting from the Reader’s address (with a SENSOR of 20). The address to which the Reader will output data from each specific Sensor is determined by the field “Sensor ID” (sensor number in the group, hereinafter referred to as “SG”) in the Sensor settings (see “Appendix A”, Fig. A.8). Accordingly, to receive a response with data from the Sensor, the value of the CDS in the Reader must be no less than the value of the NDG in the settings of this particular Sensor. You can get an idea of the addressing and combination of parameters in the settings of the Reader and Sensor from the following table:

Number sensor in group (NDG)	Bias addresses Reader	Type bias	CDS (minimum)	Content of the response to the command 06h (short)
0	any	any	any	Sensor is "off", response is empty (zero)
1	+ 0	even	0	Signal strength, NDG, distance, voltage
	+ 0	even	1	Signal strength, NDG, distance, voltage
	+ 1	odd		Temperature, differential angle, deflection angle
2	+ 2	even	2	Signal strength, NDG, distance, voltage
	+ 3	odd		Temperature, differential angle, deflection angle
3	+ 4	even	3	Signal strength, NDG, distance, voltage
	+ 5	odd		Temperature, differential angle, deflection angle
4	+ 6	even	4	Signal strength, NDG, distance, voltage
	+ 7	odd		Temperature, differential angle, deflection angle
5	+ 8	even	5	Signal strength, NDG, distance, voltage
	+ 9	odd		Temperature, differential angle, deflection angle
6	+ 10	even	6	Signal strength, NDG, distance, voltage
	+ 11	odd		Temperature, differential angle, deflection angle
7	+ 12	even	7	Signal strength, NDG, distance, voltage
	+ 13	odd		Temperature, differential angle, deflection angle

8	+ 14	even	8	Signal strength, NDG, distance, voltage
	+ 15	odd		Temperature, differential angle, deflection angle
9	+ 16	even	9	Signal strength, NDG, distance, voltage
	+ 17	odd		Temperature, differential angle, deflection angle
10	+ 18	even	10	Signal strength, NDG, distance, voltage
	+ 19	odd		Temperature, differential angle, deflection angle
11	+ 20	even	11	Signal strength, NDG, distance, voltage
	+ 21	odd		Temperature, differential angle, deflection angle
12	+ 22	even	12	Signal strength, NDG, distance, voltage
	+ 23	odd		Temperature, differential angle, deflection angle
13	+ 24	even	13	Signal strength, NDG, distance, voltage
	+ 25	odd		Temperature, differential angle, deflection angle
14	+ 26	even	14	Signal strength, NDG, distance, voltage
	+ 27	odd		Temperature, differential angle, deflection angle
15	+ 28	even	15	Signal strength, NDG, distance, voltage
	+ 29	odd		Temperature, differential angle, deflection angle
16	+ 30	even	16	Signal strength, NDG, distance, voltage
	+ 31	odd		Temperature, differential angle, deflection angle
17	+ 32	even	17	Signal strength, NDG, distance, voltage
	+ 33	odd		Temperature, differential angle, deflection angle
18	+ 34	even	18	Signal strength, NDG, distance, voltage
	+ 35	odd		Temperature, differential angle, deflection angle
19	+ 36	even	19	Signal strength, NDG, distance, voltage
	+ 37	odd		Temperature, differential angle, deflection angle
20	+ 38	even	20	Signal strength, NDG, distance, voltage
	+ 39	odd		Temperature, differential angle, deflection angle

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	06h	Team code
+ 3	1	00h...FFh	CRC8

Even offset address response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	06h	Team code
+ 3	1	- 128...0	Sensor signal power, dBm
+ 4	2	0000h...FFFFh	Sensor ID (SDI)
+ 6	1	0...255	Distance to the Sensor, dm
+ 7	1	0...255	Battery voltage, code. Conversion to volts (V): (Field value)/100+1.5
+ 8	1	00h...FFh	CRC8

Response format for odd offset address

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	06h	Team code
+ 3	1	- 128...127	Temperature, °C
+ 4	2	- 900...900	Differential tilt angle, 0.1°/bit (degrees * 10)
+ 6	2	- 900...900	Angle of deviation from vertical, 0.1°/bit (degrees * 10)
+ 8	1	00h...FFh	CRC8

D.4.2 Periodic data output without request (command 07h)

The command is intended for quick activation of the periodic mode (without a request from the RP) of data output. After receiving the command, the Reader issues a one-time response with a return code. If the code value corresponds to the successful execution of the command, the Reader starts sending messages with the specified periodicity. The format of periodic messages in this mode is identical (except for the “Command code” field, instead of 06h the field contains 07h) to the Reader’s responses to the 06h command.

The number of addresses for which the Reader will issue periodic messages is determined by the value of the CDS (see “One-time data reading (command 06h)”). The Reader sequentially issues messages with all addresses specified by the CDS value in a cycle. The message period is determined by the value of the “Repeat interval” field in the Reader settings (see “Appendix B”, Fig. B.4). For example, with a CDS of 2 and a repeat interval of 1, the message period with one specific address will be 4 seconds.

The mode is deactivated after receiving any valid command or restarting the Reader (turning the power off and on again).

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	07h	Team code
+ 3	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	07h	Team code
+ 3	1	00h or Exh	Return code: 00h - command executed successfully, Exh - error
+ 4	1	00h...FFh	CRC8

Format of a periodic message to an even offset address

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	07h	Team code
+ 3	1	- 128...0	Sensor signal power, dBm
+ 4	2	0000h...FFFFh	Sensor ID (SDI)
+ 6	1	0...255	Distance to the Sensor, dm
+ 7	1	0...255	Battery voltage, code. Conversion to volts (V): (Field value)/100+1.5
+ 8	1	00h...FFh	CRC8

Format of a periodic message to an address with an odd offset

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	07h	Team code
+ 3	1	- 128 ... 127	Temperature, °C
+ 4	2	- 900...900	Differential tilt angle, 0.1°/bit (degrees * 10)
+ 6	2	- 900...900	Angle of deviation from vertical, 0.1°/bit (degrees * 10)
+ 8	1	00h...FFh	CRC8

It is also possible to activate periodic data output after power-on, using commands 54h and 55h. In this case, after receiving any valid command, periodic data output is disabled, and to enable it, the Reader must be restarted (power off and on again) or the 07h command must be re-issued.

D.4.3 Reading technological parameters (command 41h)

The command is intended to read the technological parameters of the Reader: release date, serial number, model code, firmware version, firmware date, network address, data issuance period, data issuance mode.

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	41h	Team code
+ 3	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	41h	Team code
+ 3	1	01h...31h	Release date in BCD format: 1...31
+ 4	1	01h...12h	Release month in BCD format: 01h – January, ... , 12h - December
+ 5	1	00h...99h	Year of manufacture in BCD format: 00h corresponds to 2000.
+ 6	3	000001h...FFFFFFh	Serial number (1 ... 16777215)
+ 9	1	A0h...A6h	Model code (see the following table)
+ 10	1	00h...99h	Firmware subversion, in BCD format
+ 11	1	01h...99h	Firmware version in BCD format
+ 12	1	01h...31h	Built-in Day software in BCD format: 1...31
+ 13	1	01h...12h	Firmware month in BCD format: 01h – January, ..., 12h - December
+ 14	1	00h...99h	Year of firmware in format BCD: 00h corresponds to 2000.
+ 15	1	-	Reserved
+ 16	1	-	Reserved
+ 17	1	00h...FFh	Network address
+ 18	1	00h...FFh	The value of the issuance period data, p.
+ 19	2	0000h...023Dh	Data output mode (see command 55h)
+ 21	1	00h...FFh	CRC8

Decoding the Reader model code

Model code (HEX)	Model name
A0	BTR4
A1	BTR2
A2	BR21
A3	BR41
A4	BR22
A5	BR42
A6	BRU2

D.4.4 Reading the serial number and release date (command 42h)

The command is intended to read the following parameters of the Reader: release date, serial number, model code, firmware version.

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	42h	Team code
+ 3	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	42h	Team code
+ 3	1	01h...31h	Release date in BCD format: 1...31
+ 4	1	01h...12h	Release month in BCD format: 01h – January, ... , 12h - December
+ 5	1	00h...99h	Year of manufacture in BCD format: 00h corresponds to 2000.
+ 6	3	000001h...FFFFFFh	Serial number (1 ... 16777215)
+ 9	1	A0h...A6h	Model code (See the decoding table) model code)
+ 10	1	00h...99h	Firmware subversion, in BCD format
+ 11	1	01h...99h	Firmware version in BCD format
+ 12	1	00h...FFh	CRC8

D.4.5 Setting the data output period (command 54h)

The command is intended to set the data output period of the periodic (without request) data output mode, activated by commands 07h and 55h.

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	54h	Team code
+ 3	1	00h...FFh	The value of the data release period, sec.
+ 4	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address

+ 2	1	54h	Team code
+ 3	1	00h or Exh	Return code: 00h - command executed successfully, Exh - error
+ 4	1	00h...FFh	CRC8

D.4.6 Setting the data transfer mode (command 55h)

The command is intended to set the following parameters: broadcast request response parameters, serial port baud rate (2400...115200 bps), and permission for periodic data output after restart (enabled/disabled).

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	55h	Team code
+ 3	2	0000h...07FFh	See table below mode code decryption data output
+ 5	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	55h	Team code
+ 3	1	00h or Exh	Return code: 00h - command executed successfully, Exh - error
+ 4	1	00h...FFh	CRC8

Decoding the data release mode code

Bit	Appointment	Description	Value by default
10 - 15	Reserved	-	0
9	The answer is only yours. address	0: response to broadcast request is determined by bit 5 1: reply only to your own address	0
6 - 8	Reserved	-	0
5	Answer to broadcast request	0: reply with request address 1: reply with own address	0
4,3,2	Exchange rate by serial port, bit/s	000 – speed does not change; 001 - 2400; 010 - 4800; 011 - 9600;	100 (19200 bps)

		100 - 19200 (set by default); 101 - 38400; 110 - 57600; 111 – 115200	
1	Reserved	-	0
0	Periodic data release after restart	0: disabled 1: enabled	0 (off)

D.4.7 Setting the network address (command 56h)

The command is intended to set the Reader's network address for operation of multiple Readers on one RS-485 interface.

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	56h	Team code
+ 3	1	00h...FFh	New reader network address
+ 4	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	56h	Team code
+ 3	1	00h or Exh	Return code: 00h - command executed successfully, Exh - error
+ 4	1	00h...FFh	CRC8

D.4.8 Reading the device type (command 80h)

The command is designed to determine the type of connected device.

Team format

Bias, Byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Recipient's network address
+ 2	1	80h	Team code
+ 3	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	80h	Team code

+ 3	4	'RF20'	Reader Type BTRx/BR2x/BR4x/BRU2. Type data – char[4].
+ 7	1	00h...FFh	CRC8

D.4.9 One-time extended data read (B6h command)

The command is intended for reading current data, using, unlike the 06h command, the Sensor identifier (sensor number in the group – NDG) to select the Sensor.

Team format

Bias, byte	Field size, byte	Value	Description
0	1	31h	Prefix
+ 1	1	00h...FFh	Reader network address
+ 2	1	B6h	Team code
+ 3	1	0...20	Sensor ID (SDI)
+ 4	1	00h...FFh	CRC8

Response format

Bias, byte	Field size, byte	Value	Description
0	1	3Eh	Prefix
+ 1	1	00h...FFh	Sender's network address
+ 2	1	B6h	Team code
+ 3	2	0000h...FFFFh	Sensor ID (SDI)
+ 5	1	- 128...0	Sensor signal power, dBm
+ 6	1	- 128...0	Sensor signal strength on distance 1 m, dBm
+ 7	1	0...255	Distance to the Sensor, dm
+ 8	1	0...255	Battery voltage, code. Conversion to volts (V): (Field value)/100+1.5
+ 9	1	- 90...90	The angle of deviation of the Z axis from the horizontal, degrees
+ 10	1	- 90...90	The angle of deviation of the X axis from the horizontal, degrees
+ 11	1	- 90...90	The angle of deviation of the Y axis from the horizontal, degrees
+ 12	1	00h...FFh	CRC8

Appendix D – Firmware Download Reader support. Saving and restoring Reader configuration data

(mandatory)

D.1 The “RCS_AppLoader” loader program is used to update the firmware of the BLE sensor reader (hereinafter referred to as the “Reader”) of the BTR2/BR2x, BTR4/BR4x and BRU2 models, as well as to save and restore configuration data from a file.

The following sequence of operations must be performed:

D.2 Connect the Reader to the appropriate USB/RS-485 (for BTR4/BR4x models) or USB/RS-232 (for BTR2/BR2x models) interface converter, observing the polarity of the interface and power wires, and provide power to the Reader from the vehicle's on-board network or an external source. The connection diagram is given in the section "Appendix D". It is enough to connect the BRU2 model reader (USB adapter) to a free USB port of the PC (the driver of the built- in converter based on Silicon Labs CP2102 is usually installed automatically), no additional actions are required.

D.3 Run the “RCS_AppLoader” program.

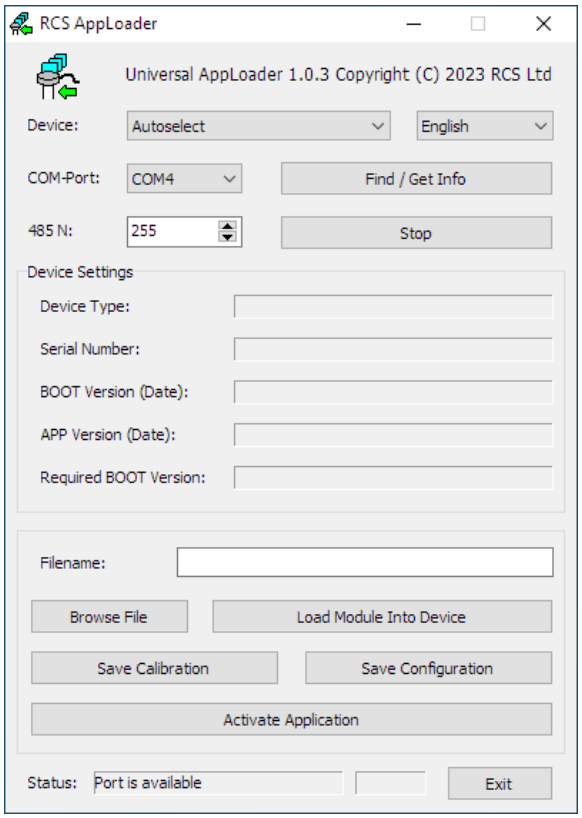
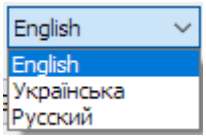


Figure D.1 – “RCS_AppLoader” program window

D.4 Select the appropriate interface language from the list:



D.5 Select COM port. You can find out the availability and numbers of ports on your PC here: *"Computer\Properties\Device Manager\Ports (COM and LPT)".* For For BTR4/BR4x models, select the RS-485 interface port. When connecting 2 or more Readers to a network, specify the device network address in the “485 N” field. For BTRx/BR2x/BR4x Reader models **necessarily**Turn off the device power. Press the “Search / Get Information” button and turn on the power. If the device is successfully detected, the search will stop, its type will be displayed in the “Device:” list, and the data of the connected device will appear in the “Device Settings” section (Fig. D.2).

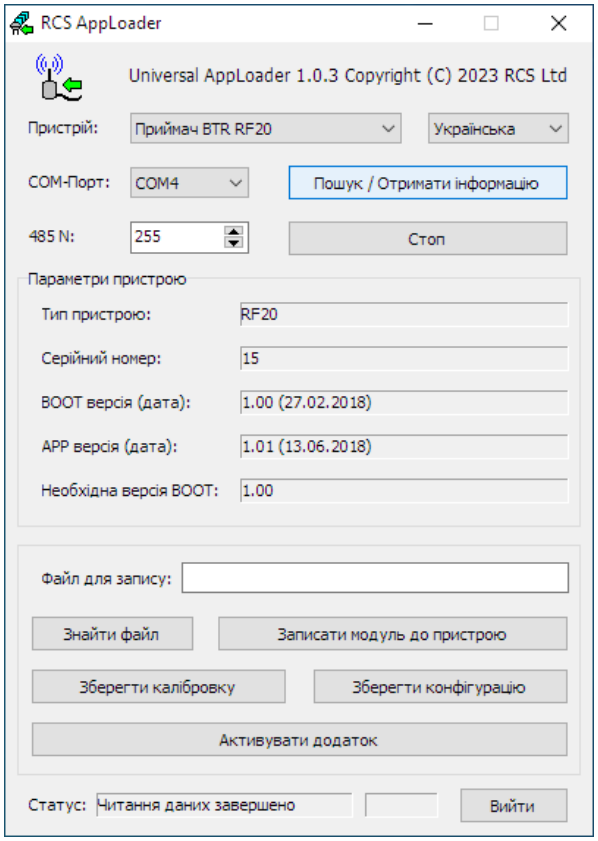


Figure D.2 – Read information about the Reader

D.6 Select the firmware file using the “Find File” button (Fig. D.3).

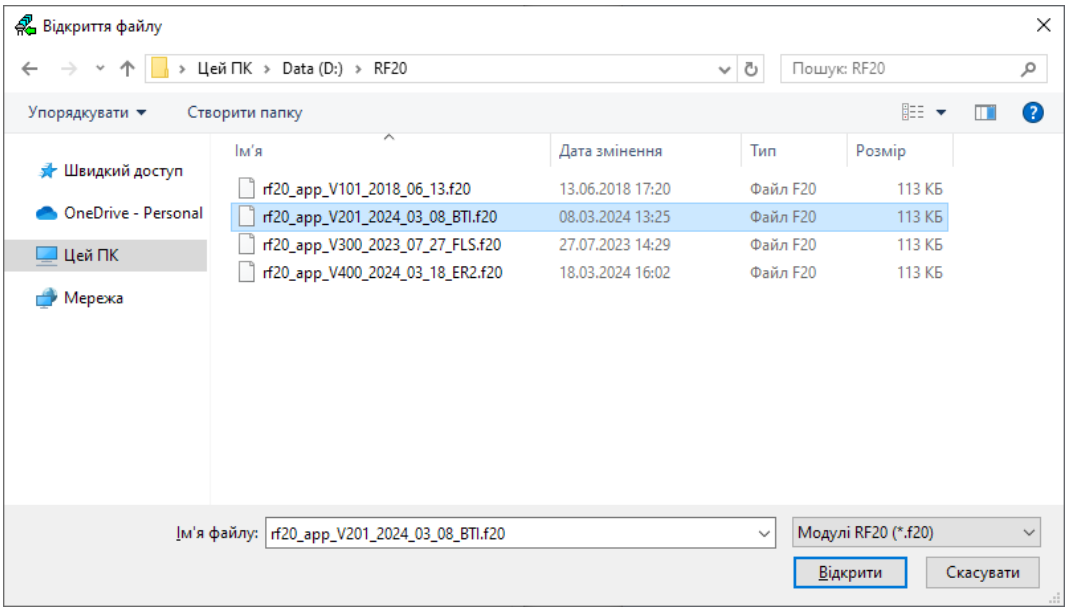
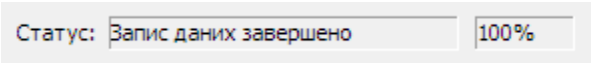


Figure D.3 – Selecting the firmware file

D.7 Download the firmware by clicking the “Write module to device” button.

The download progress is displayed in percentage:

After the download is complete, a message will be displayed:



And in the "Device Settings" section, a new firmware version will appear:

D.8 To save the configuration data to a file, click the "Save Configuration" button.

D.9 In the file selection window, select the folder to save and the file name, click the "Save" button (Fig. D.4):

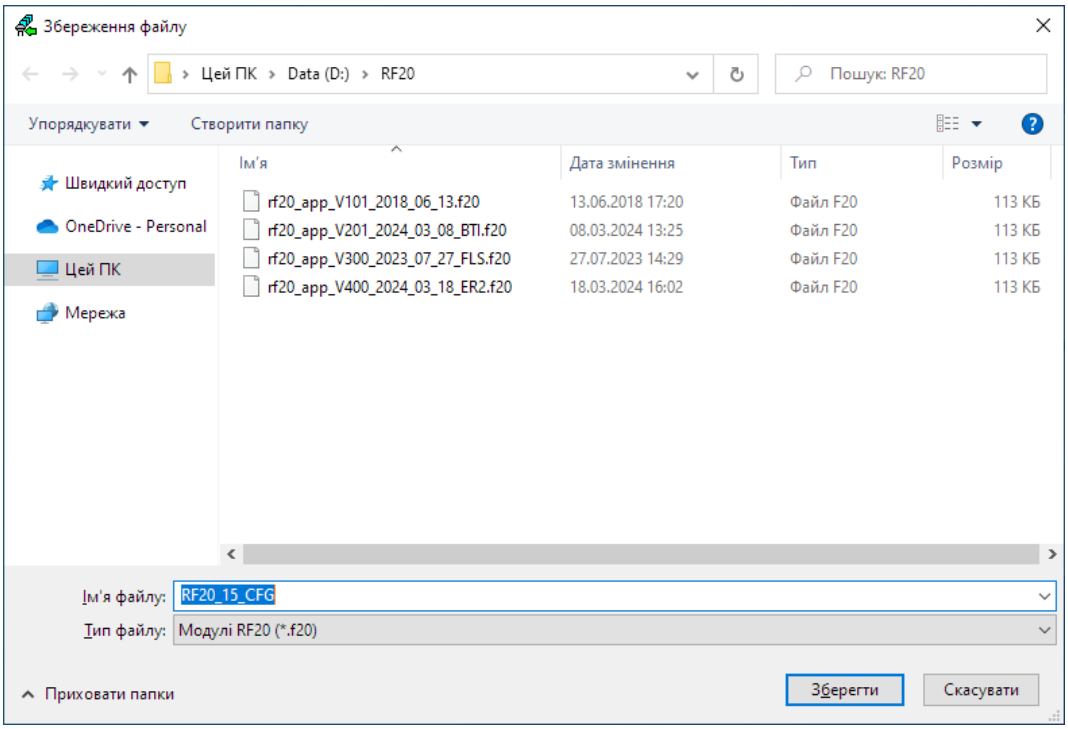


Figure D.4 – Selecting a folder and file name for saving

By default, the program offers to save the file with a name like "RF20_XXXXX_CFG.f20", where XXXXX is the Reader's serial number.

D.10 Restoring configuration data is performed similarly to loading firmware, but instead of the firmware file, you need to select a configuration file.

E.11 To activate the new firmware, click the “Activate App” button or power cycle the device.

D.12 To exit the bootloader program, click the "Exit" button or close the program window.

Appendix E – Reader to PC Connection Diagrams
(mandatory)

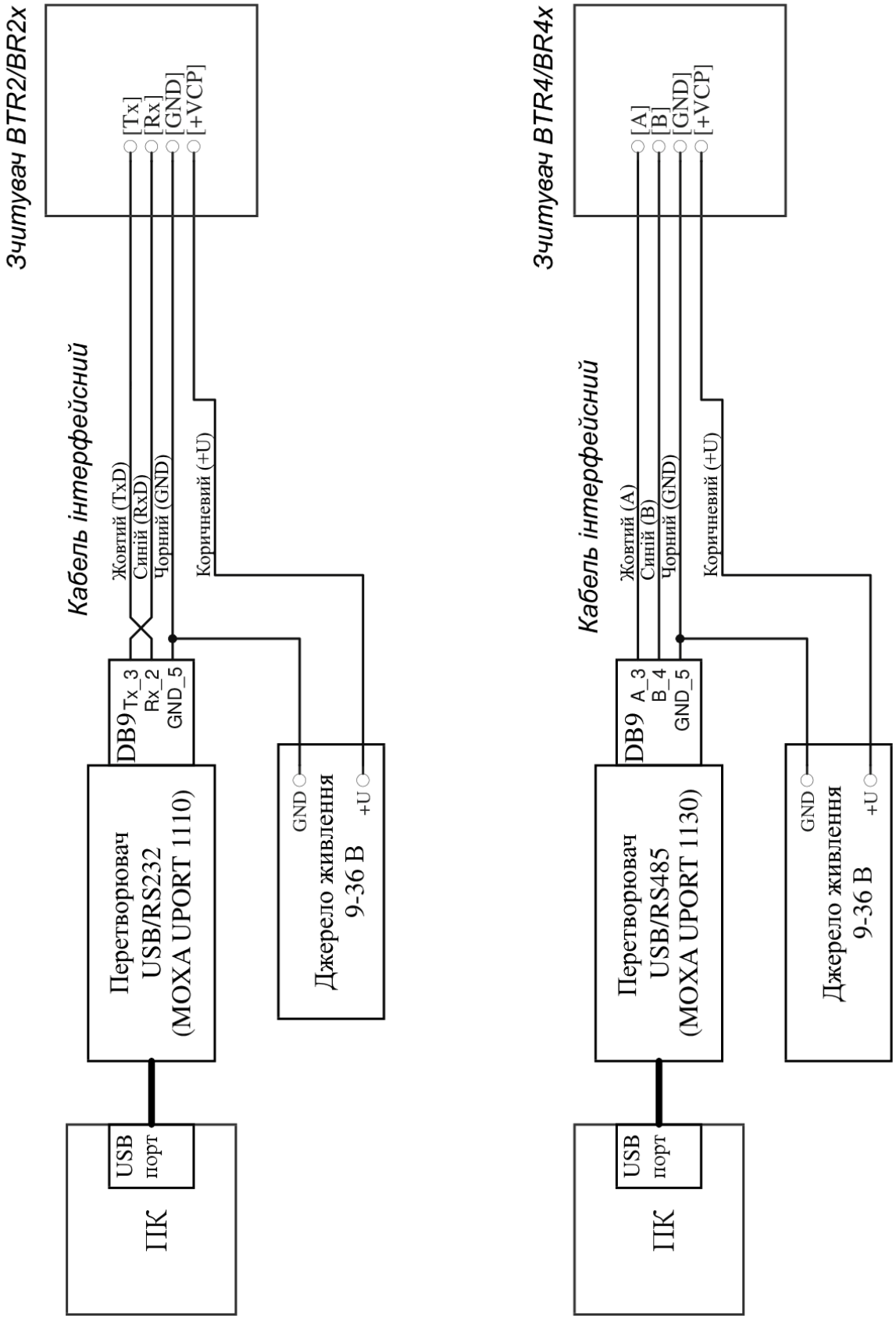


Figure E.1 – Connection diagrams of the BTRx/BR2x/BR4x Reader to the PC

Appendix G – Description of the Sensor's broadcast package

Sensor software version 2.00

(mandatory)

The BTI BLE wireless tilt angle sensor (hereinafter referred to as the "Sensor"), in terms of data transmission, operates in "beacon" mode with an interval of 300*ms*in the working and 2500 *ms*in sleep mode on one of the three Bluetooth advertising channels (37, 38, 39).

The Sensor data packet is transmitted in a standard uncoded Bluetooth LE air packet (see Bluetooth Core Specification Version 5.4, Vol 6, Part B, Packet Format For The LE Uncoded PHYs, page 2683) in the "Manufacturer Specific Data" field of the advertising packet:

Preamble:	0xAA (10101010b)
Access Address:	0x8E89BED6
PDUs:	Bluetooth LE Advertising Channel PDU
CRC:	24 bits (3 bytes)

The Sensor PDU has a total length of 39 bytes. The structure of the PDU is presented in Tables J.1 and J.2.

In sleep mode, the Sensor constantly emits only one PDU with data of the type "Beacon. Informational" (table G.1). In working mode, the data emission cycle is: 5 PDU packets with data of the type "Beacon. Sensor" (table G.2) and one PDU with data of the type "Beacon. Informational" (table G.1), i.e., in working mode, the full emission period takes 1800*ms*.

Table J.1 – Sensor Information PDU Structure

Field name	Offset in blocks Manufacturer Specific Data, byte	Size (type data)	Value	Description
PduType	-	uint8_t	0x00	ADV_IND.
Length	-	uint8_t	0x25	Length of subsequent data.
AdvA	-	uint8_t [6]		MAC address of the device.
FlagsLen	-	uint8_t	0x02	Block length
FlagsType	-	uint8_t	0x01	0x01 – Block type: “Flags”.
Flags	-	uint8_t	0x06	Contents of the "Flags" block
ManDataLen	-	uint8_t	0x1B	Block length (determined by the Sensor manufacturer)
ManDataType	-	uint8_t	0xFF	0xFF – Block type: "Manufacturer Specific Data".
dbBeaconId	0	uint8_t	0xE0	BTI data packet type: 0xE0 – “Beacon. Information”
dbSeqNumber	+ 1	uint8_t	0 – 255	Packet number. Incremented by 1 with each new packet.
daDeviceId	+ 2	uint8_t [4]	"RF22"	Device type identifier. ASCII.
dwOwnerId	+ 6	uint16_t	0 – 65535	Owner ID operational system (enterprise).
dwGroupId	+ 8	uint16_t	0 – 65535	Sensor group identifier (gas station, vehicle, etc.).
daSerialNumber	+ 10	uint8_t [3]		Device serial number.
dwLabelId	+ 13	uint16_t	0 – 20	Sensor ID (sensor number in the group).
ibCblRssi	+ 15	int8_t	- 48	RSSI at 1 m. Typical value. May be changed during calibration of a specific device.
dbBattVoltage	+ 16	uint8_t	0 – 255	Battery voltage. U(mV) = dbBattVoltage *10+1500.
dwBootVersion	+ 17	uint16_t		Device bootloader version. BCD. 0x0123 means 1.23.
dwFwVersion	+ 19	uint16_t		Device firmware version. BCD. 0x4567 means 45.67.
sExtraWord	+ 21	uint16_t	Bitova mask	[3:0] – additional operating mode (see explanation below) [7:4] – status, depends on the mode (see explanation below)
ibAngleZ	+ 23	int8_t	- 90...+90	Z-axis deviation angle from horizontal, 1°/bit
ibAngleX	+ 24	int8_t	- 90...+90	X-axis deviation angle from horizontal, 1°/bit
ibAngleY	+ 25	int8_t	- 90...+90	Y-axis deviation angle from horizontal, 1°/bit

Additional operating modes and mode statuses:

Bits are counted from right to left. In the meaning *uint16_t* parameter *sExtraWord*, bit0 is the least significant, bit15 is the most significant.

In the bit field [3:0] of the parameter *sExtraWord* the selected additional is encoded sensor operating mode, in bit field [7:4] of the parameter *sExtraWord* encoded status of the selected additional operating mode.

Below is a list of additional operating modes as a decimal value of the bit field [3:0], along with a list of possible status values for each mode:

- 0 – without additional operating mode (status – not applicable);
- 1 – rotation (status ([7:4]): 0 – no rotation, 1 – rotation to the left, 3 – rotation to the right);
- 2 – angle control (status (bit[7:4]): 0 – angle not exceeded, 1 – angle exceeded);
- 3 – bucket (status ([7:4]): 0 – idle, 1 – in operation);
- 4 – dump (status ([7:4]): 0 – inactive, 1 – in operation);

Table G.1 – Sensor PDU Structure

Field name	Offset in blocks Manufacturer Specific Data, byte	Size (type data)	Value	Description
PduType	-	uint8_t	0x00	ADV_IND.
Length	-	uint8_t	0x25	Length of subsequent data.
AdvA	-	uint8_t [6]		MAC address of the device.
FlagsLen	-	uint8_t	0x02	Length of the "Flags" block
FlagsType	-	uint8_t	0x01	0x01 – Block type: “Flags”.
Flags	-	uint8_t	0x06	Contents of the "Flags" block
ManDataLen	-	uint8_t	0x1B	Length of the Manufacturer Specific Data block
ManDataType	-	uint8_t	0xFF	0xFF – Block type: "Manufacturer Specific Data".
dbBeaconId	0	uint8_t	0xE5	BTI data packet type: 0xE5 – “Beacon. Sensor”
dbSeqNumber	+ 1	uint8_t	0 – 255	Packet number. Incremented by 1 with each new packet.
dwOwnerId	+ 2	uint16_t	0 – 65535	Owner ID operational system (enterprise).
dwGroupId	+ 4	uint16_t	0 – 65535	Sensor group identifier (gas station, vehicle, etc.).
dwLabelId	+ 6	uint8_t	0 – 20	Sensor ID (sensor number in the group).
iwAxisOrigX	+ 7	int16_t	- 16384... + 16384	Acceleration along the X axis. Instantaneous value
iwAxisOrigY	+ 9	int16_t	- 16384... + 16384	Acceleration along the Y axis. Instantaneous value
iwAxisOrigZ	+ 11	int16_t	- 16384... + 16384	Z-axis acceleration. Instantaneous value
iwAxisFiltX	+ 13	int16_t	- 16384... + 16384	X-axis acceleration. Filtered value
iwAxisFiltY	+ 15	int16_t	- 16384... + 16384	Y-axis acceleration. Filtered value
iwAxisFiltZ	+ 17	int16_t	- 16384... + 16384	Z-axis acceleration. Filtered value
iwAngleZ	+ 19	int16_t	- 90...+90	Z-axis deviation angle from horizontal, 0.01°/bit
iwAngleX	+ 21	int16_t	- 90...+90	X-axis deviation angle from horizontal, 0.01°/bit
iwAngleY	+ 23	int16_t	- 90...+90	Y-axis deviation angle from horizontal, 0.01°/bit
dbDeviceId	+ 25	uint8_t	0xAA	Model ID. For a BTI sensor, this is 0xAA

Appendix K – Connecting the Sensor to an External Device

(mandatory)

Various GPS monitoring equipment, both with and without BLE technology support, can act as an external control device for the BTI BLE wireless fuel level sensor (hereinafter referred to as the "Sensor"). In the absence of BLE support, a BLE sensor reader must be used additionally.

K.1 Configuring the Teltonika FMC125 tracker to receive data from the Sensor

This example used:

• trackerTeltonika FMC125 (firmware version 03.27.13 Rev: 57);

• configurator programTeltonika.Configurator 1.7.72.B.3.29_R.10.

K.1.1 On the “Bluetooth” tab (Fig. K.1): 1.

Turn on the “Enable (visible)” mode;

2. Save the configuration by clicking "Save to device".

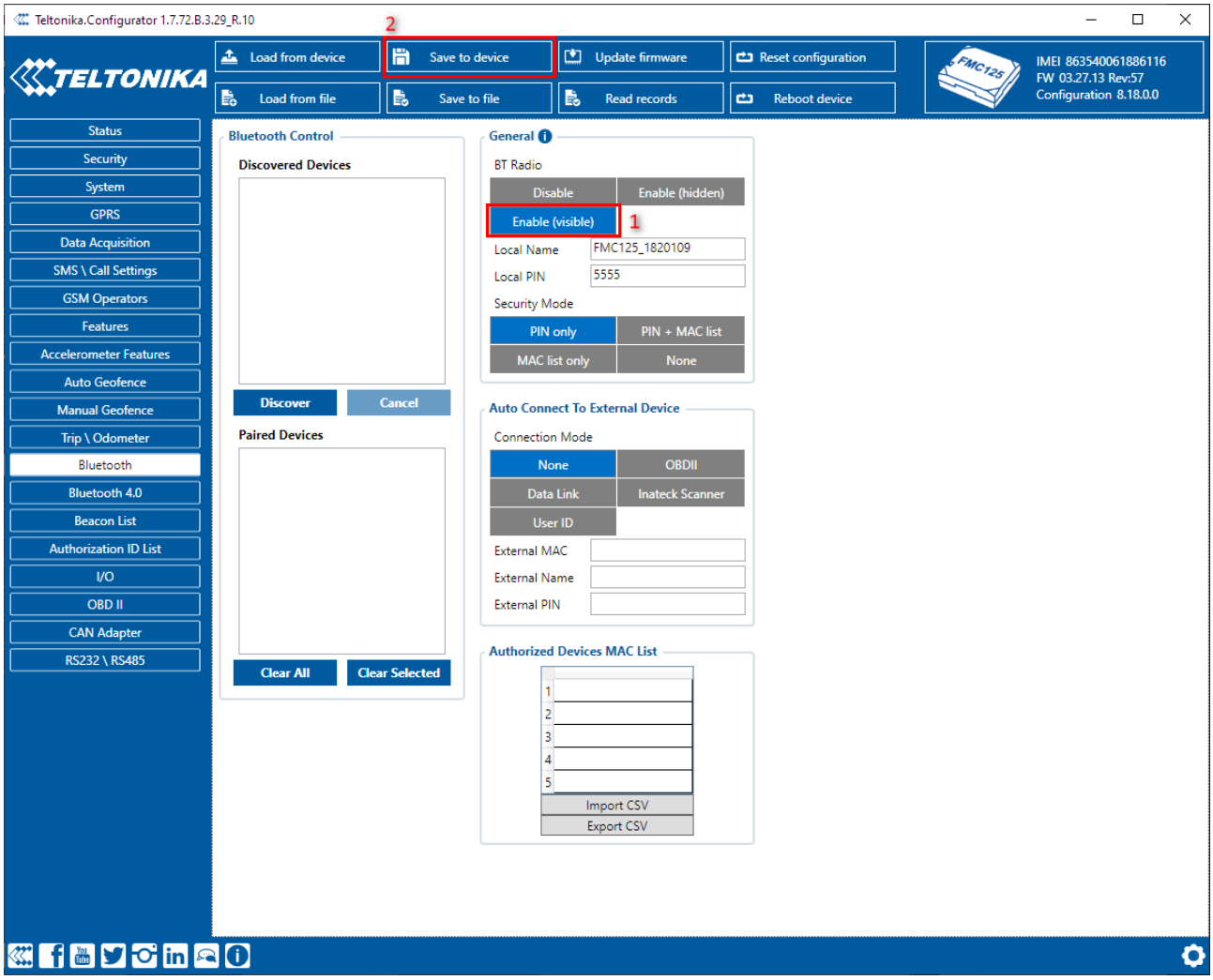


Figure K.1

K.1.2 On the “Bluetooth 4.0” tab, set the parameters (Fig. K.2): 1. “Non Stop Scan” – “Enable”;
2. "BT Power Level" – 7;
3. Save the configuration by clicking "Save to device".

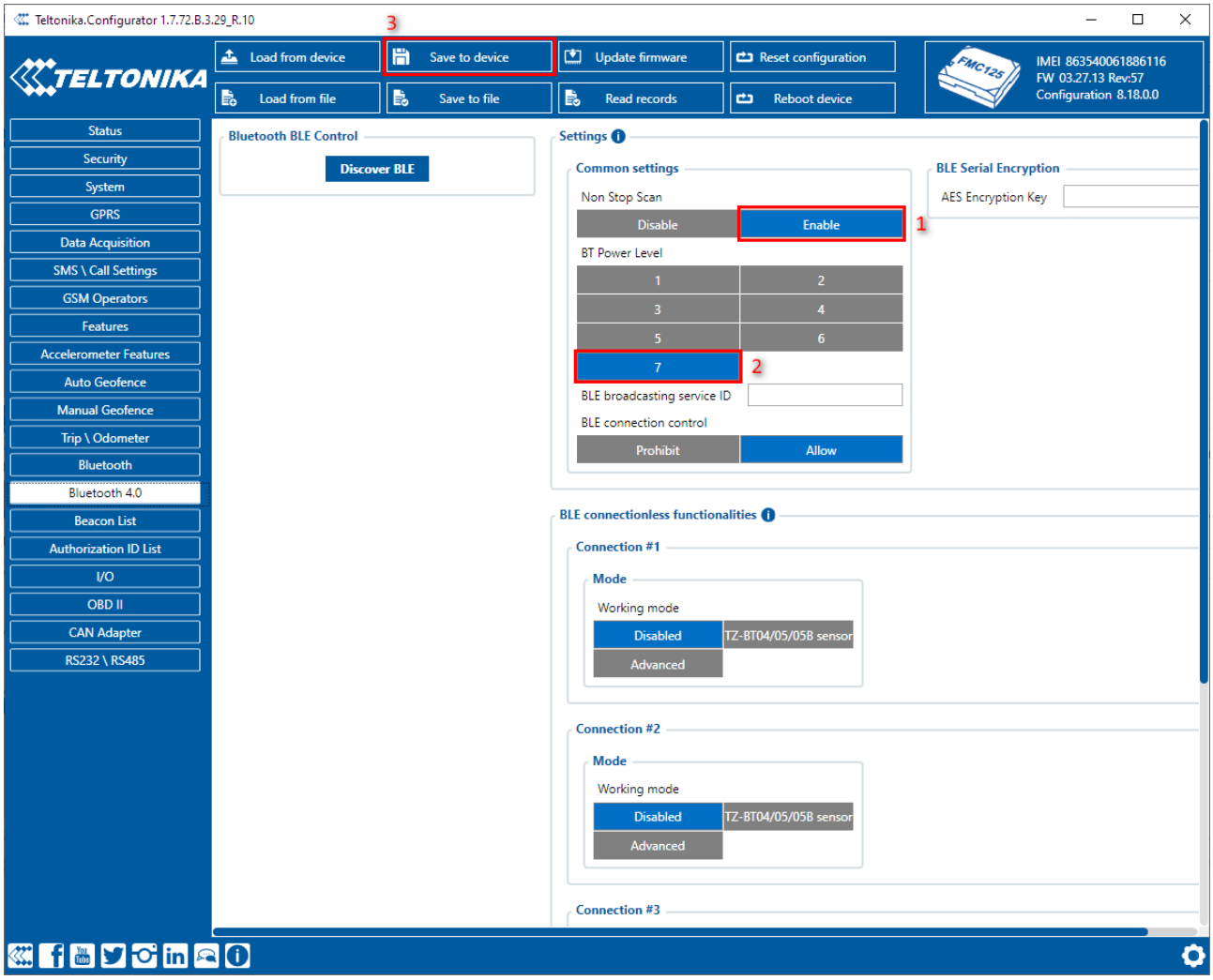


Figure K.2

K.1.3 On the “Bluetooth 4.0” tab (Fig. K.3):

1. Use the “Discover BLE” button to start searching for BLE devices;
2. Find the required Sensor in the list. You can focus on the name and MAC address of the Sensor (you can find them for a specific Sensor using the "BTI_User_Tool" program, see "Appendix A") and the signal strength "Signal Strength" (value in dB). If necessary, copy the required MAC address by clicking the right mouse button.

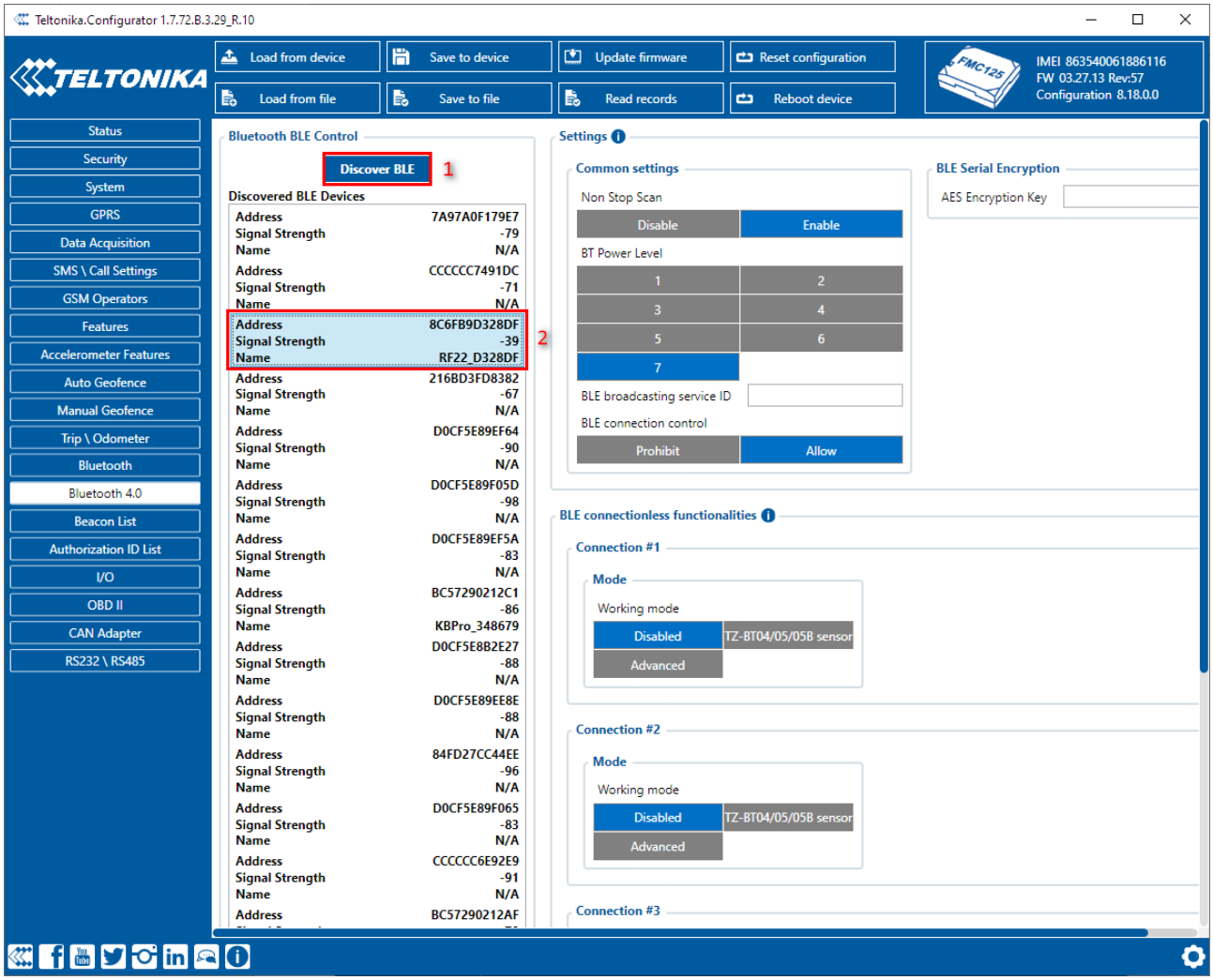


Figure K.3

K.1.4 On the “Bluetooth 4.0” tab (Fig. K.4):

1. In the group of fields “Connection #1” (or #2, #3, #4, you can connect up to 4 Sensors) select “Advanced”;
2. In the "MAC" field, enter the MAC address of the Sensor;
3. In the "Data clear period" field, enter the value of the time period (in seconds) after which, in the absence of a Sensor signal, the BLE I/O data will be cleared. In other words, if the Sensor's ethernet packet was not received within the set time, the values of the deviation angles will be reset to zero. The recommended value is 50 seconds. If the value is 0, the data is not cleared;
4. In the “1st Sensor” field (or “2nd Sensor” for “Connection #2”, etc.), fill in the lines as indicated in the table:

Type	Data Offset	Data Size	Action	IO	Match	Endianness	Multiplier	Offset
FF	0	1	Match	None	E0	Little Endian	1	0
FF	16	1	Save	Battery		Little Endian	1	0
FF	23	1	Save	Custom2		Little Endian	1	0
FF	24	1	Save	Custom3		Little Endian	1	0
FF	25	1	Save	Custom4		Little Endian	1	0
FF	21	1	Save	Custom5		Little Endian	1	0

5. Save the configuration by clicking "Save to device"

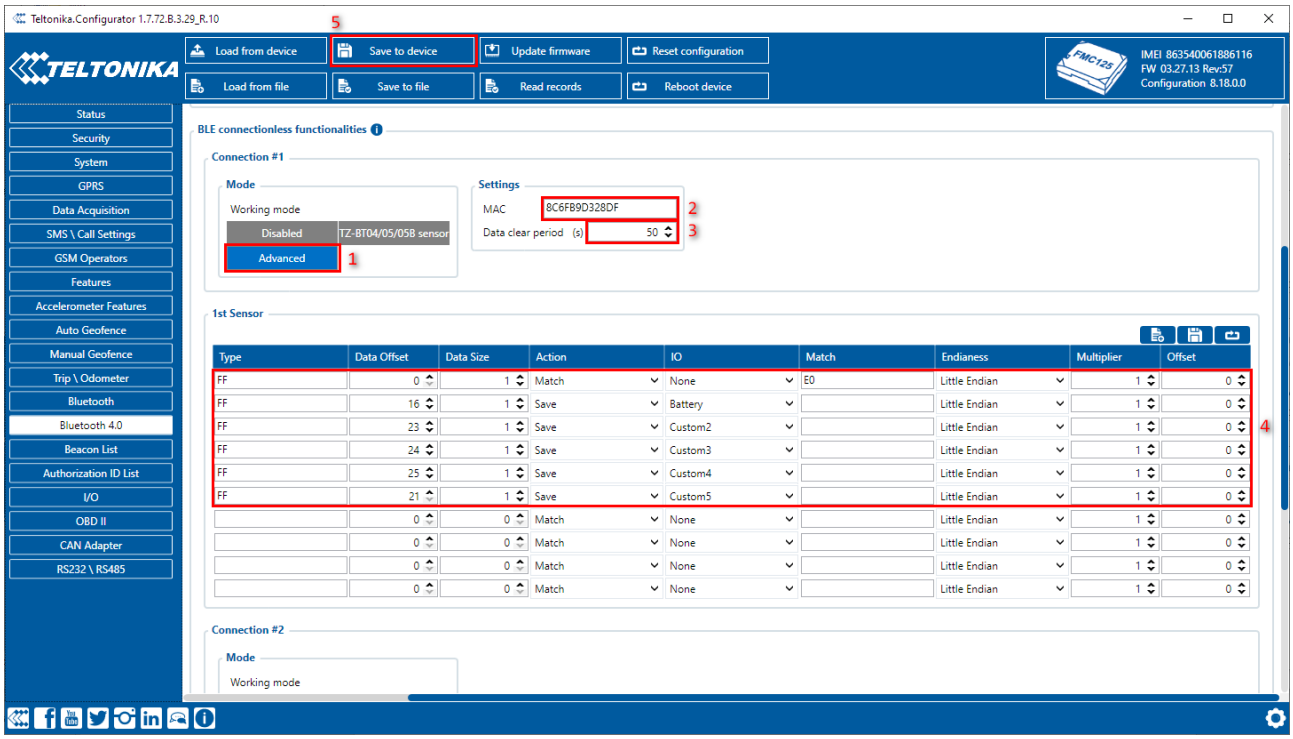


Figure K.4

K.1.5 It is recommended to save the Sensor settings template for future use, to do this:

1. On the “Bluetooth 4.0” tab, click the “Save Preset” button ;
2. Enter the template name and click the "Save" button (Fig. K.5):

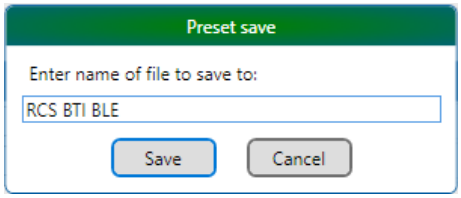


Figure K.5

K.1.6 If it is necessary to connect additional Sensors, repeat items K.1.3 and K.1.4, while entering data into the unoccupied group of fields “Connection #x” – #2, #3 or #4.

If you have a saved template, sub-clause 4 of clause K.1.4 is simplified. To download the template, you must:

1. Go to the desired group of fields "Connection #x" and click the button "Preset list";
2. Select the saved template and click the “Load” button (Fig. K.6):

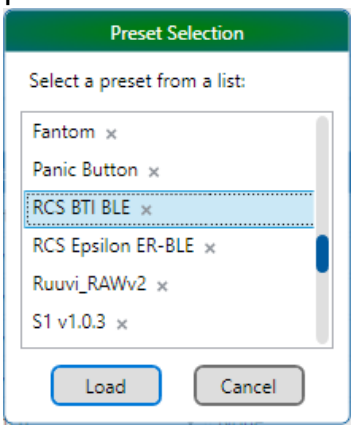


Figure K.6

3. The template will be loaded, the parameter fields will be filled in (Fig. K.7):

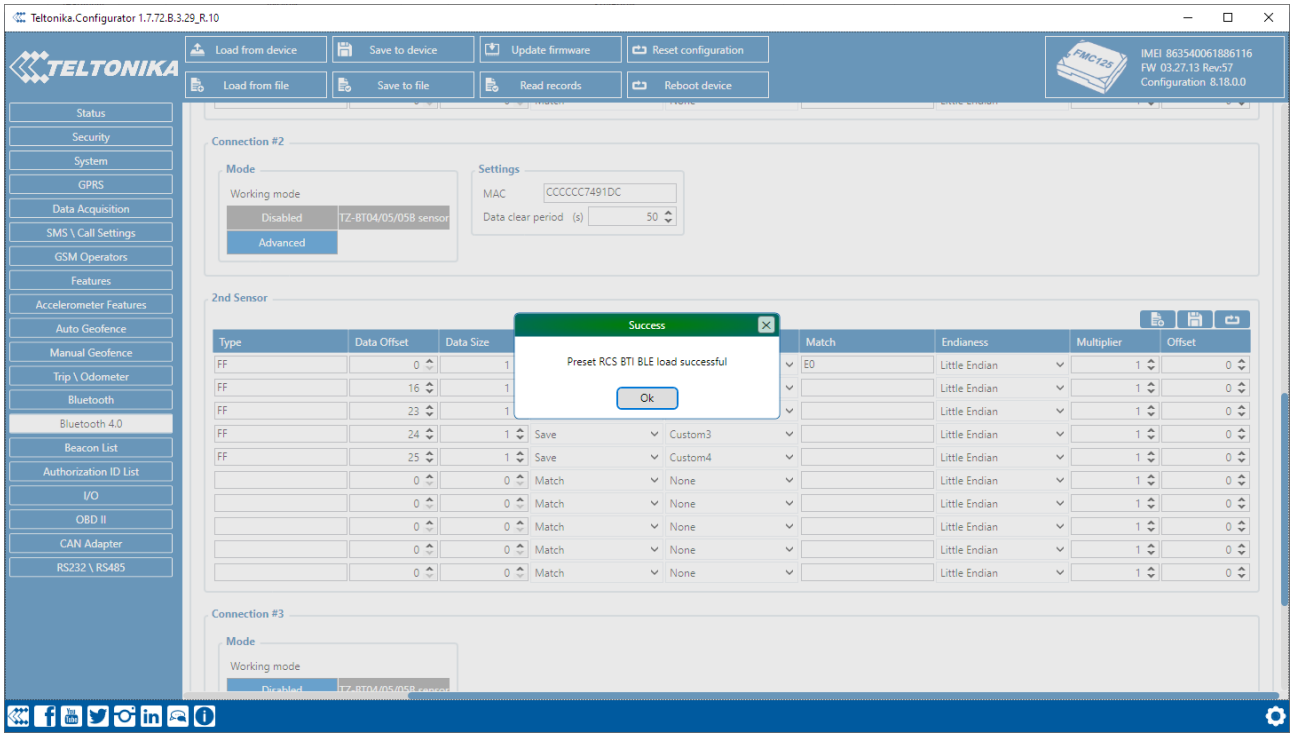


Figure K.7

K.1.7 On the “I/O” tab (Fig. K.8):

To enable data transfer to the server:

To enable data transfer to the server, select the "Low/High" transmission priority:

1. For battery voltage data;
2. For given angles of deviation of the first Sensor;
3. For given angles of deviation of the second Sensor (if necessary);
4. Save the configuration by clicking "Save to device".

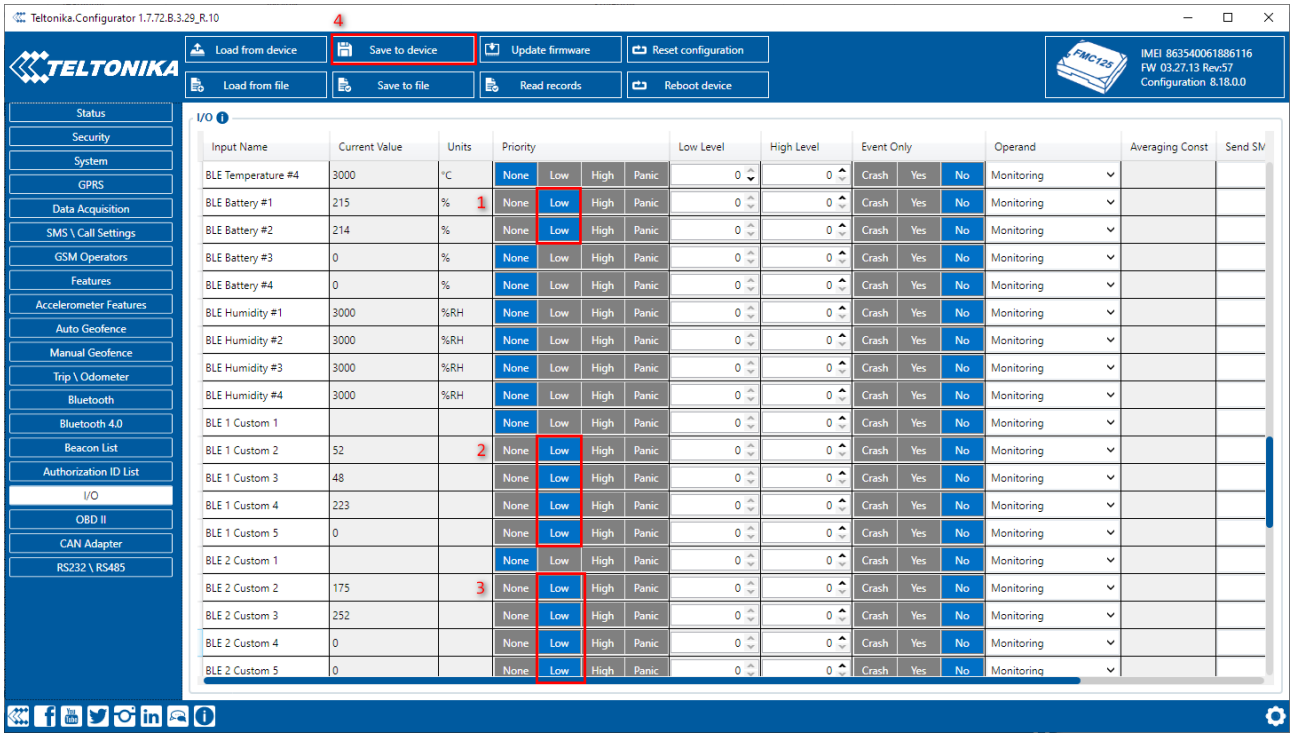


Figure K.8

K.1.8 On the “System” tab (Fig. K.9):

1. In the "Data Protocol" field, select "Codec 8 Extended";
2. Save the configuration by clicking "Save to device".

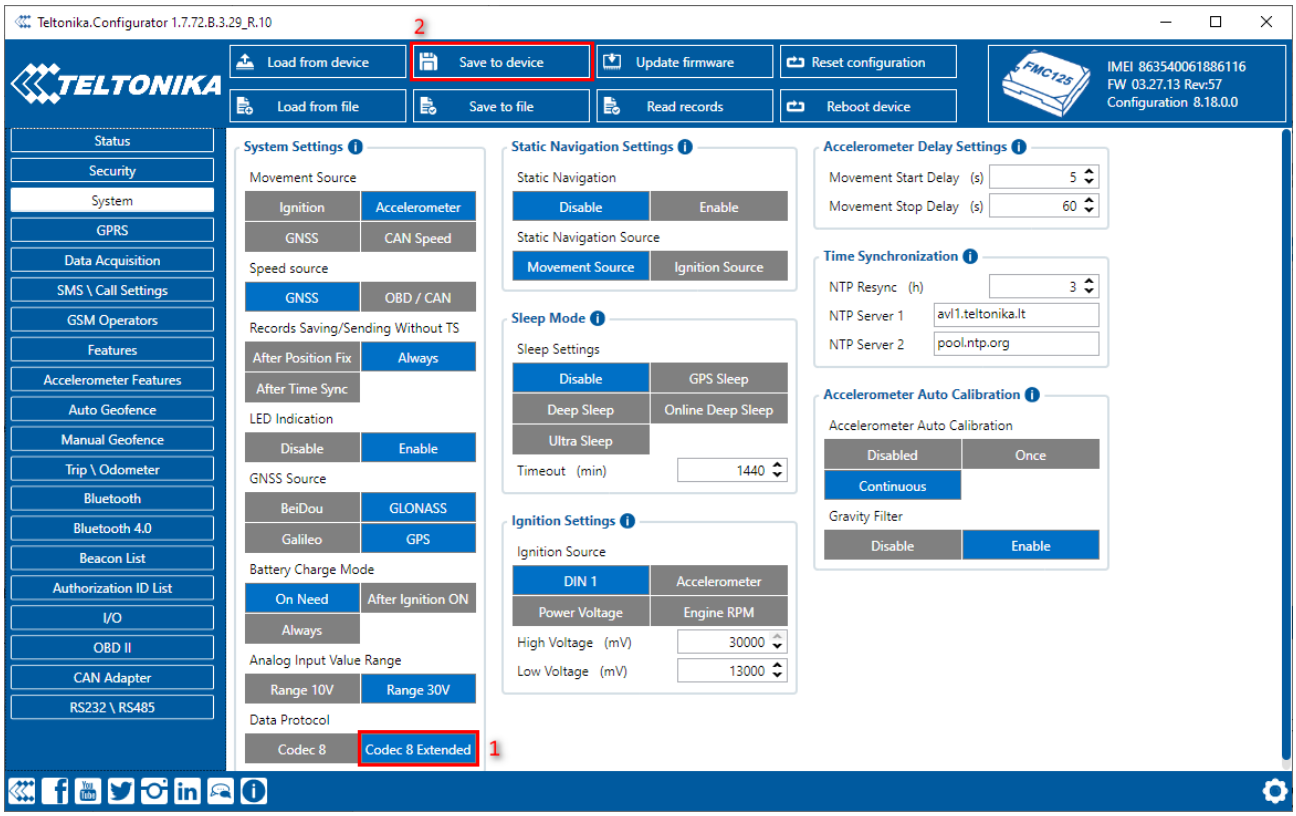


Figure K.9

K.1.9 After the configuration is complete, the I/O elements “BLE #x Custom” will contain the values of the deviation angles (Fig. K.10), namely:

- BLE #x Custom 2 – angle of deviation from the horizontal of the Z axis (signed, additional code, range: -90° ... 90°);
- BLE #x Custom 3 – angle of deviation from the horizontal of the X axis (signed, additional code, range: -90° ... 90°);
- BLE #x Custom 4 – angle of deviation from the horizontal of the Y axis (signed, additional code, range: -90° ... 90°);
- BLE #x Custom 5 – operating modes and mode statuses (see table G.1 Sensor Information PDU Structure).

In the example in Fig. K.10, the BLE 1 Custom 5 field contains the value 49, i.e. 31h in HEX format, or 0b00110001 in binary, where:

- bit field [3:0] (operation mode) is 0b0001, decimal value is 1 – rotation detection mode is activated;
- bit field [7:4] (mode status) is 0b0011, decimal value is 3 – right rotation detected.

The BLE 2 Custom 5 field contains the value 0, i.e. 00h in HEX format, or 0b00000000 in binary, where:

- bit field [3:0] (operating mode) is 0b0000, decimal value is 0 – additional operating mode is not activated (status not applicable);

- bit field [7:4] (mode status) is 0b0000, decimal value is 0 – it does not matter;

To calculate the Sensor battery voltage in the dispatch software, the following formulas should be used with the element "BLE Battery #x" (unsigned):

- U (mV) = (BLE Battery #x)*10+1500 (result in millivolts);
- U (V) = (BLE Battery # x)/100+1.5 (result in volts).

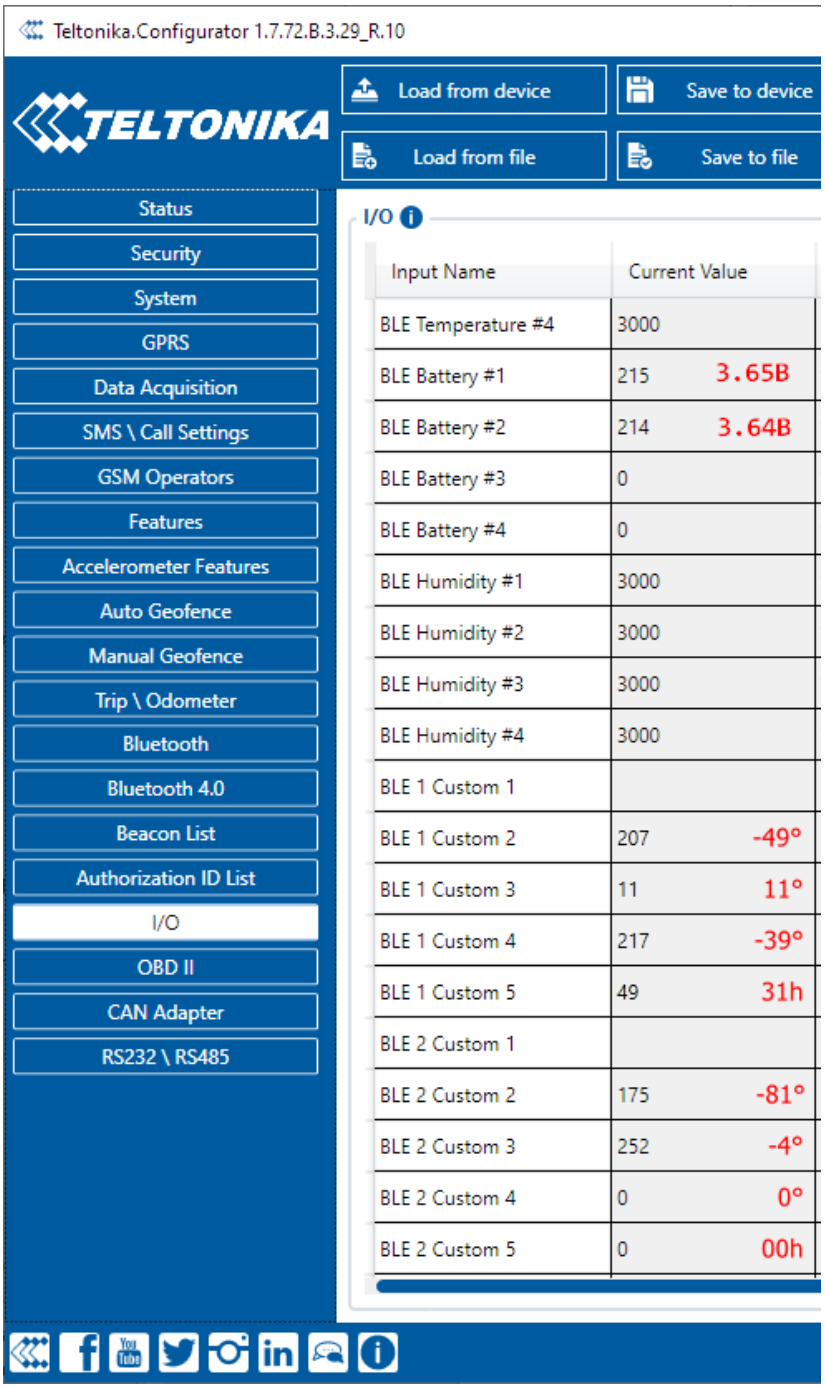


Figure K.10