

Technical and Operational Documentation of the Parking Space Occupancy Sensor “KSK- 150420_P”

Project Name:	Parking Space Occupancy Sensor “KSK-150420_P”
Date:	20-05-2021
Author:	Krzysztof Mrozowski
Owner:	KSK Developments Sp. z o.o. str. ks. Jerzego Badestinusa 39 41-814 Zabrze NIP (Tax ID) 648-277-06-49
Document Number:	DTR/02/21

Change History

Next Update Date:

Update	Previous Update	Summary of Changes
20.05.2021	-	Version 1.0
22.10.2021	20.05.2021	Version 1.1 <ul style="list-style-type: none">Added information about the battery replacement procedure (Chapter 6)
04.02.2021	22.10.2021	Version 1.2 <ul style="list-style-type: none">Completed information on waking the sensor with a magnet and resetting to factory settings.Firmware version upgrade.

Approvals

Full Name	Signature	Approval Date
MSc Eng. Paweł Kasperek		

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1. Device Description

Manufacturer Name	KSK Developments Sp. z o.o. street ks. Jerzego Badestinusa 39 41-814 Zabrze
Device Name	KSK-150420_P
Model	V3 - radar/magnetic detection
Type	A, firmware v4.01

The radar-based vehicle detection system is an innovative tool that allows for easy and convenient monitoring of parking space availability in enclosed parking areas, as well as guiding users to available spots through occupancy indication. The sensor, based on radar detection, is resistant to changing environmental conditions, dirt, etc., ensuring very high detection accuracy. As a secondary detection system, a geomagnetic sensor is used, ensuring a minimum device lifespan of 10 years. The parking management system, through data transmission, can observe real-time parking load and utilization, allowing for effective and informed usage management policies.

The system consists of a set of components, including: parking space occupancy sensors, a gateway, software supporting the LoRa network (LoRa Gateway Bridge, LoRa Network Server, LoRa Application Server), and a system that integrates the output data for the client.

The parking space occupancy sensors are placed in the roadway, at the center of parking spaces. The gateway supporting the LoRa standard requires access to both the electrical and internet networks. It is placed in a location that allows it to cover the detectors installed on the parking lot. The type of gateway and the type of antenna define the maximum distance at which the gateway can be placed from the detectors.

This document describes the construction and operating principle of the parking space occupancy sensors, specifying the components used in the device.

The V3 version of the sensor is equipped with a 17.5Ah battery, which ensures the device operates for at least 5 years. The design of the device allows for the battery to be replaced independently.

Parking Space Occupancy Sensor:

- **Returns information** on whether the parking space is free or occupied.
- **Returns detailed detection data** such as: radar measurement values, values from individual X and Y axes of the geomagnetic sensor.
- **Returns battery voltage data** and the current air temperature.

- **Sends data** via the LoRa network to the central system.
- **Allows configuration of the following parameters:**
 - Detection threshold
 - Stable measurement threshold
 - Radar activation level
 - Stable radar background level
 - Initial radar scan distance
 - Frame life timer
 - Number of LoRa retransmissions
 - Settings for frames with acknowledgements (ACK) or without
 - Number of radar calibration repetitions
 - Maximum difference between calibration scans
 - Number of radar scan repetitions
 - Maximum difference between radar scans
 - Adaptive data rate settings
 - Data range settings from SF7 to SF12
 - Selection of detailed or general detection
 - Enabling sleep mode

2. List of Main Components of the Parking Space Occupancy Sensor

Name	Function	Transmit Power	Frequency Range	Temperature Range
Li-SOCI2 Battery 17500mAh 3.6V LSH20	Power supply for the device	Not applicable	Not applicable	-60°C to 85°C
PCB Board with Device Components	Mechanical part of the device enabling the attachment of the battery, antenna, and electronic components	Not applicable	Not applicable	-60°C to 85°C
Microcontroller with LoRa Communication Module	Manage sensor data and handle wireless communication. Management of the overall operation of the device.	+14dB	868MHz - 915MHz	-40°C to 85°C
Radar Sensor	Verification of parking space occupancy.	+10dBm	57GHz - 71GHz	-40°C to 85°C

Geomagnetic Sensor	Preliminary detection of parking space occupancy.	Not applicable	Not applicable	-40°C to 125°C
868 MHz Antenna	Conversion of electromagnetic waves into an electrical signal and vice versa.	2.4dBi	865-965MHz	-40°C to 80°C
Device Enclosure	Sealed storage of components. Protection against damage.	Not applicable	Not applicable	-40°C to 80°C

3. Parking Space Occupancy Sensor

The parking space occupancy sensors are placed in the roadway, at the center of parking spaces.

3.1. Operating Principle

The central unit of the system is the microcontroller, which runs a program that manages the operation of the device. The program cyclically performs measurements of the Earth's magnetic field changes in the X and Y axes every second. If a deviation greater than the threshold set in the operating parameters occurs, the sensor enters detection mode. The device collects 16 additional measurements while waiting for value stabilization. Once stabilization is achieved, the detection is verified using the radar sensor. If the radar sensor data exceeds the set threshold, the presence of a vehicle is detected.

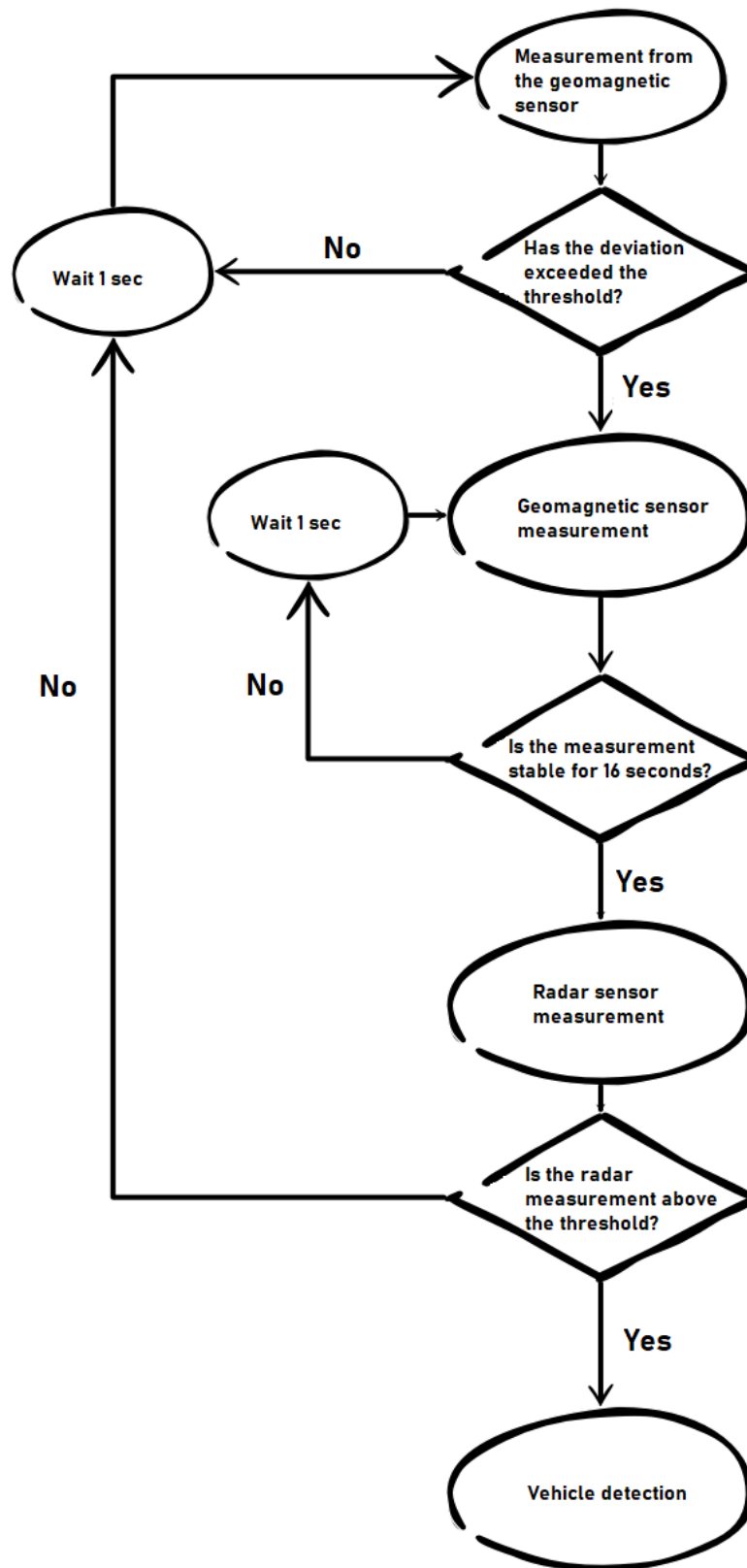
After detecting a vehicle, the sensor wirelessly transmits a data frame. Additionally, according to the set time interval, the sensor sends a 'life' frame containing detailed information about the occupancy status, readings from the geomagnetic sensor, radar, air temperature, and battery voltage.

The sensor can be reset using a magnet. A reed switch is placed in the system, and its closure and then opening trigger a reset of the device. A five-time closure of the reed switch within 2-10 seconds from the last closure will restore the factory settings of the device.

After resetting, the sensor reconnects to the LoRa network. Each sensor has three unique keys used for identification in the LoRa network. To ensure proper operation, the device must be added to the network from the 'Application Server' level.

Once the sensor successfully connects to the network, it sends the following frames: a connection frame, an information frame with the software version, and then the first detection frame.

The operating principle is illustrated by the block diagram:



3.2. Sensor Components

3.2.1. Power Supply

The device is powered by a Li-SOCl₂ battery with a capacity of 17.5Ah, size LSH20 (R20), which, due to its non-standard design, is characterized by stable performance throughout most of the device's service life. All battery cells are enclosed in stainless steel cans, making them resistant to weather conditions. A non-flammable electrolyte is used. The self-discharge rate is below 1%. The device's design allows the user to replace the battery independently.



3.2.2. PCB board of the device containing the electronic components of the unit

All electronic components that make up the device are soldered onto the manufactured PCB board. The 868 MHz antenna is integrated directly as a trace on the PCB.

3.2.3. Microcontroller with LoRa Communication Module

The device uses a central unit — a microcontroller — selected to enable control of all peripheral components and communication via the LoRa protocol. Additionally, the chosen microcontroller features low power consumption.

3.2.4. Radar Sensor

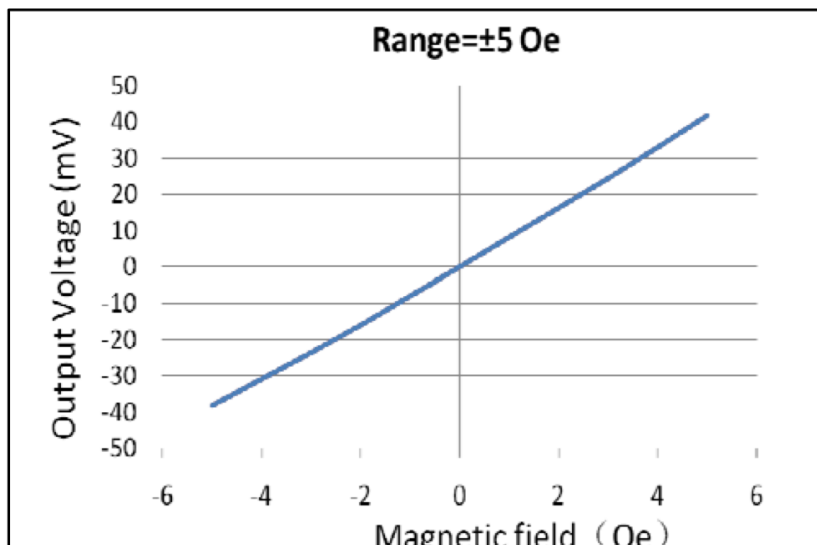
The radar sensor embedded in the device is based on pulsed coherent radar (PCR) technology. The 60 GHz radar system is optimized for high precision and very low power consumption. The RF antenna is integrated directly within the sensor package. The sensor enables distance measurement of obstacles within a range from 2 mm to 2 m.

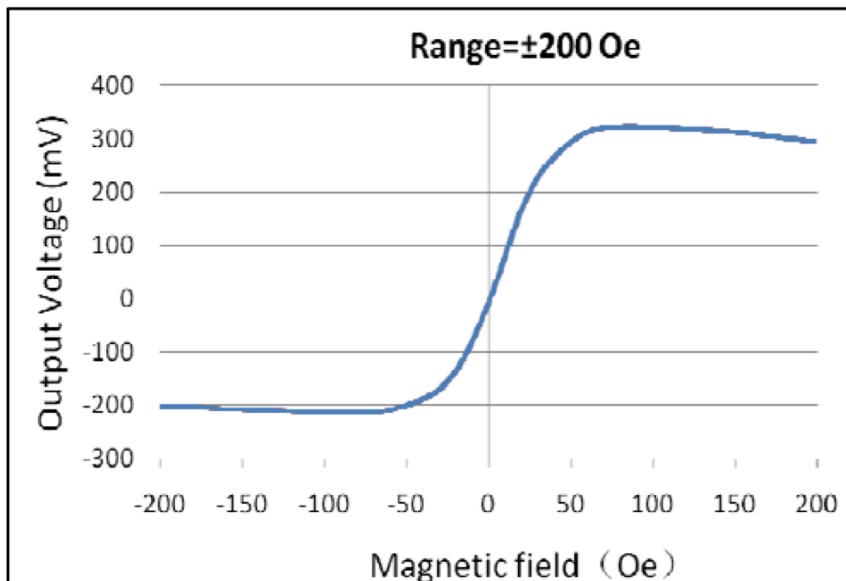
3.2.5. Geomagnetic Sensor

The device utilizes a tunnel magnetoresistance (TMR) sensor, which operates based on a Wheatstone bridge configuration.

This sensor is characterized by high sensitivity, low energy consumption, and high stability under varying ambient temperatures.

The diagram below illustrates the sensor's response to an applied magnetic field in the ranges of ± 5 Oe and ± 200 Oe.





3.2.6. 868 MHz Antenna

The device has an antenna integrated into the PCB, allowing it to operate inside the enclosure. The following parameters characterize the applied antenna:

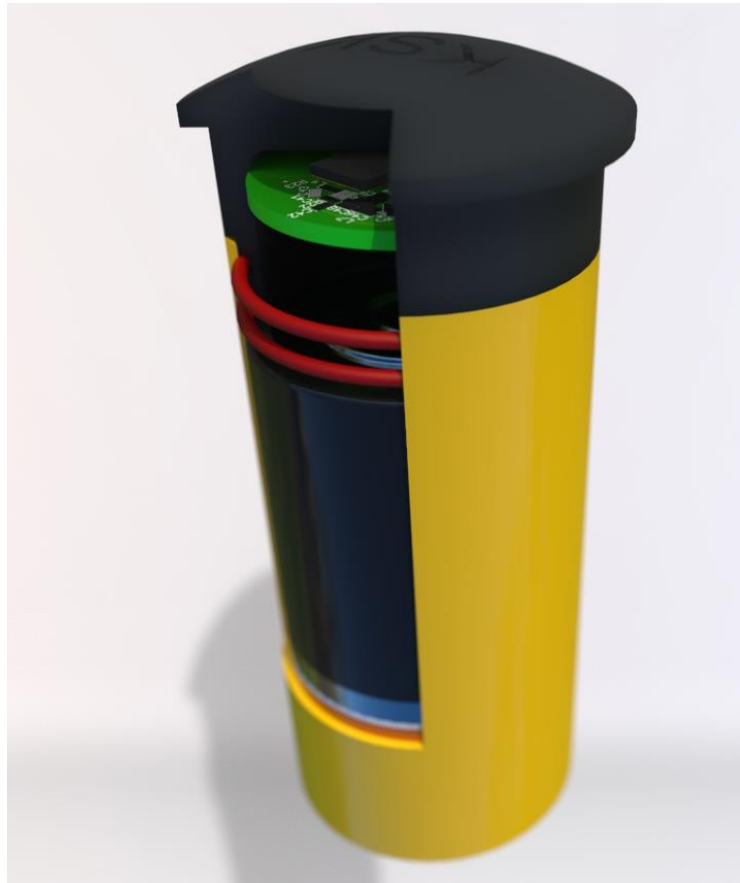
Center Frequency	916 MHz
Recommended Operating Frequency	865-965 MHz
Wavelength	$\frac{1}{4}$ wavelength
VSWR	≤ 2.0 at the center of the operating range
Peak Gain	5dBi
Impedance	50 Ohm
Operating Temperature Range	-40°C do 80°C

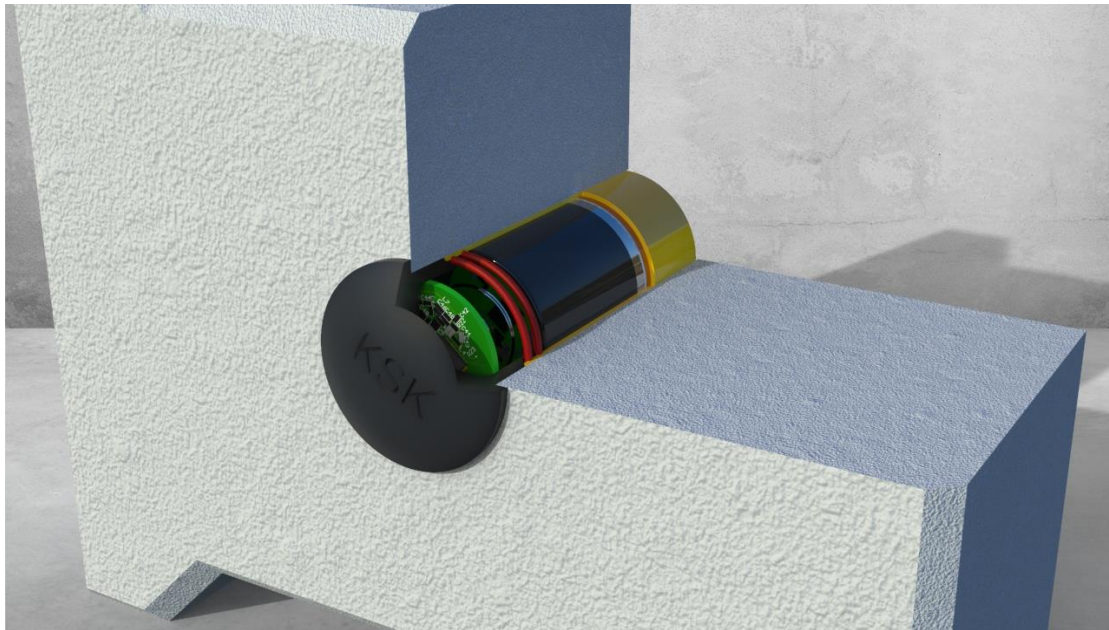
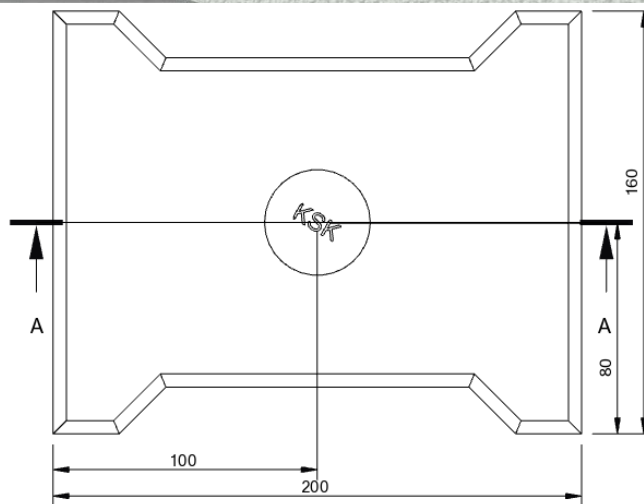
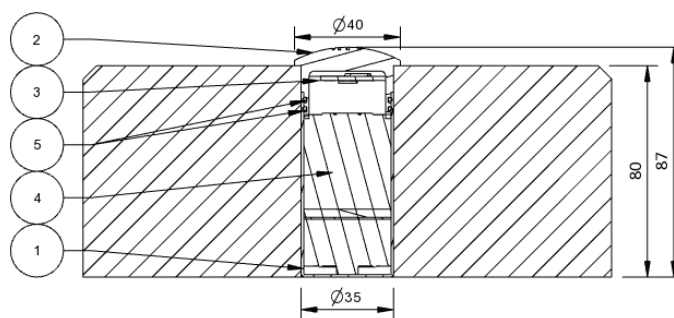
3.2.5. Enclosure

The device enclosure is made of stainless steel and polycarbonate.

Device Dimensions:

Height:	80 mm
Diameter:	35 mm
Weight:	200 g





3.3. Operating Temperature of the Device

Considering the operating temperature values of the components used in the device, it can be concluded that the device should operate correctly in temperatures ranging from -40°C to $+80^{\circ}\text{C}$.

3.5. Electrical Parameters

Supply Voltage	3.6VDC
Current Consumption	120mA (pulse)
Power Supply Circuit Protection	1A
Detection	Magnetic + Radar
Detection Reporting Delay	17s
Temperature Effect	-
Settings	Configurable via downlink frames
Enclosure:	The enclosure is made of PBT polycarbonate, LSR, and stainless steel.
Flammability Class (according to UL 94)	V0
Connection	Wireless LoRaWAN 868 MHz
Protection Rating	IEC IP68
Mechanical Vibration Resistance	IEC 61984 and UL773 Mechanical: 3g, 11 ms half-sine, 18 shocks Vibration: 0.5 mm p-p, 10 to 60 Hz

4. User Manual

Requirements:

The sensor requires a configured multi-channel Gateway in the LoRa network for proper operation, which is connected to the LNS.

In the LNS, the following settings must be selected (example for Chirpstack, similarly for other LNS).

LoRaWAN MAC version *

1.0.2

The LoRaWAN MAC version supported by the device.

LoRaWAN Regional Parameters revision *

B

Revision of the Regional Parameters specification supported by the device.

ADR algorithm *

Default ADR algorithm (LoRa only)

The ADR algorithm that will be used for controlling the device data-rate.

Max EIRP *

20

Maximum EIRP supported by the device.

Uplink interval (seconds) *

21600

The expected interval in seconds in which the device sends uplink messages. This is used to determine if a device is active or inactive.

Before activating the sensor, it must be added (its 3 keys must be loaded) to the LoRa network. Depending on the system used, the payload decoder should be properly configured.

Example Payload Decoder:

```
function Decode(fPort, bytes) {
var decoded = {};
decoded.frameType = fPort;
if(decoded.frameType == 1)
{
    decoded.x = 256*bytes[0]+bytes[1];
    if(decoded.x > 32768)
    {
        decoded.x = -1*(65535 - decoded.x);
    }
    decoded.y = 256*bytes[2]+bytes[3];
    if(decoded.y > 32768)
    {
        decoded.y = -1*(65535 - decoded.y);
    }
    decoded.radar = 256*bytes[4]+bytes[5];
    if(decoded.radar > 32768)
    {
        decoded.radar = -1*(65535 - decoded.radar);
    }
    decoded.temperature = 256*bytes[6]+bytes[7];
    if(decoded.temperature > 32768)
    {
        decoded.temperature = -1*(65535 - decoded.temperature);
    }
    decoded.battery = 256*bytes[8]+bytes[9];
    decoded.isBusy = bytes[10];
}
if(decoded.frameType == 2)
{
    decoded.rejoinStatus = bytes[0];
    decoded.rejoinCount = bytes[1];
}
if(decoded.frameType == 0x03)
{
    decoded.TMRDetectionThreshold = 256*bytes[0]+bytes[1];
}
```

```

    decoded.TMRStableThreshold = 256*bytes[2]+bytes[3];
    decoded.RadarThresholdHigh = 256*bytes[4]+bytes[5];
    decoded.RadarThresholdLow = 256*bytes[6]+bytes[7];
    decoded.RadarStart = 256*bytes[8]+bytes[9];
    decoded.RadarEnd = 256*bytes[10]+bytes[11];
    decoded.LiveFrameInterval = 256*bytes[12]+bytes[13];
    decoded.RetransmissionAmount = 256*bytes[14]+bytes[15];
    decoded.Flags = 256*bytes[16]+bytes[17];
    decoded.CalibrationRepeat = 256*bytes[18]+bytes[19];
    decoded.CalibrationDifference = 256*bytes[20]+bytes[21];
    decoded.MeasurementRepeat = 256*bytes[22]+bytes[23];
    decoded.MeasurementDifference = 256*bytes[24]+bytes[25];
    /*decoded.FrameTimePeriod = 256*bytes[26]+bytes[27];
    decoded.FrameTimeAmount = 256*bytes[28]+bytes[29];*/
}
if(decoded.frameType == 0x04)
{
    decoded.ADRon = bytes[0];
}
if(decoded.frameType == 0x05)
{
    decoded.DataRateMIN = bytes[0];
    decoded.DataRateMAX = bytes[1];
}
if(decoded.frameType == 0x06)
{
    decoded.DetectionDetails = bytes[0]
}
if(decoded.frameType == 0x07)
{
    decoded.IsBusy = bytes[0];
}
if(decoded.frameType == 0x08)
{
    decoded.isBusy = bytes[0];
    decoded.radar = 256*bytes[1]+bytes[2];
    if(decoded.radar > 32768)
    {
        decoded.radar = -1*(65535 - decoded.radar);
    }
    decoded.x = 256*bytes[3]+bytes[4];
    decoded.y = 256*bytes[5]+bytes[6];
    if(decoded.x > 32768)
    {
        decoded.x = -1*(65535 - decoded.x);
    }
    if(decoded.y > 32768)
    {
        decoded.y = -1*(65535 - decoded.y);
    }
}
if(decoded.frameType == 0x0B)
{
    decoded.version = bytes[0];
    decoded.compilation = bytes[1];
    decoded.pcb = String.fromCharCode(bytes[2]);
    if(bytes[3] == 0x01)
    {
        decoded.hardware = 'TMR';
    }
    else
    {
        decoded.hardware = 'AMR';
    }
    decoded.battery = 256*bytes[4]+bytes[5];
    decoded.resetCode = bytes[6];
}
if(decoded.frameType == 0x21)
{

```

```

    if(bytes[0] == 1)
    {
        decoded.joinType = "OTAA"
    }
    else
    {
        decoded.joinType = "ABP"
    }

}

if(decoded.frameType == 0x14)
{
    decoded.detectionOnStateChange = bytes[0];
}

return decoded;
}

```

Sensor Wake-Up

Each sensor is by default set to a sleep state (it will not send frames until it is awakened). To wake up the sensor, apply a magnet to the sensor **5 times within 20 seconds (for 1s - 1.5s each time)**.

Approximately 40 seconds after reset, the sensor should connect to the network and then start sending frames with data.

After the reset, the sensor will send a connection frame, a software version frame, and a detection frame.

Subsequent detection frames will only be sent when the sensor detects a change in the magnetic field (vehicle entry, exit, or passage).

Every 6 hours, the sensor will send a "life" frame.

Frames sent from the LNS are in the following format:

Example JSON (frame 0x0B):

```

{"applicationID": "1", "applicationName": "parkingApp", "deviceName": "WL_2703", "devEUI": "0650534e7e394d20", "rxInfo": [{"gatewayID": "fcc23dffe2ec3e2", "uplinkID": "ff0bb844-8761-455f-8a3a-91bf8494bcb8", "name": "LorixOne", "rssi": -64, "loRaSNR": 8.2, "location": {"latitude": 0, "longitude": 0, "altitude": 0}], "txInfo": {"frequency": 867900000, "dr": 5}, "adr": false, "fCnt": 2, "fPort": 11, "data": "AwhEAQD+Ag==", "object": {"battery": 254, "frameType": 11, "hardware": "TMR", "kompilacja": 8, "pcb": "D", "resetCode": 2, "wersja": 3}}

```

Example JSON (Frame 0x07):

```

{"applicationID": "1", "applicationName": "parkingApp", "deviceName": "WL_2703", "devEUI": "0650534e7e394d20", "rxInfo": [{"gatewayID": "fcc23dffe2ec3e2", "uplinkID": "2dd9a86d-c3d9-4f63-9286-8799076e2b8d", "name": "LorixOne", "rssi": -53, "loRaSNR": 8.5, "location": {"latitude": 0, "longitude": 0, "altitude": 0}], "txInfo": {"frequency": 867300000, "dr": 5}, "adr": false, "fCnt": 3, "fPort": 7, "data": "AA==", "object": {"IsBusy": 0, "frameType": 7}}

```

At the end of each frame, there is an object – a decoded frame with values characteristic of the specific type of frame. Below are the frame types along with their fields.

Frame Types:

Life status

Identifier: 0x001

Sending frequency: 6h (can be changed)

Byte	Bit	Length	Description	MQTT Label	Limit
1		16	Resulting differential value of the X axis of the magnetometer	x	0xFFFF
3		16	Resulting differential value of the Y axis of the magnetometer	y	0xFFFF
5		16	Resulting measurement value from the radar	radar	0xFFFF
7		16	Temperature	temperature	
9		16	Battery status under load	battery	0xFFFF
11		8	Occupancy status	isBusy	

Configuration Settings

Identifier: 0x003

Transmission Frequency: On request

Byte	Bit	Length	Description	MQTT Label	Limit
1		16	Detection Threshold	TMRDetectionThreshold	0xFFFF
3		16	Stable Measurement Threshold	TMRStableThreshold	0xFFFF
5		16	Radar Sensor Excitation Level	RadarThresholdHigh	0xFFFF
7		16	Radar Sensor Stable Background Level	RadarThresholdLow	0xFFFF
9		16	Radar Scan Start Distance	RadarStart	0xFFFF
11		16	Radar Scan End Distance	RadarEnd	0xFFFF
13		16	Frame Life Timer	LiveFrameInterval	0xFFFF
15		16	LoRa Retransmission Count	RetransmissionAmount	0xFFFF
17		16	Flags	Flags	
	5		LoRa ACK		Enable - 10010
	6		LoRa ACK detection		Enable - 10020
	7		EEPROM format		Enable - 10040
19		16	Radar Calibration Repeat Count	CalibrationRepeat	0xFFFF
21		16	Maximum Difference Between Calibration Scans	CalibrationDifference	0xFFFF
23		16	Radar Scan Repeat Count	MeasurementRepeat	0xFFFF
25		16	Maximum Difference Between Radar Scans	MeasurementDifference	0xFFFF

Configuration ADR

Identifier: 0x004

Sending frequency: on request

Byte	Bit	Length	Description	MQTT Label	Limit
1		8	ADR ON/OFF Enabling ADR activates SF12	ADRon	1 - OFF 2 - ON

Data Range Settings

Identifier: 0x005

Transmission frequency: On request

Byte	Bit	Length	Description	MQTT Label	Limit
1		8	Data rate min	DataRateMIN	0-5
2		8	Data rate max	DataRateMAX	0-5

Detailed Detection Settings

Identifier: 0x006

Transmission frequency: On request

Byte	Bit	Length	Description	MQTT Label	Limit
1		8	ON/OFF	DetectionDetails	1 - OFF 2 - ON

General Detection Frame

Identifier: 0x007

Transmission frequency: Detection

Byte	Bit	Length	Description	MQTT Label	Limit
1		8	Sensor Occupancy	IsBusy	Brak detekcji - 0 Czujnik zajęty - 1

Detailed Detection Frame

Identifier: 0x008

Transmission frequency: Detection

Byte	Bit	Length	Description	MQTT Label	Limit
1		8	Sensor Occupancy	isBusy	No Detection - 0 Sensor Occupied - 1
2		16	Radar Level	radar	
4		16	Resulting Differential Value of the X-Axis Magnetometer	x	
6		16	Resulting Differential Value of the Y-Axis Magnetometer	y	

Software Version

Identifier: 0x0B

Transmission Frequency: Upon restart

Byte	Bit	Length	Description	MQTT Label	Limit
1		8	Version	wersja	
2		8	Compilation	compilation	
3		16	PCB Version	pcb	
5		16	Battery Status (No Load)	battery	
7		8	Reset Cause	resetCode	00 - Sub-GHz radio reset flag 01 - Option Byte Loader reset flag 02 - Pin reset flag (NRST pin) 03 - BOR reset flag 04 - Software Reset flag 05 - Watchdog reset flag 06 - Window watchdog reset flag 07 - Low-Power reset flag 11 - N/A

Sleep Frame

Identifier: 0x10

Sending Frequency: None

Byte	Bit	Length	Description	State	Resolution	Limit
1		8	On			01 – sleep mode activation

Factory Reset

Within 20 seconds, place a strong magnet against the sensor 5 times (for 1 to 1.5 seconds each).

Then, within the next 20 seconds, hold the magnet against the sensor for 3 seconds, remove it for 3 seconds, and then place it again for another 3

seconds.

5. Sensor Installation

1. Determine the sensor installation location. By default, the sensor is mounted in the center of the parking space.
2. Drill a hole with a 35 mm diameter drill bit to a depth of 80 mm. The sensor's size is designed to match the standard paving stone thickness. If the hole is deeper, the space beneath the sensor may be filled with sealing compound, as described in points 3 and 4.
3. The asphalt-based sealing compound can be applied either directly from container A (or another suitable vessel) or mechanically using a special gun. Components A and B of the sealing agent must be mixed together. Add the separately packaged component B to container A and mix with an appropriate electric mixer until a homogeneous mass is achieved.



4. Place the prepared compound into the hole for the sensor. Adjust the amount of the compound according to the hole size so that the sensor is flush with the asphalt or paving stones.

Alternatively, the prepared hole can be backfilled with moisture-curing repair asphalt. **Bitumix WET-REP** can be applied after cleaning the area of loose materials and debris. The surface must be dry or slightly damp. The edges of the joints should be pre-coated with a thin layer of primer (approx. 0.25–0.50 kg/m²) to ensure better adhesion of the material. Then, the application can begin.

When applying in low temperatures, the material should be stored at room temperature beforehand to reach optimal consistency. Additional heating is not necessary.

Bitumix WET-REP should be applied slightly overfilled and spread without compacting the material. Moistening of the Bitumix WET-REP is necessary. The material should be compacted using a tamper. **The amount of material should be adjusted so that the**

sensor is level with the asphalt or paving surface.



5. Apply a small amount of bituminous compound around the perimeter (under the top cap) and on the bottom of the sensor. This will help level the contact surface and ensure proper adhesion.
6. Place the sensor into the hole.

6. Battery Replacement

6.1. Battery Placement Method in the Sensor

The battery in the sensor is placed with the positive terminal (+) facing downward, as shown in the photos below:



6.2. Battery replacement using a paving stone gripper (recommended method)

Using a paving stone gripper, remove the paving stone with the sensor. Then, from the bottom, gently push out the sensor and remove the plastic cover. Afterward, take out and replace the battery. The orientation of the battery is shown in section 6.1.





6.3. Battery replacement by removing/prying off the cap (with special care).

Gently pry off the sensor cap and then open it.

Next, remove and replace the battery. The battery orientation is shown in section 6.1.



It should be emphasized that this method of battery replacement is **NOT RECOMMENDED**, as it requires the operator to maintain the cleanliness of the sealing surfaces, which can be challenging in field conditions. Special attention must be paid to ensure that both the cap

surface and the paver are free from any dirt. During the cap installation, make sure the metal casing is properly centered with respect to the cap to avoid the O-ring being flipped.