

Exposure Calculation Report

IoT Solutions

Model: IOTPAK_SURFACE_SIGFOX-868

In accordance with EN 50665

Prepared for: IoT Solutions Ltd
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EXECUTIVE SUMMARY

The calculation of exposure for this product was found to be compliant at a minimum distance of 20 cm with EN 50665 assuming continuous exposure of 6 minutes or more. If alternative antennas are used with greater gains, the distance must be recalculated.



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1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	22 January 2025

Table 1

1.2 Introduction

Applicant	IoT Solutions Ltd
Manufacturer	IoT Solutions Ltd
Model Number(s)	IOTPARK_SURFACE_SIGFOX-868
Hardware Version(s)	52
Software Version(s)	radio_test_iotpark_52832_v1_0
Specification/Issue/Date	<ul style="list-style-type: none">• EN 50665:2017 Generic standard for assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)•
Order Number	00460
Date	12-December-2024
Related Document(s)	<ul style="list-style-type: none">• European Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), Official Journal, L199, of 1999-7-30, p.59-70.• EN 62311:2008 Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz to 300 GHz)• Directive 2013/35/EU on minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

1.3 Brief Summary of Results

The wireless device described within this report was compliant with the restrictions related to human exposure to electromagnetic fields for both general public and worker/occupational exposures.

The calculations shown in this report were made in accordance with the procedures specified in the applied test specification(s).

1.4 Product Information

1.4.1 Technical Description

The IoT Solutions SIGFOX Parking Sensor is a battery-operated parking lot sensor that detects vehicles using radar and magnetometer technologies. Occupancy states are reported to the cloud via a SIGFOX transceiver. Configuration and debugging of the device is carried out using BLE.

1.4.2 Transmitter Description

The following radio access technologies and frequency bands are supported by the equipment under test.

Radio Access Technology	Frequency Band (MHz)	Minimum Frequency (MHz)	Output Power (dBm)	Duty Cycle (%)
Pulsed Coherent Radar Sensor	57000-64000	57000	4	2
Bluetooth Low Energy	2402-2480	2402	4	32
SIGFOX Radio Transceiver	700-960	700	14	100

Table 2 – Transmitter Description

Note: Transmitter power includes upper bounds of uncertainty therefore maximum values are used in accordance with Section 2.5.

1.4.3 Antenna Description

The following antennas are supported by the equipment under test.

Radio Access Technology	Antenna Model	Gain (dBi)	Antenna length (cm)	Minimum Separation Distance (cm)
Pulsed Coherent Radar Sensor	Folded dipole antennas, integrated in package (AiP)	6.00	1.30	20
Bluetooth Low Energy	PCB Trace	4.33	3.05	20
SIGFOX Radio Transceiver	Quectel YFCA002HA	-1.00	11.90	20

Table 3 – Antenna description



In the case of more than one type of antenna being supported by the equipment, the calculation is based on the maximum of the antenna gains. If other antennas can be used that have greater gains, the minimum separation distances will need to be recalculated.

Note: Antenna gain includes upper bounds of uncertainty therefore maximum values are used in accordance with Section 2.5.

1.4.4 Equipment Configuration

Simultaneous transmissions:

- BLE (2.4 GHz) & Radar (60 GHz)
- BLE (2.4 GHz) & SIGFOX Radio (920.8 MHz)

The worst case has been calculated as BLE & SIGFOX, so this has been included in the combined TX section.

2 Assessment Details

2.1 Assessment Method

The assessment method is by calculation of the power density S, electric field strength E, magnetic field strength H or magnetic flux density B.

The calculation uses the spherical model applicable under far field conditions and also radiating near field conditions where applicable (see Section 2.4).

$$S = E \times H = \frac{E^2}{\eta} = H^2 \times \eta = \frac{P \times G_i}{4 \times \pi \times r^2}$$

Where:

η - Impedance of free space (377 ohm in far field)

P – Average transmitter power W ($P_{av} = P_{max} \times \text{Duty Cycle}$)

G_i – Antenna gain ratio relative to isotropic

r – Separation distance m

The magnetic flux density is related to the magnetic field strength by a constant:

$$B = \mu_0 \times H$$

Where:

μ_0 – Permeability of free space $4 \times \pi \times 10^{-7}$ H/m

This assessment assumes that exposure is continuous for 6 minutes or more in accordance with the averaging time required by the exposure standards at the stated minimum compliance boundary separation distance. Exposures of less than 6 minutes at other separation distances are not addressed by this report.

This assessment method of RF exposure is applicable to separation distances of 20 cm or more beyond the reactive near field boundary. Separation distances of less than 20 cm require a Specific Absorption Rate (SAR) assessment.

The reactive near field boundary and far field region boundary depend on the frequency and wavelength and also on the antenna dimension. The boundaries of the field regions are calculated in Section 2.4 to demonstrate the validity of using the spherical model.

The result is compared to the limits in Annex A to determine compliance or to calculate the required compliance distance. The calculation is based on the lowest frequency in each band as the most onerous requirement as the limits increase with frequency for frequencies above 10-50 MHz (dependent on region).



2.2 Individual Antenna Port Exposure Results

2.2.1 Calculation of Exposure at Specified Separation Distance

The frequencies shown in the tables below have been chosen based on the lowest possible frequency that the EUT can transmit. A full list of the regional requirements is shown in Annex A.

RAT	Frequency (MHz)	RF Exposure Level at minimum compliance boundary of 0.2 m							
		S Power Density (W/m ²)		E Field (V/m)		H Field (A/m)		B Field (μT)	
		Result	Limit	Result	Limit	Result	Limit	Result	Limit
Radar Sensor	57000.0	0.0004	50	0.39	140.00	0.0010	N/A	0.0013	0.4500
BLE	2402.0	0.0043	N/A	1.28	140.00	0.0034	N/A	0.0043	0.4500
SIGFOX	700.0	0.0397	N/A	3.87	79.37	0.0103	N/A	0.0129	0.2646

Table 4 – Worker/Occupational Individual Transmitter Result

The calculations show that the EUT complies with the worker/occupational exposure levels described in the listed specifications in Annex A at the point of investigation, a minimum distance of 0.2 m.

RAT	Frequency (MHz)	RF Exposure Level at minimum compliance boundary of 0.2 m							
		S Power Density (W/m ²)		E Field (V/m)		H Field (A/m)		B Field (μT)	
		Result	Limit	Result	Limit	Result	Limit	Result	Limit
Radar Sensor	57000.0	0.0004	10.00	0.39	61.00	0.0010	0.1600	0.0013	0.2000
BLE	2402.0	0.0043	10.00	1.28	61.00	0.0034	0.1600	0.0043	0.2000
SIGFOX	700.0	0.0397	3.50	3.87	36.38	0.0103	0.0979	0.0129	0.1217

Table 5 – General Public Individual Transmitter Result

The calculations show that the EUT complies with the general public exposure levels described in the listed specifications in Annex A at the point of investigation, a minimum distance of 0.2 m.



2.3 Combined Antenna Port RF Exposure Results

As the frequency of operation for each transmitter is not the same, in order to evaluate compliance with the limit which is dependent on frequency, the fractional exposure value is calculated: The calculated S power density is divided by the limit to get a fractional exposure value. The calculated E and H fields are divided by the limit and squared to get a fractional exposure value. The summation of the fractional RF exposure results for each transmitter provides the combined result. Any values less than one are compliant with the limit.

Calculations are made on an Excel spreadsheet and numbers may not add up exactly due to rounding.

EN 62311:2008 specifies the method of summation in clause 8.3 with results as follows:

RAT	Frequency (MHz)	Calculated RF exposure level at minimum compliance boundary of 0.2 m as a fraction of the limit			
		S Power Density	E Field	H Field	B Field
		Summation for simultaneous exposure; value to be <1			
BLE	2402.0	N/A	0.0001	N/A	0.0001
SIGFOX	700.0	N/A	0.0024	N/A	0.0024
Summation		N/A	0.0025	N/A	0.0025

Table 6 – EN Worker/Occupational Combined Exposure

The calculations show that the EUT complies with the worker/occupational exposure levels described in the listed specifications in Annex A at the point of investigation, a minimum distance of 0.2 m.

RAT	Frequency (MHz)	Calculated RF exposure level at minimum compliance boundary of 0.2 m as a fraction of the limit			
		S Power Density	E Field	H Field	B Field
		Summation for simultaneous exposure; value to be <1			
BLE	2402.0	0.0004	0.0004	0.0004	0.0005
SIGFOX	700.0	0.0113	0.0113	0.0110	0.0112
Summation		0.0118	0.0117	0.0114	0.0117

Table 7 – EN General Public Combined Exposure

The calculations show that the EUT complies with the general public exposure levels described in the listed specifications in Annex A at the point of investigation, a minimum distance of 0.2 m.



2.4 Far Field Region Boundary Results

The far field region boundary calculation result is shown in Table 8

Near Field / Far Field Boundary (Ref: EN 62311:2008)			
RAT Name	Frequency MHz	Reactive Near Field Boundary (Wave Impedance Dependent)	Radiating Near Field Boundary (Antennas on axis)
		$\lambda/4$ (m)	$2D^2/\lambda$ (m)
Radar Sensor	57000.0	0.0013	0.0642
BLE	2402.0	0.0312	0.0149
SIGFOX	700.0	0.1071	0.0661

Table 8 – Far Field Boundary

The table below shows the maximum calculated near field / far field region boundaries.

The compliance boundary of 0.2 m is in the far field region and therefore, the approach described in section 2.1 is valid

Field Region	Reactive Near Field Region	Radiating Near Field Region	Far Field Region $\lambda/4 < r \leq 2D^2/\lambda$ (m)
Maximum Boundary	< 0.1071 m	N/A	> 0.1071 m
Validity of Regions	Spherical model potential under-estimate: SAR / test assessment required	Spherical model over-estimate and conservative	Spherical model valid
Compliance Boundary Location	N/A	N/A	0.2 m

Table 9 – Assessment Method Validity

2.5 Uncertainty

The basic computation formulas presented in section 2.1 are conservative formulas for the estimation of RF field strength or power density.

No uncertainty estimations are required when using these formulas but there is clear guidance on where and when these formulas are applicable. For the estimate of S, E or H to be conservative, the transmitter power P and antenna gain G_i values shall be the upper bounds of uncertainty therefore maximum values are used.

The spherical formula is valid under far field conditions which are established in section 2.4.



ANNEX A

REGIONAL REQUIREMENTS



Frequency Range (MHz)	Power Density (W/m ²)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Magnetic Flux Density (μT)
0.1 - 1	-	610	N/A	2/f
1 - 10	-	610/f	N/A	2/f
10 - 400	-	61	N/A	0.2
400 - 2000	-	$3 \cdot f^{0.5}$	N/A	$1E-2 \cdot f^{0.5}$
2000 - 6000	-	140	N/A	0.45
6000 - 300000	50	140	N/A	0.45

Table A.1 – EN: Action levels in Directive 2013/35/EU Annex III Table B1 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (W/m ²)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Magnetic Flux Density (μT)
0.003 - 0.15	-	87	5	6.25
0.15 - 1	-	87	$0.73/f$	$0.92/f$
1 - 10	-	$87/f^{0.5}$	$0.73/f$	$0.92/f$
10 - 400	2	28	0.073	0.092
400 - 2000	$f/200$	$1.375 \cdot f^{0.5}$	$0.0037 \cdot f^{0.5}$	$0.0046 \cdot f^{0.5}$
2000 - 300000	10	61	0.16	0.2

Table A.2 – EN: Council Recommendation 1999/519/EC Annex II Table 1 General Public Limits