RF-EXPOSURE REPORT

FCC 47 CFR Part 2.1091
ISED RSS-102

Maximum permissible exposure

Report Reference No	G0M-2403-2508-TFC091MP01-V01
Testing Laboratory	Eurofins Product Service GmbH
Address	Storkower Str. 38c 15526 Reichenwalde Germany
Accreditation	A2LA Accredited Testing Laboratory, Certificate No.: 1983.01 FCC Test Firm Designation Number: DE0008 ISED Testing Laboratory site: 3470A
Applicant	Jungheinrich AG
Address	Friedrich-Ebert-Damm 129 22047 Hamburg Germany
Test Specification	According to FCC rules
Standard	FCC 47 CFR 2.1091
Non-Standard Test Method	None
Equipment under Test (EUT):	
Product Description	UWB-Location-System is able to measure distances between the UWB components
Model(s)	52445052, Truck Tag
Additional Model(s)	None
Brand Name(s)	zoneCONTROL
Hardware Version(s)	10625 FS:04
Software Version(s)	0.0.51
FCC-ID	2AK6M-52445052
Test Result	**PASSED**

Possible test case verdicts:		
required by standard but not tested	N/T	
not required by standard	N/R	
test object does meet the requirement	P(PASS)	
test object does not meet the requirement	F(FAIL)	
Testing:		
Test Lab Temperature	20 °C - 30 °C	
Test Lab Humidity	25 % - 55 %	
Date of performance	2024-11-27	
Date of receipt of test item	See test sample identification table on page 7	
Report:		
Compiled by	Stephan Liebich	
Tested by (+ signature) (Responsible for Test)	Stephan Liebich	
Approved by (+ signature) (Senior Radio Expert)	Radwan Jaafar	
Date of Issue	2024-11-27	
Total number of pages	24	
General Remarks:		

The test results presented in this report relate only to the object tested.

The results contained in this report reflect the results for this particular model and serial number. It is the responsibility of the manufacturer to ensure that all production models meet the intent of the requirements detailed within this report.

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The above equipment has been tested by Eurofins Product Service GmbH, and found compliance with the requirements of the above standards. The test record, data evaluation & Equipment Under Test (EUT) configurations represented herein are true and accurate accounts of the measurements of the sample's RF characteristics under the conditions specified in this report.

Compliance of electromagnetic emission from electronic and electrical equipment with the basic restrictions usually is determined by measurements and, in some cases, calculation of the exposure level. If the electrical power used by or radiated by the equipment is sufficiently low, the electromagnetic fields emitted will be incapable of producing exposures that exceed the basic restrictions.

Any relevant compliance assessment procedure which is consistent with the state of the art, reproducible and gives valid results can be used.

For transmitters intended for use with more than one antenna configuration option, the combination of transmitter and antenna(s) which generates the highest available antenna power and/or average total radiated power shall be assessed.
Additional Comments:
RF-Exposure calculation is partly based on measurement results from reference documents.

VERSION HISTORY

Version History			
Version	Issue Date	Remarks	Revised By
01	2024-11-27	Initial Release	--

ABBREVIATIONS AND ACRONYMS

Acronyms	
Acronym	Description
EIRP	Equivalent Isotropic Radiated Power
EUT	Equipment Under Test
MPE	Maximum Permissible Exposure

REPORT INDEX

1 Equipment (Test Item) Under Test

Description	UWB-Location-System is able to measure distances between the UWB components			
Model	52445052, Truck Tag			
Additional Model(s)	None			
Brand Name(s)	zoneCONTROL			
Sample Identification	EUT #	Sample-ID	Serial Number	Date of receipt
	EUT 1	48550	51853934	2024-05-14
	EUT 2	See reference documents	See reference documents	See reference documents
Hardware Version(s)	10625 FS:04			
Software Version(s)	0.0.51			
FCC ID	2AK6M-52445052			
Equipment type	End Product			
Number of antenna ports	2			
Number of radios	2			
Radio 1	Radio type	Transceiver		
	Assigned frequency bands	2400.0 MHz - 2483.5 MHz		
	Radio technology	IEEE 802.15.4		
	Modulation	O-QPSK		
	Port	IF1		
Antenna 1	Type	Integrated		
	Model	PCB Antenna		
	Manufacturer	Siemens		
	Gain	5.97 dBi		
	Port	IF1		
Radio 2	Radio type	Transceiver		
	Assigned frequency bands	3.1 – 10.6 GHz		
	Radio technology	Ultra Wide-band		
	Modulation	BPSK with BPM		
	Port	IF2		
Antenna 2	Type	Integrated antenna		
	Model	PCB Antenna		
	Manufacturer	Siemens		
	Gain	3.47 dBi @ 4.0 GHz 5.65 dBi @ 6.5 GHz		
	Port	IF2		
Supply Voltage	V_{NOM}	24 V DC		
Dedicated AC/DC-Adaptor	None			
Environment	General public			

1.3 Reference Documents

Document Type	Document No.	Issued by	Date
RADIO REPORT	G0M-2403-2508-TFC15FUW-V01	Eurofins Product Service GmbH	2024-11-26
RADIO REPORT	G0M-2403-2508-TFC247ZB-V01	Eurofins Product Service GmbH	2024-11-26
ANTENNA UNDER TEST REPORT	G0M-2403-2508-TFCAUT-V01	Eurofins Product Service GmbH	2024-11-26

1.4 Support Equipment

Product Type	Device	Manufacturer	Model	Comment
AE	Laptop	HP	ProBook	For setting test modes
AE	USB-Serial-Adapter	Agilon	Not specified	--
AE	JH-Tester	Siemens	Tag Mobile	Test hardware to attach the EUTs CAN
CBL	Cable	Siemens	Not specified	From PCB with COM port to EUT
CBL	Connection Cord	Siemens	Not specified	Link between Tester and EUT
CBL	USB Cable	A-B Cable	Not specified	--
SFT	RadioMode Setup Tool v3.1.0	Siemens	Not specified	For setting test modes
Description:				
AE	Auxiliary Equipment			
SIM	Simulator			
CBL	Connecting Cable			
SFT	Software			
Comment: --				

1.5 Test Modes

Mode	Description
Transmit	Mode = Transmit Modulation = BPSK with BPM Duty cycle = 100% Power setting = -6 dB (set by the software provided by customer)
Comment: --	

1.6 EUT Configuration

Configuration #	Description
1	EUT is powered by external power supply with a supply voltage of ~24.0 V DC. Ultra-wide band operates in 2 frequency bands (4 GHz and 6.5 GHz).

1.7 Sample emission level calculation

The following is a description of terms and a sample calculation, as appears in the radiated emissions data table. The numbers used in the calculation are for example only. There is no direct correlation to the specific data taken for the product described in this document:

Reading:

This is the reading obtained on the spectrum analyzer in dBµV. Any external preamplifiers used are taken into account through internal analyzer settings.

A.F.:

This is the antenna factor for the receiving antenna. It is a conversion factor, which converts electric fields strengths to voltages, which can be measured directly on the spectrum analyzer. It is treated as a loss in dB. Cable losses have been included with the A.F. to simplify the calculations. The antenna factor is used in calculations as follows:

Reading on Analyzer (dBµV) + A.F. (dB/m) = Net field strength (dBµV/m)

Net:

This is the net field strength measurement (as shown above).

Margin:

This is the margin of compliance below the FCC limit. The units are given in dB. A negative margin indicates the emission was below the limit. A positive margin indicates that the emission exceeds the limit.

Field strength limit:

This is the FCC Class B radiated emission limit (in units of dBµV/m). The FCC limits are given in units of µV/m. The following formula is used to convert the units of µV/m to dBµV/m:

Field strength limit (dBµV/m) = 20 · log (µV/m)

Example only for radiated field strength:

Reading + AF	= Net Reading	:	Net reading	- Field strength limit	= Margin
+21.5 dBµV	+ 26 dB/m	:	47.5 dBµV/m	- 57.0 dBµV/m	= -9.5

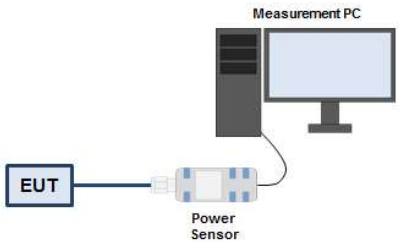
1.8 Test Conditions and Results - Maximum RMS conducted output power

1.8.1 Information

Test Information	
Measurement Uncertainty	± 2.86 dB
Operator	Md Abu Bakar Siddique
Date	2024-11-25
EUT #	EUT 1

1.8.2 Setup

Test Setup



1.8.3 Equipment

Test Equipment					
Description	Manufacturer	Model	Identifier	Cal. Date	Cal. Due
Power meter	Rohde & Schwarz	NRVD	EF00157	2024-07	2026-07
Power sensor	Rohde & Schwarz	NRV-Z51	EF00172	2023-08	2026-08

1.8.4 Procedure

Test Procedure

1. EUT set to test mode
2. The EUT antenna port is connected to a wideband power sensor
3. The RMS power is measured with the power sensor

1.8.5 Results

Test Results		
Channel [GHz]	Power [dBm]	Power [W]
3.9935	-27.45	0.00180
6.4895	-27.21	0.00190

1.9 Power density radiation sources

Mode	Operating Frequency [MHz]	Maximum conducted power [dBm]	Maximum radiated power [dBm EIRP]	Maximum duty cycle [%]	Maximum antenna gain [dBi]	Maximum antenna diameter [cm]
IEEE 802.15.4 (2.4 GHz)	2405	5.868	11.838	100	5.97	N/A
	2440	6.913	12.883	100	5.97	N/A
	2475	5.219	11.189	100	5.97	N/A
UWB (4 GHz)	3993.5	-27.45	-23,98	100	3.47	N/A
UWB (6.5 GHz)	6489.5	-27.21	-21.56	100	5.65	N/A
Comment: --						

1.10 Field strength radiation sources

None

1.11 Concurrent Sources

Concurrent operating conditions
IEEE 802.15.4 (2.4 GHz) + UWB (4 GHz) + UWB (6.5 GHz)
Comment: --

2 Result Summary

FCC MPE Evaluation - Single radiation sources					
Product Standard Reference	**Requirement**	**Reference Method**	**Mode**	**Distance [m]**	**Verdict**
47 CFR 2.1091	Maximum permissible exposure	FCC KDB 447498	IEEE 802.15.4 (2.4 GHz)	0.20	PASS
47 CFR 2.1091	Maximum permissible exposure	FCC KDB 447498	UWB (4 GHz)	0.20	PASS
47 CFR 2.1091	Maximum permissible exposure	FCC KDB 447498	UWB (6.5 GHz)	0.20	PASS
Comment: --					

FCC MPE Evaluation - Multi-transmitter sources					
Product Standard Reference	**Requirement**	**Reference Method**	**Mode**	**Distance [m]**	**Verdict**
47 CFR 2.1091	Maximum permissible exposure	FCC KDB 447498	IEEE 802.15.4 (2.4 GHz) + UWB (4 GHz) + UWB (6.5 GHz)	0.20	PASS
Comment: --					

3 RF-Exposure classification

RF-Exposure Categories	
Fixed	A fixed device is defined as a device physically secured at one fixed location and cannot be easily re-located.
Mobile	A mobile device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons.
Portable	A portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.

RF-Exposure Categories	
Occupational / Controlled	Limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.
General population / Uncontrolled	Exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure.

4 RF-Exposure limits

FCC Limits – General Population / Uncontrolled Exposure				
Frequency range [MHz]	**Electric field strength [V/M]**	**Magnetic field strength [A/M]**	**Power density [W/m²]**	**Averaging time [min]**
0.3 – 1.34	614	1.63	1000	30
1.34 – 30	824/f	2.19/f	1800/f²	30
30 – 300	27.5	0.073	2	30
300 – 1500	-	-	f/150	30
1500 – 100000	-	-	10.0	30

FCC Limits – Occupational / Controlled Exposure				
Frequency range [MHz]	**Electric field strength [V/M]**	**Magnetic field strength [A/M]**	**Power density [W/m²]**	**Averaging time [min]**
0.3 – 3.0	614	1.63	1000	6
3.0 – 30	1842/f	4.89/f	9000/f²	6
30 – 300	61.4	0.163	10.0	6
300 – 1500	-	-	f/30	6
1500 – 100000	-	-	50	6

5 RF-Exposure Evaluation

Evaluation Relations

$$\lambda[m] = \frac{c\left[\frac{m}{s}\right]}{f[Hz]} \; ; \; R_{FF}[m] \geq \frac{2 \cdot D[m]^2}{\lambda[m]}$$

$$S[W/m^2] = \frac{P_{E.I.R.P.}[W]}{4\pi R[m]^2} \; ; \; R[m] = \sqrt{\frac{P_{E.I.R.P.}[W]}{4\pi S[W/m^2]}}$$

$$DCC\ [dB] = 10 \cdot Log_{10}\left(\frac{DC[\%]}{100}\right)$$

$$\sum_{i=1}^{N} \frac{S_i\left[\frac{W}{m^2}\right]}{S_{Li}\left[\frac{W}{m^2}\right]} + \sum_{j=1}^{M}\left(\frac{E_j\left[\frac{V}{m}\right]}{E_{Lj}\left[\frac{V}{m}\right]}\right)^2 + \sum_{k=1}^{O}\left(\frac{H_k\left[\frac{A}{m}\right]}{H_{Lk}\left[\frac{A}{m}\right]}\right)^2 < 1$$

Evaluation Procedure

Standalone operation evaluation:

For each radio and frequency band the worst case transmission mode with the highest peak conducted or radiated power is evaluated at the frequency that results in the most restrictive rf-exposure limit. From the peak power values, antenna gains and duty cycles taken from the reference documents, the source average radiated power values are calculated. From the average radiated power the power densities at antenna far-field distance is calculated. The distance from the radiation source for compliance power density is calculated. If the separation distance is lower than the far-field distance, the far-field distance is given as compliance separation distance because the plane wave power density assessment is only valid in the far-field of the radiation source.

For radiation sources for which the average electric and magnetic fields are measured using field probes, the measured field strength values are compared to the reference limits. For those sources no calculations are performed. Compliance with the reference values is determined with the near field measurements.

Concurrent operation evaluation:

First the evaluation distance is set to an appropriate value. For all radiation sources for which power densities are calculated, the power densities at the evaluation distance are calculated and for all other sources the electric or magnetic field strengths are measured using field probes. Finally the ratios of the power densities and/or field strength values and the corresponding limits are calculated and summed and the sum is compared to the maximum of 1.

6 Single Source Evaluation Results - FCC

IEEE 802.15.4 (2.4 GHz)			
Transmission Mode			
Transmission Frequency (f) [MHz]	2405	2440	2475
Antenna far-field distance			
Maximum antenna diameter (D) [m]	N/A	N/A	N/A
Transmission wavelength (λ) [m]	N/A	N/A	N/A
Antenna far-field distance (R_{FF}) [m]	N/A	N/A	N/A
Source average power			
Peak radiated power (PR) [dBm EIRP]	11.838	12.883	11.189
Maximum transmission duty cycle (DC)	1.00	1.00	1.00
Duty cycle correction (DCC) [dB]	0.00	0.00	0.00
Average radiated power (PRAVG) [dBm EIRP]	11.84	12.88	11.19
Power density			
Compliance power density limit [W/m²]	10.000	10.000	10.000
Power density (S) @ Antenna far-field distance [W/m²]	N/A	N/A	N/A
Power density (S) @ 0.20 m [W/m²]	0.030	0.039	0.026
Power density ratio @ 0.20 m	0.00	0.00	0.00
Distance for compliance power density (S=SL) [m]	0.011	0.012	0.010
Compliance			
Verdict	PASS	PASS	PASS
Comment: --			

UWB (4 GHz)	
Transmission Mode	
Transmission Frequency (f) [MHz]	3993.5
Antenna far-field distance	
Maximum antenna diameter (D) [m]	N/A
Transmission wavelength (λ) [m]	N/A
Antenna far-field distance (R_{FF}) [m]	N/A
Source average power	
Peak radiated power (PR) [dBm EIRP]	-23,98
Maximum transmission duty cycle (DC)	1.00
Duty cycle correction (DCC) [dB]	0.00
Average radiated power (PRAVG) [dBm EIRP]	-2398.00
Power density	
Compliance power density limit [W/m²]	10.000
Power density (S) @ Antenna far-field distance [W/m²]	N/A
Power density (S) @ 0.20 m [W/m²]	0.000
Power density ratio @ 0.20 m	0.00
Distance for compliance power density (S=SL) [m]	0.000
Compliance	
Verdict	PASS
Comment: --	

UWB (6.5 GHz)	
Transmission Mode	
Transmission Frequency (f) [MHz]	6489.5
Antenna far-field distance	
Maximum antenna diameter (D) [m]	N/A
Transmission wavelength (λ) [m]	N/A
Antenna far-field distance (R_{FF}) [m]	N/A
Source average power	
Peak radiated power (PR) [dBm EIRP]	-21.56
Maximum transmission duty cycle (DC)	1.00
Duty cycle correction (DCC) [dB]	0.00
Average radiated power (PRAVG) [dBm EIRP]	-21.56
Power density	
Compliance power density limit [W/m^2]	10.000
Power density (S) @ Antenna far-field distance [W/m^2]	N/A
Power density (S) @ 0.20 m [W/m^2]	0.000
Power density ratio @ 0.20 m	0.00
Distance for compliance power density (S=SL) [m]	0.000
Compliance	
Verdict	PASS
Comment: --	

7 Concurrent Evaluation Results - FCC

IEEE 802.15.4 (2.4 GHz) + UWB (4 GHZ) + UWB (6.5 GHZ)	
Information	
Number of concurrent modes	3
Evaluation distance [m]	0.20
Maximum MPE Ratios	
IEEE 802.15.4 (2.4 GHz)	0.00
UWB (4 GHZ)	0.00
UWB (6.5 GHZ)	0.00
Sum of MPE Ratios	
Sum	0.00
Compliance	
Verdict	PASS

=== End of test report ===