

FCC RF Exposure Evaluation

Report Number:

F230973E3

Equipment under Test (EUT):

**Level probing radar
FMR43**

Applicant:

Endress+Hauser SE+Co. KG

Manufacturer:

Endress+Hauser SE+Co. KG



Deutsche
Akkreditierungsstelle
D-PL-17186-01-00

References

CFR 47 Rule part 1 Practice and Procedure

CFR 47 Rule part 2 Frequency Allocations and Radio Treaty Matters; General Rules and Regulations

KDB 447498 D01 General RF Exposure Guidance v06

Assessed and
written by:

Signature

Reviewed and
approved by:

Signature

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| Contents: | Page |
|---|-------------|
| 1. Identification | 4 |
| 1.1. Applicant..... | 4 |
| 1.2. Manufacturer | 4 |
| 1.3. Test Laboratory | 4 |
| 1.4. EUT (Equipment under Test) | 5 |
| 1.5. Technical Data of Equipment | 5 |
| 1.6. Additional Information | 6 |
| 2. Methods..... | 7 |
| 2.1. RF exposure test exemptions for single sources | 7 |
| 1.1.1 General Exemption CFR 47 §1.1307(b)(3)(i)(A) | 7 |
| 1.1.2 SAR Based Exemption CFR 47 §1.1307(b)(3)(i)(B)..... | 7 |
| 1.1.3 MPE Based Exemption CFR 47 §1.1307(b)(3)(i)(C) | 7 |
| 1.1.4 Stand alone MPE evaluation limits | 8 |
| 2.2. RF exposure test exemptions for simultaneous transmission sources..... | 9 |
| 1.1.5 1 mW Test Exemption for simultaneous transmission sources..... | 9 |
| 1.1.6 Simultaneous transmission SAR based and MPE based test exemptions | 9 |
| 1.1.7 Test exemption based on the SAR to Peak Location Separation Ratio..... | 10 |
| 3. Results of evaluation..... | 11 |
| 3.1. Used evaluation methods..... | 11 |
| 3.2. Evaluation Distance | 11 |
| 3.3. Output power | 11 |
| 4. MPE evaluation..... | 12 |
| 4.1. Stand-alone MPE results | 12 |
| 4.2. Simultaneous MPE results | 13 |
| 5. Conclusion..... | 13 |
| 6. Report History..... | 13 |

1 Identification

1.1 Applicant

| | |
|----------------------------|-------------------------------|
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1.2 Manufacturer

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1.3 Test Laboratory

The tests were carried out by: **PHOENIX TESTLAB GmbH**
Königswinkel 10
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Germany

Accredited by *Deutsche Akkreditierungsstelle GmbH* in compliance with
DIN EN ISO/IEC 17025 under Reg. No. D-PL-17186-01-06.

1.4 EUT (Equipment under Test)

| EUT number | Model name | Serial number | Sensor board | Display board | Mainboard | Power board | Terminal board | Hardware version | Software version |
|------------|------------|----------------|--------------|---------------|-----------|-------------|----------------|------------------|------------------|
| 5b | FMR43 | FMR43_IOL-_035 | 71607254 | 71599584 | 71439136 | 71502179 | 71508546 | 01.00.00 | 01.00.00 |
| 6b | | FMR43_IOL_019 | | | | | | | |

| EUT number | Display type | Housing material | Antenna | Antenna gain |
|------------|--------------------|------------------|-----------|--------------|
| 5b | Front Foil display | Stainless steel | PTFE M24 | 29.17 dBi |
| 6b | | | PTFE 1/2" | 26.93 dBi |

*: Declared by the applicant.

Note: PHOENIX TESTLAB GmbH does not take samples. The samples used for tests are provided exclusively by the applicant.

1.5 Technical Data of Equipment

| General | | | |
|-------------------------------|---|-------------------------|-------------------------|
| Power supply EUT: * | DC | | |
| Supply voltage range: * | $U_{nom} = 24.0 V_{DC}$ | $U_{min} = 12.0 V_{DC}$ | $U_{max} = 30.0 V_{DC}$ |
| Temperature range: * | -50 °C to +80 °C | | |
| FCC ID: * | LCGFMR43L | | |
| Highest internal frequency: * | Internal clock frequency: 125 MHz Bluetooth low energy: 2480 MHz Radar: 182 GHz | | |

* Declared by the applicant

| Radar part | |
|---------------------------------|----------------------------|
| Rated rf-output power: * | 20 dBm/MHz |
| Antenna type: * | Refer table above |
| Operating frequency band: * | 174,800 MHz to 182,000 MHz |
| Nominal channel bandwidth(s): * | 174,800 MHz to 182,000 MHz |
| Type of modulation: * | FMCW |
| Antenna connector: * | None |
| FCC ID: | LCGFMR43L |
| Lowest internal frequency: * | 32 MHz |

*: Declared by the applicant.

| Bluetooth part | |
|------------------------------------|---------------------------|
| Fulfils Bluetooth specification: * | Bluetooth Low Energy™ 5.2 |
| Operating frequency range: * | 2402 MHz – 2480 MHz |
| Number of channels: * | 40 |
| Type of modulation: * | GFSK |
| Antenna type / name: * | Integral PCB antenna |

* Declared by the applicant

Ports/Connectors

| Identification | Connector | | Length |
|----------------|-----------|-----------|--------|
| | EUT | Ancillary | |
| DC and data | Fixed | - | 2.0 m |
| - | - | - | - |
| - | - | - | - |

*: Length during the test

1.6 Additional Information

- Radar test report: F230973E1 from PHOENIX TESTLAB GmbH.
- Bluetooth test reports: F230973E4 and F230973E6 from PHOENIX TESTLAB GmbH.

The radar part of the EUT operates on frequencies between 174.8 GHz to 182 GHz, which are higher than the defined 100 GHz limits for the MPE evaluation. After consultation with the FCC, the 100 GHz limit value was used for the following calculations.

As declared by the applicant, is a level probing radar with Bluetooth LE functionality, which will be installed in tanks in industrial environments. Therefore, the distance between to the user and the EUT can be regarded as larger than 5 cm.

2 Methods

2.1 RF exposure test exemptions for single sources

2.1.1 General Exemption CFR 47 §1.1307(b)(3)(i)(A)

The available maximum time-averaged power is no more than 1 mW, regardless of separation distance. This exemption may not be used in conjunction with other exemption criteria other than those in paragraph (b)(3)(ii)(A) of this section. Medical implant devices may only use this exemption and that in paragraph (b)(3)(ii)(A);

2.1.2 SAR Based Exemption CFR 47 §1.1307(b)(3)(i)(B)

The available maximum time-averaged power of effective radiated power (ERP), whichever is greater, is less than or equal to the threshold P_{th} (mW) described in the following formula. This method shall only be used at separation distances (cm) from 0.5 cm to 40 cm and at frequencies from 0.3 GHz to 6 GHz inclusive.

For the following separation distances [d] and frequency ranges P_{th} is given by the following formulas

| | 0.5 cm ≤ d ≤ 20cm | 20 cm < d ≤ 40 cm |
|-----------------------|--|---|
| 0.2 GHz ≤ f < 1.5 GHz | $P_{th}(mW) = ERP_{20cm} \left(\frac{d}{20} \right)^x$ $ERP_{20cm} (mW) = 2040f$ $x = -\log_{10} \left(\frac{60}{ERP_{20cm} \sqrt{f}} \right)$ | $P_{th}(mW) = ERP_{20cm}$ $ERP_{20cm} (mW) = 2040f$ |
| 1.5 GHz ≤ f ≤ 6 GHz | $P_{th}(mW) = ERP_{20cm} \left(\frac{d}{20} \right)^x$ $ERP_{20cm} (mW) = 3060$ $x = -\log_{10} \left(\frac{60}{ERP_{20cm} \sqrt{f}} \right)$ | $P_{th}(mW) = ERP_{20cm}$ $ERP_{20cm} (mW) = 3060$ |

2.1.3 MPE Based Exemption CFR 47 §1.1307(b)(3)(i)(C)

By using Table 1 and the minimum separation distance (d in meters) from the body of a nearby person for the frequency (f in MHz) at which the source operates, the ERP (watts) is no more than the calculated value prescribed for that frequency. For the exemption in Table 1 to apply, d must be at least $\lambda/2\pi$, where λ is the free-space operating wavelength in meters. If the ERP of a single RF source is not easily obtained, then the available maximum time-averaged power may be used in lieu of ERP if the physical dimensions of the radiating structure(s) do not exceed the electrical length of $\lambda/4$ or if the antenna gain is less than that of a half-wave dipole (1.64 linear value).

| RF Source frequency [MHz] | Threshold ERP [W] |
|---------------------------|-------------------------------------|
| 0.3 - 1.34 | 1920 d ² |
| 1.34 – 30 | 3450 d ² /f ² |
| 30 – 300 | 3.83 d ² |
| 300 – 1500 | 0.0128 d ² /f |
| 1500 - 100000 | 19.2 d ² |

d: Minimal separation distance from antenna to the user

2.1.4 Stand alone MPE evaluation limits

The human exposure to RF emissions from such devices could be evaluated based on the MPE limits adopted by the FCC for electric and magnetic field strength and / or power density. The limits for General Population / Uncontrolled Exposure are given in the following table from CFR 47 §1.1310(e)1:

| Frequency range [MHz] | Electric field strength (E) [V/m] | Magnetic field strength (H) [A/m] | Power density (S) [mW/cm ²] | Averaging time [min] |
|---|--------------------------------------|--------------------------------------|--|-------------------------|
| (i)Limits for Occupational/Controlled Exposure | | | | |
| 0.3 – 3.0 | 614 | 1.63 | *(100) | ≤6 |
| 3.0 – 30 | 1842/f | 4.89/f | *(900/f ²) | <6 |
| 30 – 300 | 61.4 | 0.163 | 1.0 | <6 |
| 300 – 1,500 | | | f/300 | <6 |
| 1,500 – 100,000 | | | 5 | <6 |
| (ii)Limits for General Population / Uncontrolled Exposure | | | | |
| 0.3 – 1.34 | 614 | 1.63 | *(100) | < 30 |
| 1.34 – 30 | 824/f | 2.19/f | *(180/f ²) | < 30 |
| 30 – 300 | 27.5 | 0.073 | 0.2 | < 30 |
| 300 – 1500 | | | f/1500 | < 30 |
| 1500 – 100,000 | | | 1.0 | < 30 |

Note: f = frequency in MHz; * Plane – wave equivalent power density

The power density is calculated as follows:

$$S = \frac{P \cdot G \cdot D}{4 \cdot \pi \cdot d^2}$$

Where:

P: conducted power

G: Antenna gain (linear)

D: Duty Cycle

d: Minimal separation distance from antenna to the user

2.2 RF exposure test exemptions for simultaneous transmission sources

2.2.1 1 mW Test Exemption for simultaneous transmission sources

As discussed in CFR 47 §1.1307(b)(3)(ii)(A) [1] the 1 mW exemption intended for single transmitters may be also applied to simultaneous transmission conditions, within the same host device, according one of the following criteria:

- a. When the maximum available power each individual transmitting antenna with the same time averaging period is ≤ 1 mW, and the nearest parts of the antenna structures of the simultaneously operating transmitters are separated by at least 2 cm
- b. When the aggregate maximum available power of all transmitting antennas is ≤ 1 mW in the same time-averaging period

This exemption may not be combined with any other exemption.

2.2.2 Simultaneous transmission SAR based and MPE based test exemptions

Although this is not a module integration in the sense of product approval, the procedure for simultaneous transmission specified in KDB 447498 D04 Interim General RF Exposure Guidance v01 [3] in chapter 2.2 was taken into account:

According to the RF exposure KDB 447498 D04 General RF Exposure Guidance v01 [3] in chapter 2.2.2: This case is described in detail in CFR 47 § 1.1307(b)(3)(ii)(B) and covers the situations where both SAR-based and MPE-based exemption may be considered for test exemption in fixed, mobile, or portable device exposure conditions. For these cases, a device with multiple RF sources transmitting simultaneously will be considered an RF exempt device if the condition of the following formular is satisfied.

$$\sum_{i=1}^a \frac{P_i}{P_{th,i}} + \sum_{j=1}^b \frac{ERP_j}{ERP_{th,j}} + \sum_{k=1}^c \frac{Evaluated_k}{Exposure Limit_k} \leq 1$$

For these test exemptions to apply, the maximum output power, duty factor, and other applicable parameters used in the standalone ERP determination tests, must be the same, or corresponding to a more conservative choice, than those required for simultaneous transmission.

Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneously transmitting antennas incorporated in a host device is ≤ 1.0 , according to calculated/estimated, numerically modelled, or measured field strengths or power density. The MPE ratio of each antenna is determined at the minimum test separation distance required by the operating configurations and exposure conditions of the host device, according to the ratio of field strengths or power density to the MPE limit at the test frequency.

2.2.3 Test exemption based on the SAR to Peak Location Separation Ratio

When the ERP-based condition in the previous section does not apply, a test exemption may be still applicable based on the SAR to peak location separation ratio (SPLSR) procedure.

In this case, the simultaneously transmitting antennas in each operating mode and exposure condition combination must be considered one pair at a time to determine the SPLSR that qualifies for the additional test exemption.

This ratio is defined as:

$$SPLSR = (SAR_1 + SAR_2)^{\frac{1.5}{R_i}}$$

Where: SAR_1 and SAR_2 = highest reported SAR or estimated SAR values for the two sources in the pair i , and R_i is their distance in mm.

When $SPLSR \leq 0.04$ (rounded to two decimal digits), for all antenna pairs in the configuration, then the device qualifies for 1 g SAR test exemption.

When 10 g SAR applies (e.g. for extremities) the corresponding test exemption condition is $SPLSR \leq 0.10$.

If any antenna pair does not qualify for simultaneous transmission SAR test exemption, then the device must be tested for SAR compliance, according to the enlarged zoom scan and volume scan post-processing procedures in KDB Pub. 865664 D01.

3 Results of evaluation

3.1 Used evaluation methods

| RF Exposure test exemptions for single sources | | | |
|--|--|----------------|---------|
| Used | Method | See sub-clause | Comment |
| <input type="checkbox"/> | General Exemption CFR 47 §1.1307(b)(3)(i)(A) | 2.1.1 | - |
| <input type="checkbox"/> | SAR Based Exemption CFR 47 §1.1307(b)(3)(i)(B) | 2.1.2 | - |
| <input type="checkbox"/> | MPE Based Exemption CFR 47 §1.1307(b)(3)(i)(C) | 2.1.3 | - |
| <input checked="" type="checkbox"/> | MPE Calculation | 2.1.4 | - |

| RF Exposure test exemptions for simultaneous transmission sources | | | |
|---|--|----------------|---------|
| Used | Method | See sub-clause | Comment |
| <input type="checkbox"/> | Not applicable | | - |
| <input type="checkbox"/> | 1 mW test Exemption acc. 2.2.1 [3] | 2.2.1 | - |
| <input type="checkbox"/> | SAR Based Exemption acc. 2.2.2 [3] | 2.2.2 | - |
| <input checked="" type="checkbox"/> | MPE Based Exemption acc. 2.2.2 [3] | 2.2.2 | - |
| <input type="checkbox"/> | SAR to Peak location separation ratio acc. 2.2.3 [3] | 2.2.3 | - |

3.2 Evaluation Distance

Because the EUT will be mounted on tanks, it can be assumed, that the minimum distance to the user is larger than 20 cm. Therefore, a distance of 5 cm to a normal person was declared by the applicant and was used for the calculations documented in clause 4 of this report.

3.3 Output power

The following information is based on test-reports F230973E1 of PHOENIX TESTLAB GmbH issued 15.07.2024 and F230973E4 and F230973E6 from PHOENIX TESTLAB GmbH issued 31.07.2024.

4 MPE evaluation

The power density is calculated as follows:

$$\text{Power density} = \frac{P \cdot D \cdot G}{4 \cdot \pi \cdot R^2}$$

Where:

P: conducted power [mW]

D: Duty cycle (linear)

G: Antenna gain (linear)

R: minimum separation distance from antenna to the user [cm]

4.1 Stand-alone MPE results

| Band | Frequency [MHz] | Output power | Duty cycle [dB] | Antenna Gain [dBi] | Distance [cm] | Power Density [mW/cm ²] | Limit of Power Density [mW/cm ²] | Reference |
|--------------|--------------------|----------------------------|-----------------|--------------------|---------------|-------------------------------------|--|--------------------------|
| Radar | 174,800 to 182,000 | -30.2 dBm / 0.000955 mW | 1 *1 | -*2 | 5 | 0.00000304 | 1.0 *3 | Test report F230973E1 |
| Bluetooth LE | 2402 to 2480 | 7.2 dBm / 5.248 mW | 1 *1 | -*2 | 5 | 0.0167 | 1.0 | Test report F230973E6 |

*1: No duty cycle is regarded because the measured value is an average value.

*2: No antenna gain is regarded because the documented value is a radiated (e.i.r.p.) value, the antenna gain is already included.

*3: As clarified with the FCC, no limits are available at the time of writing this test report, the existing limits up to 100 GHz were used.

4.2 Simultaneous MPE results

The worst case MPE ratios of the stand-alone modules are calculated in the following:

For the Bluetooth part:

$$BT_{ratio} = \frac{0.0167 \text{ mW/cm}^2}{1.0 \text{ mW/cm}^2} = 0.0167$$

For the radar part:

$$Radar_{ratio} = \frac{0.00000304 \text{ mW/cm}^2}{1.0 \text{ mW/cm}^2} = 0.00000304$$

The Sum of the MPE ratios for the simultaneous transmission is:

$$\text{Sum} = 0.0167 + 0.00000304$$

$$\text{Sum} = 0.0167 < 1.0$$

5 Conclusion

As the sum of the MPE ratios is less than 1.0, the device is excluded from the simultaneous transmission MPE test.

A safety statement concerning the minimum separation distance from enclosure of the device has to be integrated in the user's manual to provide end-users with transmitter operating conditions for satisfying RF exposure compliance.

6 Report History

| Report Number | Date | Comment |
|---------------|------------|---------------------|
| F230973E3 | 31.07.2024 | Initial Test Report |
| - | - | - |
| - | - | - |