

# FCC Measurement/Technical Report on Remote control vehicle key DC12K

FCC ID: IYZDC12KA  
IC: ---

Report Reference: MDE\_MARQ\_1851\_FCCb\_rev1

Test Laboratory:  
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**Note:**

The following test results relate only to the devices specified in this document. This report shall not be reproduced in parts without the written approval of the test laboratory.

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## 1 APPLIED STANDARDS AND TEST SUMMARY

### 1.1 APPLIED STANDARDS

#### Type of Authorization

Certification for an Intentional Radiator (Periodic operation in the band above 70 MHz)

#### Applicable FCC Rules

Edition of FCC Rules: October 1, 2015

Prepared in accordance with the requirements of FCC Rules and Regulations as listed in 47 CFR Ch.1 Parts 2 and 15. The following subparts are applicable to the results in this test report.

Part 2, Subpart J - Equipment Authorization Procedures, Certification

Part 15, Subpart C – Intentional Radiators

§ 15.201 Equipment authorization requirement

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

§ 15.231 Periodic operation in the band 40.66-40.70 MHz, above 70 MHz

#### Note:

none

#### Summary Test Results:

The EUT complied with all performed tests as listed in chapter 1.3 Measurement Summary / Signatures.

## 1.2 FCC-IC CORRELATION TABLE

Correlation of measurement requirements for Momentarily (incl. Periodically) Operated Devices and Remote Control from FCC and IC

Radio equipment

| Measurement                                              | FCC reference     | IC reference                                                            |
|----------------------------------------------------------|-------------------|-------------------------------------------------------------------------|
| Conducted emissions on AC Mains                          | § 15.207          | RSS-Gen Issue 5: 8.8                                                    |
| Transmitter spurious radiated emissions                  | § 15.231 (b)      | RSS Gen Issue 5: 6.10/6.13/8.9/8.10;<br>RSS-210 Issue 9: A1.1.2, A1.1.5 |
| Duty cycle measurement (based on dwell time measurement) | § 15.231 (a)      | RSS-210 Issue 9: A1.1.1, A1.1.5                                         |
| Maximum radiated field strength at fundamental frequency | § 15.231 (b)      | RSS-210 Issue 9: A1.1.2, A1.1.5;<br>RSS Gen Issue 5: 6.12               |
| Occupied bandwidth                                       | § 15.231 (c)      | RSS-210 Issue 9: A1.1.3                                                 |
| Antenna requirement                                      | § 15.203 / 15.204 | RSS-Gen Issue 5: 8.3                                                    |
| Receiver spurious emissions                              | –                 | RSS-210 Issue 9: 2.3<br>RSS Gen Issue 5: 5/7 *)                         |

\*) Receivers are exempted from certification besides if operating in stand-alone mode in the frequency range 30–960 MHz or if these are scanner receivers.

### 1.3 MEASUREMENT SUMMARY /SIGNATURES

|                                                          |              |                      |                          |
|----------------------------------------------------------|--------------|----------------------|--------------------------|
| <b>FCC Part 15, Subpart C</b>                            |              | <b>§ 15.207</b>      |                          |
| Conducted emissions (AC power line)                      |              |                      |                          |
| The measurement was performed according to ANSI C63.10   |              |                      |                          |
| <b>OP-Mode</b>                                           | <b>Setup</b> | <b>Port</b>          | <b>2013 Final Result</b> |
|                                                          |              | AC Port (power line) | N/A                      |
| <b>FCC Part 15, Subpart C</b>                            |              | <b>§ 15.231</b>      |                          |
| Duty cycle measurement (based on dwell time measurement) |              |                      |                          |
| The measurement was performed according to ANSI C63.10   |              |                      |                          |
| <b>OP-Mode</b>                                           | <b>Setup</b> | <b>Port</b>          | <b>2013 Final Result</b> |
| op-mode 3                                                | Setup_03     | Enclosure            | passed                   |
| <b>FCC Part 15, Subpart C</b>                            |              | <b>§ 15.231</b>      |                          |
| Spurious Radiated Emissions                              |              |                      |                          |
| The measurement was performed according to ANSI C63.10   |              |                      |                          |
| <b>OP-Mode</b>                                           | <b>Setup</b> | <b>Port</b>          | <b>2013 Final Result</b> |
| op-mode 1                                                | Setup_01     | Enclosure            | passed                   |
| op-mode 1                                                | Setup_02     | Enclosure            | passed                   |
| <b>FCC Part 15, Subpart C</b>                            |              | <b>§ 15.231</b>      |                          |
| Maximum radiated field strength at fundamental frequency |              |                      |                          |
| The measurement was performed according to ANSI C63.10   |              |                      |                          |
| <b>OP-Mode</b>                                           | <b>Setup</b> | <b>Port</b>          | <b>2013 Final Result</b> |
| op-mode 2                                                | Setup_01     | Enclosure            | passed                   |
| <b>FCC Part 15, Subpart C</b>                            |              | <b>§ 15.231</b>      |                          |
| Occupied Bandwidth                                       |              |                      |                          |
| The measurement was performed according to ANSI C63.10   |              |                      |                          |
| <b>OP-Mode</b>                                           | <b>Setup</b> | <b>Port</b>          | <b>2013 Final Result</b> |
| op-mode 1                                                | Setup_01     | Enclosure            | passed                   |

N/A not applicable (the EUT is powered by internal CR2032 lithium battery)

| Report version control |              |                                                         |                  |
|------------------------|--------------|---------------------------------------------------------|------------------|
| Version                | Release date | Change Description                                      | Version validity |
| initial                | 2019-02-08   | --                                                      | invalid          |
| rev1                   | 2019-03-15   | FCC 15.231 (d) & (e) from the table on page 4, removed. | valid            |



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## 2 ADMINISTRATIVE DATA

### 2.1 TESTING LABORATORY

Company Name: 7layers GmbH

Address: Borsigstr. 11  
40880 Ratingen  
Germany

This facility has been fully described in a report submitted to the ISED and accepted under the registration number: Site# 3699A-1.

The test facility is also accredited by the following accreditation organisation:

Laboratory accreditation no: DAKKS D-PL-12140-01-00

FCC Designation Number: DE0015

FCC Test Firm Registration: 929146

Responsible for accreditation scope: Dipl.-Ing. Marco Kullik

Report Template Version: 2017-07-14

### 2.2 PROJECT DATA

Responsible for testing and report: B. Sc. Jens Dörwald

Date of Report: 2019-03-15

Testing Period: 2019-02-19 to 2019-02-26

### 2.3 APPLICANT DATA

Company Name: Marquardt GmbH

Address: Schloss-Str. 16  
78604 Rietheim-Weilheim  
Germany

Contact Person: Mr. Gerd Siegel

### 2.4 MANUFACTURER DATA

Company Name: please see applicant data

Address:

Contact Person:

### 3 TEST OBJECT DATA

#### 3.1 GENERAL EUT DESCRIPTION

|                                             |                                                                                                                                                                                                                           |
|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Kind of Device<br>product description       | SRD Transceiver, operating in 433 MHz ISM band                                                                                                                                                                            |
| Product name                                | Remote control vehicle key                                                                                                                                                                                                |
| Type                                        | DC12K                                                                                                                                                                                                                     |
| Declared EUT data by the supplier           |                                                                                                                                                                                                                           |
| Voltage Type                                | DC lithium battery, CR2025 Type                                                                                                                                                                                           |
| Normal Voltage                              | 3.0 V                                                                                                                                                                                                                     |
| Low Voltage                                 | 2.25 V                                                                                                                                                                                                                    |
| High Voltage                                | 3.1 V                                                                                                                                                                                                                     |
| Normal Temperature                          | 25 °C                                                                                                                                                                                                                     |
| Low Temperature                             | - 20 °C                                                                                                                                                                                                                   |
| High Temperature                            | +60 °C                                                                                                                                                                                                                    |
| Channel frequency                           | Ch 1 433.47 MHz<br>Ch 2 433.92 MHz<br>Ch 3 434.37 MHz                                                                                                                                                                     |
| Specific product<br>description for the EUT | The EUT is a remote-control vehicle key, part of locking and drive permission system. The remote active functions locking/unlocking the vehicles doors and boot lid are performed manually or using a keyless entry mode. |
| The EUT provides the<br>following ports:    | Enclosure                                                                                                                                                                                                                 |
| Special software used<br>for testing        | The applicant provided two kinds of samples. One with a modified software, which operates in continuously modulated carrier mode. The other one is a production sample, with not modified software.                       |

The main components of the EUT are listed and described in Chapter 3.2.

### 3.2 EUT MAIN COMPONENTS

| Sample Name      | Sample Code                                                                | Description     |
|------------------|----------------------------------------------------------------------------|-----------------|
| DE1307005 EUT A  | aa01                                                                       | radiated sample |
| Sample Parameter | Value                                                                      |                 |
| Serial No.       | 15                                                                         |                 |
| HW Version       | 15/25/00                                                                   |                 |
| SW Version       | 13/03/00                                                                   |                 |
| Comment          | Sample with test software, switchable CW and continuously modulated signal |                 |

| Sample Name      | Sample Code                                                                | Description     |
|------------------|----------------------------------------------------------------------------|-----------------|
| DE1307005 EUT B  | ab01                                                                       | radiated sample |
| Sample Parameter | Value                                                                      |                 |
| Serial No.       | 14                                                                         |                 |
| HW Version       | 15/25/00                                                                   |                 |
| SW Version       | 13/03/00                                                                   |                 |
| Comment          | Sample with test software, switchable CW and continuously modulated signal |                 |

| Sample Name      | Sample Code                                                          | Description     |
|------------------|----------------------------------------------------------------------|-----------------|
| DE1307005 EUT C  | ad01                                                                 | radiated sample |
| Sample Parameter | Value                                                                |                 |
| Serial No.       | N/A                                                                  |                 |
| HW Version       | 15/25/00                                                             |                 |
| SW Version       | 13/03/00                                                             |                 |
| Comment          | Sample with not modified software, used for a Duty Cycle measurement |                 |

#### General description of ancillary equipment

| Device | Details (Manufacturer, Type Model, OUT Code) | Reason for using |
|--------|----------------------------------------------|------------------|
| ---    | ---                                          | ---              |

#### General description of auxiliary equipment

| Device | Details (Manufacturer, HW, SW, S/N) | Description |
|--------|-------------------------------------|-------------|
| ---    | ---                                 | ---         |



### 3.3 EUT SETUPS

This chapter describes the combination of EUTs and ancillary equipment used for testing.

| Setup No. | Combination of EUTs | Description                       |
|-----------|---------------------|-----------------------------------|
| Setup_01  | EUT A               | Setup for radiated measurements   |
| Setup_02  | EUT B               | Setup for radiated measurements   |
| Setup_03  | EUT C               | Setup for Duty Cycle measurements |

### 3.4 OPERATING MODES

This chapter describes the operating modes of the EUTs used for testing.

| Op. Mode  | Description of Operating Modes | Remarks                                                                                  |
|-----------|--------------------------------|------------------------------------------------------------------------------------------|
| op-mode 1 | Continuous modulated           | Transmitter sends continuously FSK modulated signal with 10 kBd data rate                |
| op-mode 2 | CW                             | Transmitter sends continuous wave (non-modulated) signal at $f_u$ ( $f_c - \Delta f/2$ ) |
| op-mode 3 | Pulse train                    | Transmitter sends a pulse train after pressing some of the buttons                       |

Remark: For continuous modulated mode, a special test software, provided by applicant was used.

### 3.5 PRODUCT LABELLING

#### 3.5.1 FCC ID label

IYZDC12KA

#### 3.5.2 IC Label

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#### 3.5.3 LOCATION OF THE LABEL ON THE EUT

Please refer to the documentation of the applicant.

## 4 TEST RESULTS

### 4.1 DUTY CYCLE MEASUREMENT (BASED ON DWELL TIME MEASUREMENT)

Standard      FCC Part 15 Subpart C

The test was performed according to:  
ANSI C63.10

#### 4.1.1 TEST DESCRIPTION

The Equipment Under Test (EUT) was setup in a shielded room to perform the dwell time measurements. For analyzer settings please see measurement plots.

#### 4.1.2 TEST REQUIREMENTS / LIMITS

Depending on the function of the EUT different paragraphs of FCC §15.231 apply:

Either

(a)(1): A manually operated transmitter shall employ a switch that will automatically deactivate the transmitter within not more than 5 seconds of being released.

Or

(a)(2) A transmitter activated automatically shall cease transmission within 5 seconds after activation.

And

(a)(3) Periodic transmissions at regular predetermined intervals are not permitted. However, polling or supervision transmissions, including data, to determine system integrity of transmitters used in security or safety applications are allowed if the total duration of transmissions does not exceed more than two seconds per hour for each transmitter. There is no limit on the number of individual transmissions, provided the total transmission time does not exceed two seconds per hour.

Otherwise

(e) Intentional radiators may operate at a periodic rate exceeding that specified in paragraph (a) of this section and may be employed for any type of operation [...]. In addition, [...] the duration of each transmission shall not be greater than one second and the silent period between transmissions shall be at least 30 times the duration of the transmission but in no case less than 10 seconds.

This test is also performed to determine the pulse train of the transmitter and calculate the correction factor for pulse modulated transmitters according to FCC §15.35. This factor is used as a correction factor for the field strength measurements, both for Spurious radiated emissions and Maximum radiated field strength at fundamental frequency.

#### 4.1.3 TEST PROTOCOL

Temperature: 23 °C  
Air Pressure: 1009 hPa  
Humidity: 38 %

| Op. Mode  | Setup    | Port      |
|-----------|----------|-----------|
| op-mode 3 | Setup_02 | Enclosure |

a) Determine the total duration of a transmission within 100 ms:

Duty cycle =  $((L1 \cdot N1) + (L2 \cdot N2) + \dots + (Ln \cdot Nn)) / 100 \text{ ms or } T$ , whichever is less  
Correction factor =  $20 \cdot \text{LOG} (\text{Duty cycle}) [\text{dB}]$

|        |                                                                          |                 |
|--------|--------------------------------------------------------------------------|-----------------|
| Step 1 | Holdover time                                                            | Less than 5s    |
| Step 2 | Cycle to determine the on/off ratio within a cycle (period T)            | 100 ms          |
| Step 3 | Sweep of a data word to determine the on time within a data word (L1-LN) | L1 = 0.685 ms   |
|        |                                                                          | L2 = 68.5491 ms |
|        |                                                                          | L3 = 1.8216 ms  |

Calculation of Duty Cycle / Correction Factor:

If  $T > 100 \text{ ms} \Rightarrow T = 100 \text{ ms}$ ;  $L1 = 67.266 \text{ ms}$ ;  $N1 = 1$ ;  $L2 = 32.128 \text{ ms}$ ;  $N2 = 1$   
(Plot 2)  $D2 + (D4 - D3) = 67.266 + 32.128 = 99.394 \text{ ms}$   
In 100 ms  $T_{\text{on}} = 99.394 \text{ ms}$   
Duty cycle =  $99.394 / 100 = 0.99394$

CORRECTION FACTOR =  $20 \cdot \text{LOG} (0.99394) = -0.05 \text{ dB}$

b) Determine the period of periodic re-transmission, if any, or cease (deactivation) time:  
No period of retransmission occur, independent on how long the single button is pressed.

After one of the the buttons "Lock" or "Unlock" is continuously pressed, the EUT sends a sequence of 3 bursts ("triplet" shown at Plot 3), followed by a group of 16 narrow bursts wit bigger gap between them (shown at Plots 5 and 6), a group of five narrow "triplets" (shown at Plots 7 and 8) and at the end, a second normal "triplet". For the whole pulse train, please look at Plot 1.

When the button "Trunk" is pressed, the train sequence is shown at the Plot 4

Deactivation after  $T_c \approx 0.925 \text{ s}$ , Limit:  $\leq 5 \text{ s}$   
when each of buttons "Lock" or "Unlock" are continuously pressed and then released.

Deactivation after  $T_c \approx 1.133 \text{ s}$ , Limit:  $\leq 5 \text{ s}$   
when the button "Trunk" is continuously pressed and then released.

c) Determine the total duration of periodic transmissions within 1 hour, if any:

Duration  $t_d$  of all pulses/bursts during  $T_R$  ("on-time"):

$t_d$  depends on which button is pressed and then released.

By pressing each of the buttons "Lock" or "Unlock", the  $t_d \approx 0.920 \text{ s}$ .  
 $(208.15 \times 2 - 1.23 \times 4) + 16.41 \times 16 + 16.41 \times 15 = 0.92001 \text{ s}$

By pressing the button "Trunk", the  $t_d \approx 1.260 \text{ s}$ .  
 $(208.15 \times 3 - 1.23 \times 6) + 16.41 \times 16 + 16.41 \times 15 = 1.12578 \text{ s}$

Note: The time between channels in a "Triplet" is 1.23 ms

d) If the result of c) exceeds 2 seconds/hour then paragraph (e) applies

Determine the duration of each transmission (one complete pulse train) and silent time:

Duration  $t_{PT}$ , Limit:  $\leq 1$  s (Remark:  $t_{PT}$  is identical to  $t_d$  if  $T \leq 100$  ms)

There is no periodical transmission after any button is released.

Hence, the  $t_{PT}$  is identical to  $t_d$

For buttons "Lock" and "Unlock"  $t_{PT} = t_d \approx 0.920$  s

For button "Trunk"  $t_{PT} = t_d \approx 1.260$  s

Silent time between transmissions  $t_s = \text{N/A}$ , Limit:  $\leq$  Maximum (10 s and  $30 \cdot t_{PT}$ ).

NOTE: The EUT Duty Cycle in Keyless entry mode is not tested.

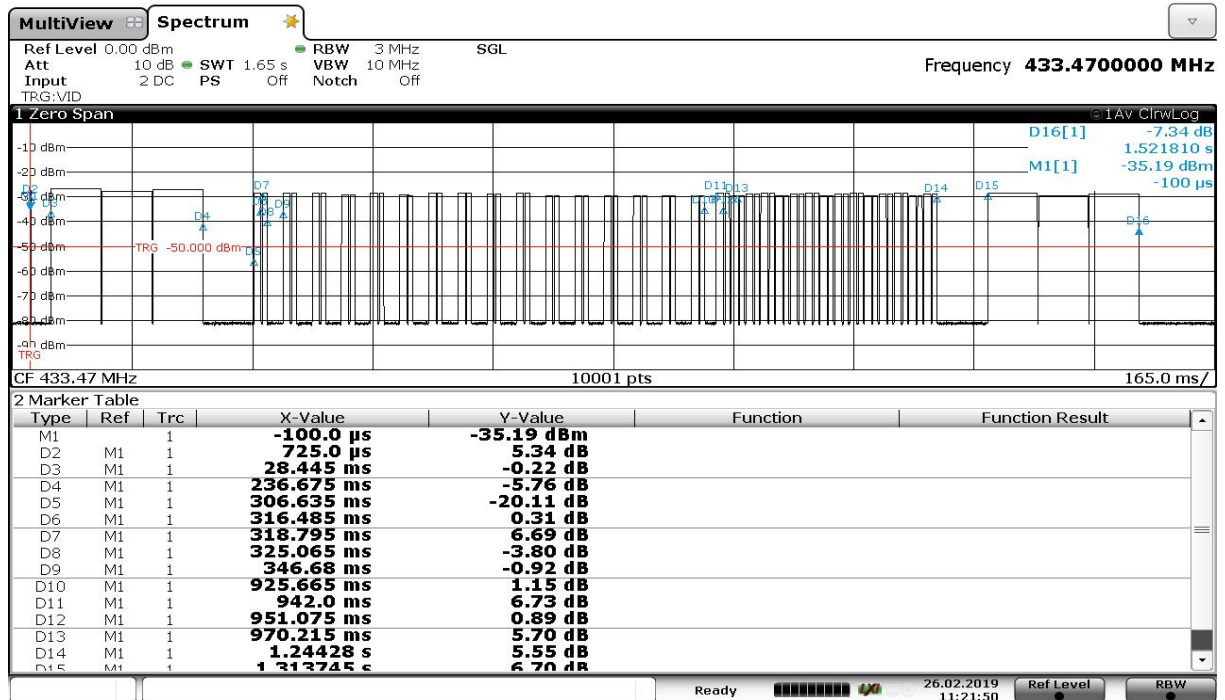
The manufacturer declared that the EUT behaviour in this mode is identical as the mode measured above, when the buttons are pressed and released.

#### 4.1.4 TEST RESULT: DUTY CYCLE / CORRECTION FACTOR

| FCC Part 15, Subpart C | Op. Mode  | Result |
|------------------------|-----------|--------|
|                        | op-mode 3 | passed |

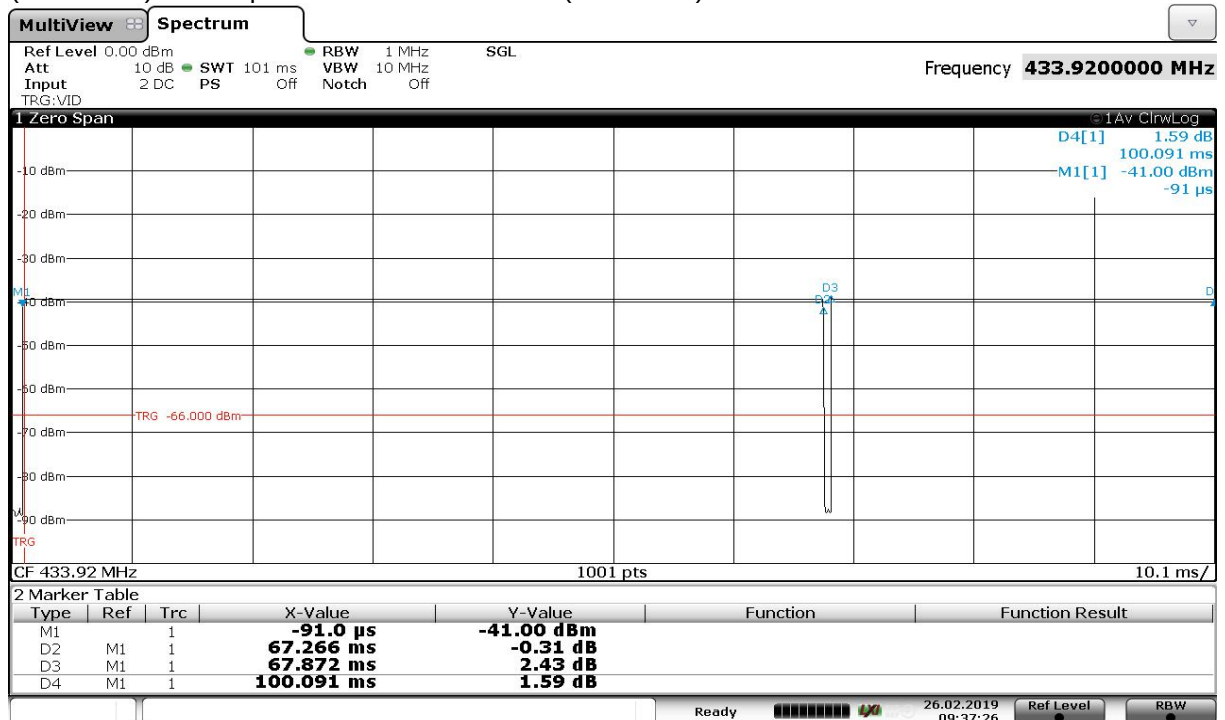
#### 4.1.5 MEASUREMENT PLOTS DUTY CYCLE

Plot 1. The transmission after continuous pressing and releasing of buttons "Lock" and "Unlock".



11:21:51 26.02.2019

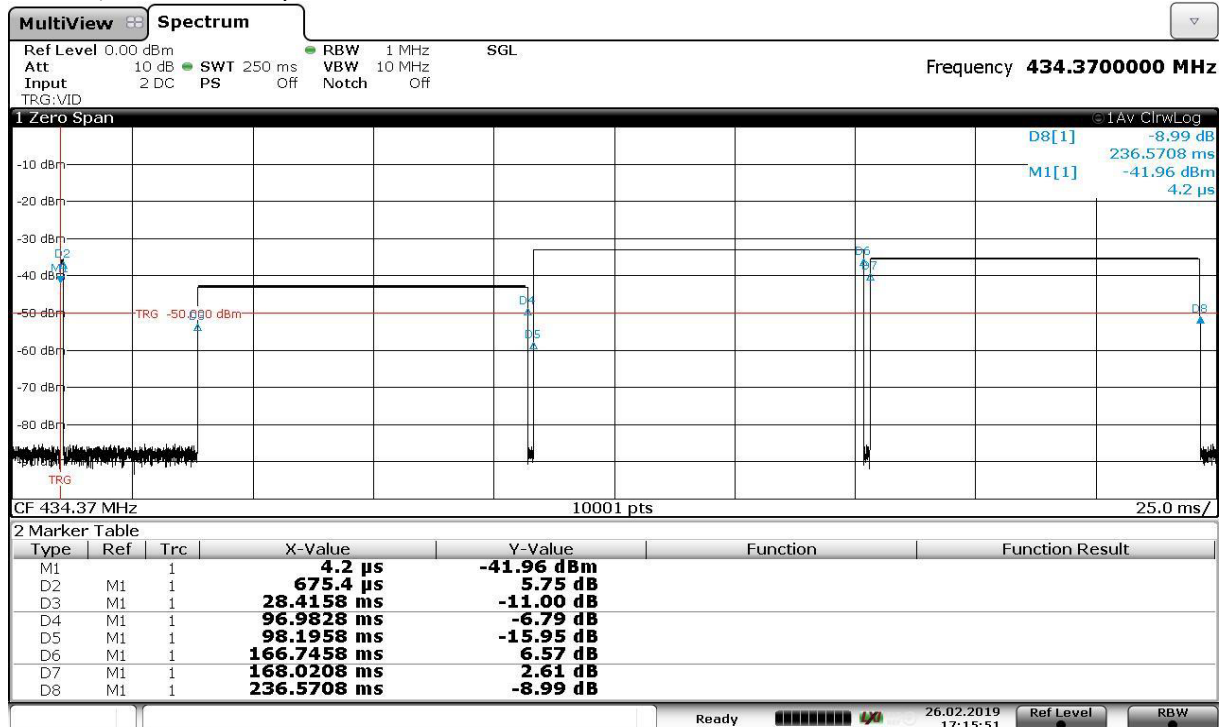
Plot 2. The transmission in 100 ms. The maximal Duty Cycle in 100 ms interval. beginning at M1, which is the first channel of a triplet. (M1 to D2) and a part of the second one (D3 to D4).



09:37:27 26.02.2019

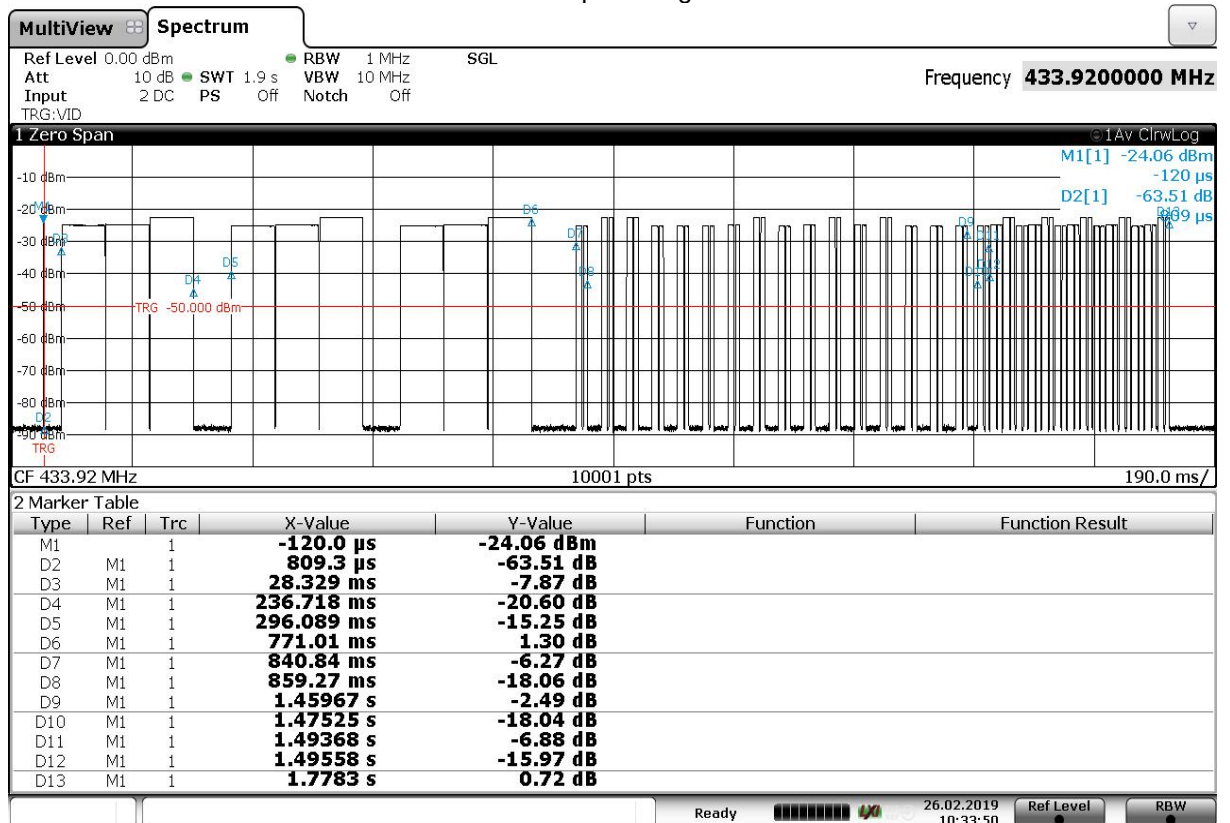
Plot 3. Very first narrow burst and first “triplet”.

Please note, that every burst of a “triplet” is transmitted on a different channel. For each button, the channel permutation is different.



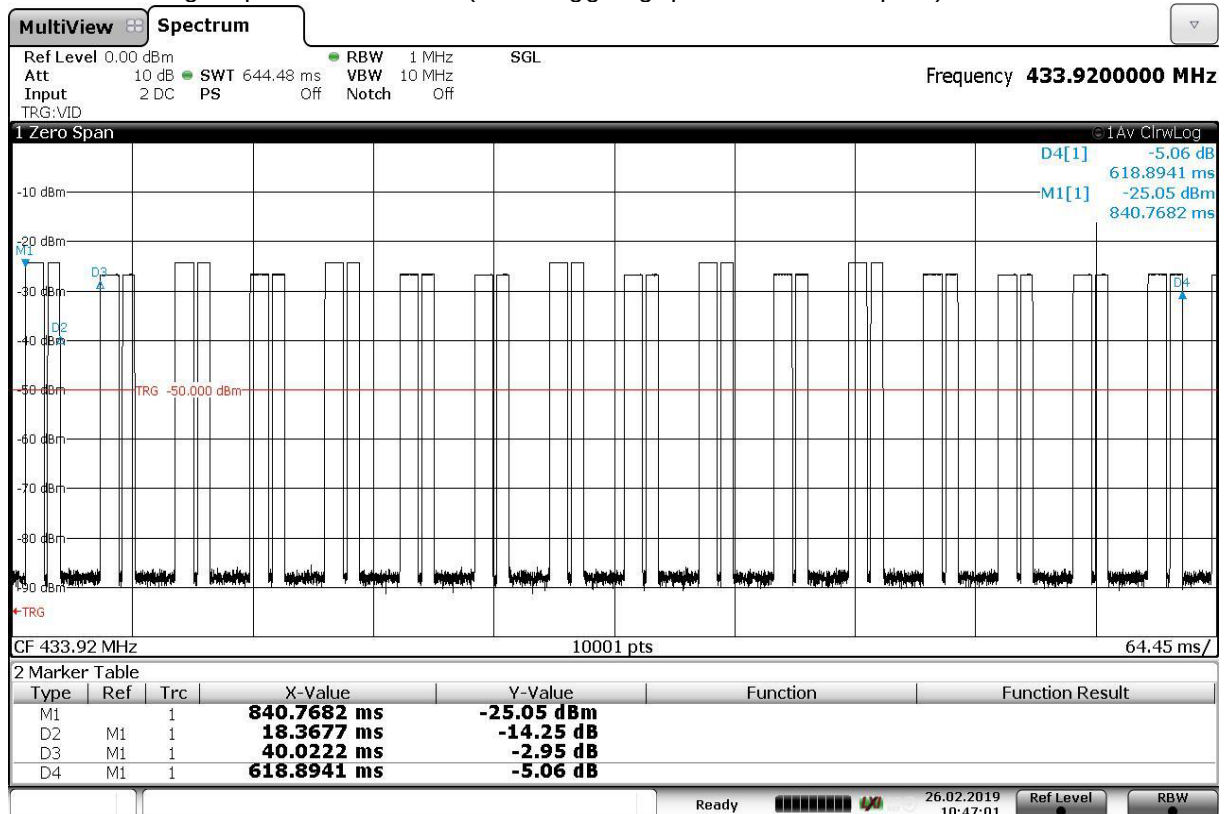
17:15:51 26.02.2019

Plot 4. The transmission after continuous pressing the button “Trunk”



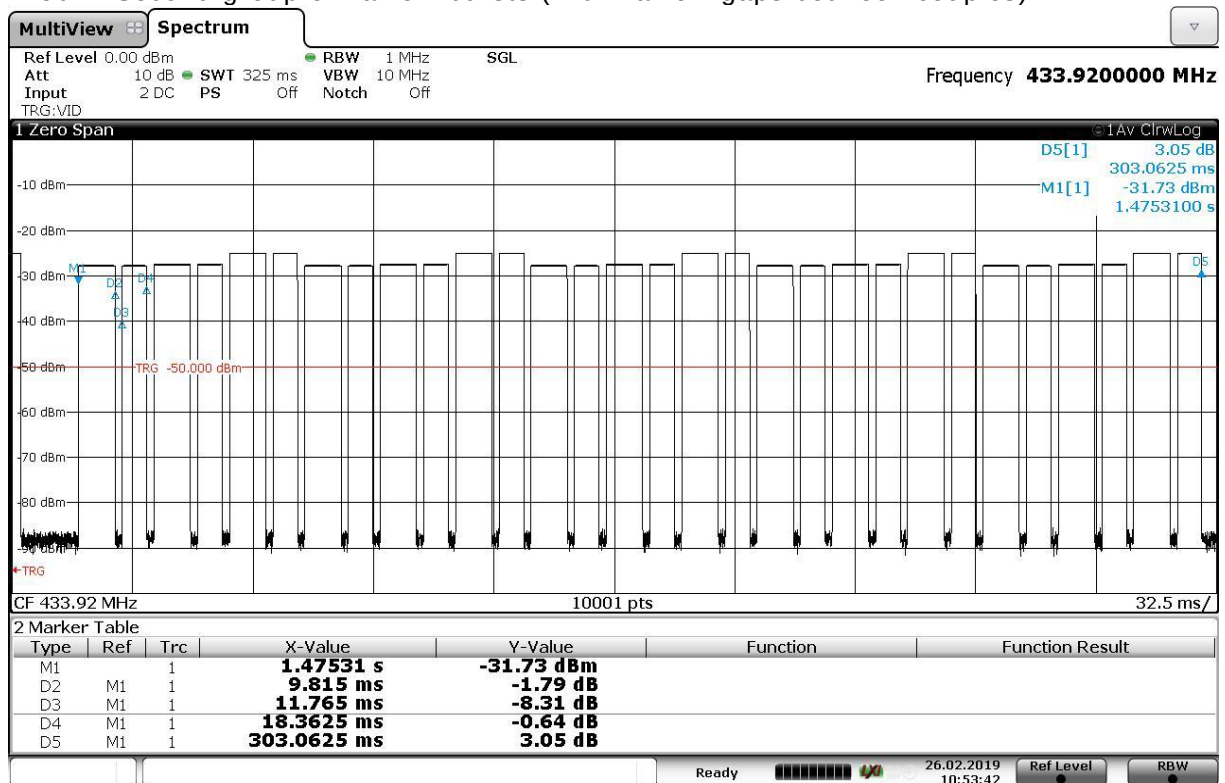
10:33:50 26.02.2019

Plot 5. First group narrow bursts (with bigger gaps between couples)



10:47:02 26.02.2019

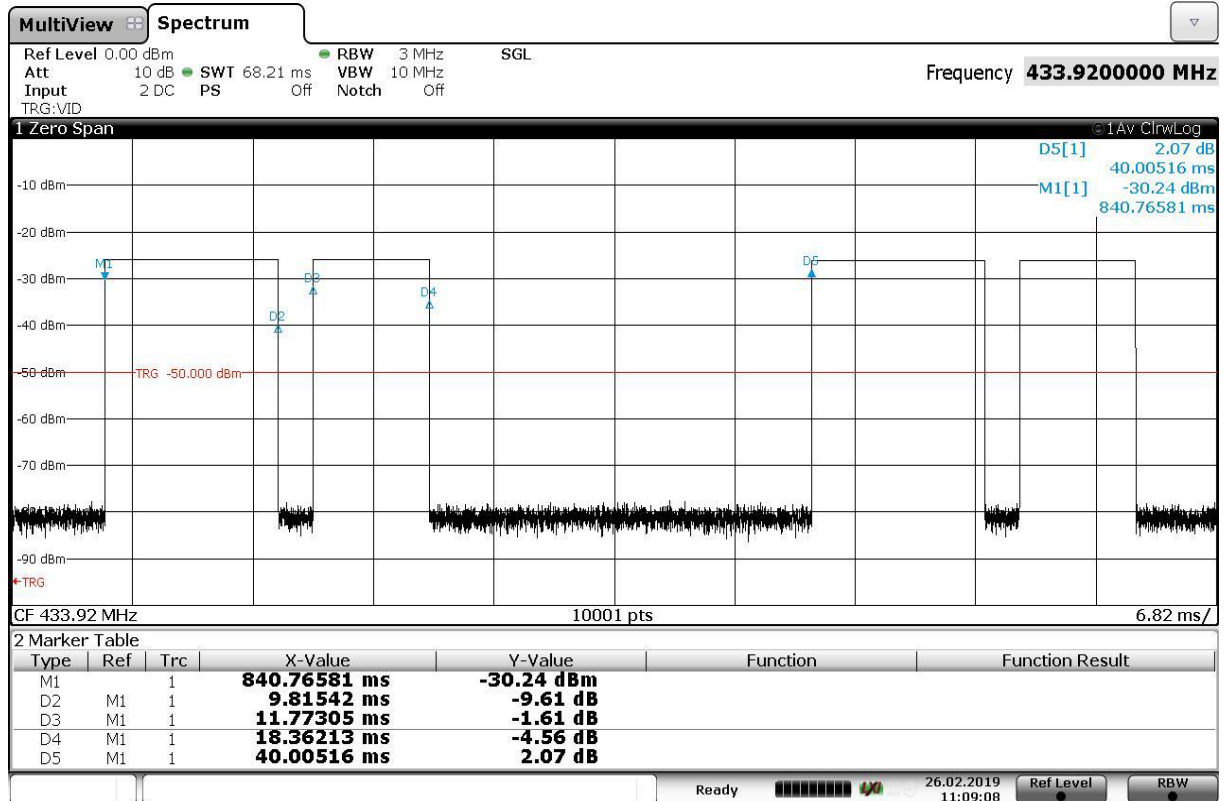
Plot 7. Second group of narrow bursts (with narrow gaps between couples)



10:53:43 26.02.2019

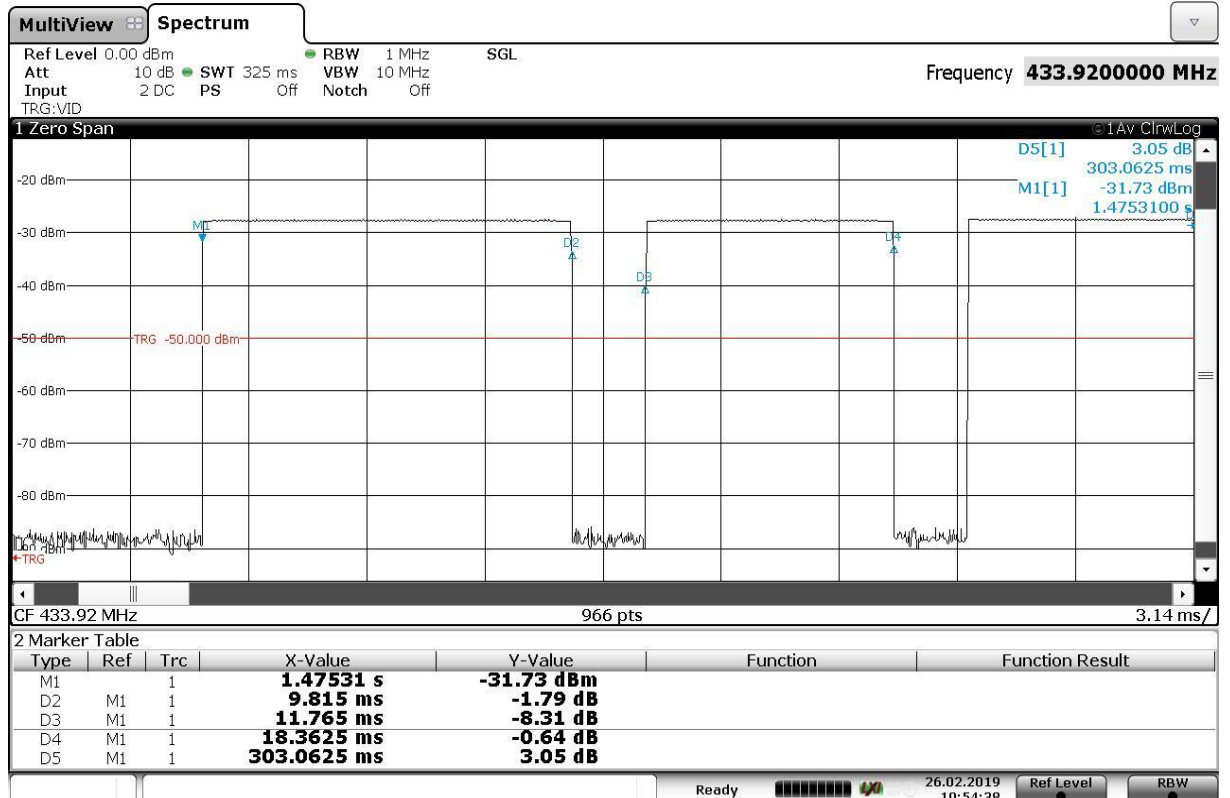


Plot 6 First bursts and gaps of the first group narrow bursts, bigger gaps



11:09:09 26.02.2019

Plot 8. First bursts and gaps of the second group narrow pulses, narrow gaps



10:54:38 26.02.2019



## 4.2 SPURIOUS RADIATED EMISSIONS

Standard      FCC Part 15 Subpart C

The test was performed according to:  
ANSI C63.10–2013

### 4.2.1 TEST DESCRIPTION

The test set-up was made in accordance to the general provisions of ANSI C63.10 in a typical installation configuration. The Equipment Under Test (EUT) was set up on a non-conductive table 1.0 x 2.0 m<sup>2</sup> in the semi-anechoic chamber. The influence of the EUT support table that is used between 30–1000 MHz was evaluated.

The measurement procedure is implemented into the EMI test software EMC32 from R&S. Exploratory tests are performed at 3 orthogonal axes to determine the worst-case orientation of a body-worn or handheld EUT. The final test on all kind of EUTs is also performed at 3 axes. A pre-check is performed while the EUT is powered from a DC power source.

#### 1. Measurement up to 30 MHz

The Loop antenna HFH2-Z2 is used.

##### Step 1: pre-measurement

- Anechoic chamber
- Antenna distance: 3 m
- Detector: Peak-Maxhold
- Frequency range: 0.009 - 0.15 MHz and 0.15 – 30 MHz
- Frequency steps: 0.05 kHz and 2.25 kHz
- IF-Bandwidth: 0.2 kHz and 9 kHz
- Measuring time / Frequency step: 100 ms (FFT-based)

Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

##### Step 2: final measurement

For the relevant emissions determined in step 1, an additional measurement with the following settings will be performed. Intention of this step is to find the maximum emission level.

- Open area test side
- Antenna distance: according to the Standard
- Detector: Quasi-Peak
- Frequency range: 0.009 – 30 MHz
- Frequency steps: measurement at frequencies detected in step 1
- IF-Bandwidth: 0.2 - 10 kHz
- Measuring time / Frequency step: 1 s

#### 2. Measurement above 30 MHz and up to 1 GHz

##### Step 1: Preliminary scan

This is a preliminary test to identify the highest amplitudes relative to the limit.

Settings for step 1:

- Antenna distance: 3 m
- Detector: Peak-Maxhold / Quasipeak (FFT-based)
- Frequency range: 30 – 1000 MHz
- Frequency steps: 30 kHz

- IF-Bandwidth: 120 kHz
- Measuring time / Frequency step: 100 ms
- Turntable angle range:  $-180^{\circ}$  to  $90^{\circ}$
- Turntable step size:  $90^{\circ}$
- Height variation range: 1 – 3 m
- Height variation step size: 2 m
- Polarisation: Horizontal + Vertical

Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

#### Step 2: Adjustment measurement

In this step the accuracy of the turntable azimuth and antenna height will be improved. This is necessary to find out the maximum value of every frequency.

For each frequency, which was determined the turntable azimuth and antenna height will be adjusted. The turntable azimuth will slowly vary by  $\pm 45^{\circ}$  around this value. During this action, the value of emission is continuously measured. The turntable azimuth at the highest emission will be recorded and adjusted. In this position, the antenna height will also slowly vary by  $\pm 100$  cm around the antenna height determined. During this action, the value of emission is also continuously measured. The antenna height of the highest emission will also be recorded and adjusted.

- Detector: Peak – Maxhold
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 100 ms
- Turntable angle range:  $\pm 45^{\circ}$  around the determined value
- Height variation range:  $\pm 100$  cm around the determined value
- Antenna Polarisation: max. value determined in step 1

#### Step 3: Final measurement with QP detector

With the settings determined in step 3, the final measurement will be performed:

EMI receiver settings for step 4:

- Detector: Quasi-Peak ( $< 1$  GHz)
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 1 s

After the measurement a plot will be generated which contains a diagram with the results of the preliminary scan and a chart with the frequencies and values of the results of the final measurement.

### 3. Measurement above 1 GHz

The following modifications apply to the measurement procedure for the frequency range above 1 GHz:

#### Step 1:

The Equipment Under Test (EUT) was set up on a non-conductive support (tilt device) at 1.5 m height in the fully-anechoic chamber.

All steps were performed with one height of the receiving antenna only.

The EUT is turned during the preliminary measurement across the elevation axis, with a step size of  $90^{\circ}$ .

The turn table step size (azimuth angle) for the preliminary measurement is  $45^{\circ}$ .

#### Step 2:

Due to the fact, that in this frequency range the test is performed in a fully anechoic room, the height scan of the receiving antenna in step 2 is omitted. Instead of this, a maximum search with a step size  $\pm 45^{\circ}$  for the elevation axis is performed.

The turn table azimuth will slowly vary by  $\pm 22.5^{\circ}$ .

The elevation angle will slowly vary by  $\pm 45^{\circ}$

EMI receiver settings (for all steps):

- Detector: Peak, Average
- IF Bandwidth = 1 MHz

Step 3:

Spectrum analyser settings for step 3:

- Detector: Peak / Average
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 1 MHz
- Measuring time: 1 s

## 4.2.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.247 (d)

... In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

FCC Part 15, Subpart C, §15.209, Radiated Emission Limits

| Frequency in MHz | Limit (µV/m)  | Measurement distance (m) | Calculate Limit (dBµV/m @10m) | Limit (dBµV/m) @10m |
|------------------|---------------|--------------------------|-------------------------------|---------------------|
| 0.009 – 0.49     | 2400/F (kHz)  | 300                      | (48.5 – 13.8) + 59.1 dB       | 107.6 – 72.9        |
| 0.49 – 1.705     | 24000/F (kHz) | 30                       | (33.8 – 23.0) + 19.1 dB       | 52.9 – 42.1         |
| 1.705 – 30       | 30            | 30                       | 29.5 + 19.1 dB                | 39.5                |

| Frequency in MHz | Limit (µV/m) | Measurement distance (m) | Limit (dBµV/m) |
|------------------|--------------|--------------------------|----------------|
| 30 – 88          | 100          | 3                        | 40.0           |
| 88 – 216         | 150          | 3                        | 43.5           |
| 216 – 960        | 200          | 3                        | 46.0           |
| above 960        | 500          | 3                        | 54.0           |

§15.35(b)

..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit....

Used conversion factor:  $\text{Limit (dBµV/m)} = 20 \log (\text{Limit (µV/m)}/1\mu\text{V/m})$

§15.35(b) ..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit ...

Used conversion factor:  $\text{Limit (dBµV/m)} = 20 \log (\text{Limit (µV/m)}/1\mu\text{V/m})$

§15.35(c):

[...] when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds.

As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted [...].

§15.231(b)(3)

The limits on the field strength of the spurious emissions in the above table are based on the fundamental frequency of the intentional radiator.

Spurious emissions shall be attenuated to the average (or, alternatively, CISPR quasi-peak) limits shown in this table or to the general limits shown in §15.209, whichever limit permits a higher field strength.

Interpretation of the test laboratory:

The last subordinate clause of §15.231(b)(3) is overruled by §15.205/209, therefore within the restricted bands the limits defined at §15.205/209 and outside the restricted bands the limits defined at §15.231(b) resp. §15.231(e) are applied.

#### 4.2.3 TEST PROTOCOL

##### 4.2.3.1 MEASUREMENT UP TO 30 MHz

Temperature: 24 °C  
Air Pressure: 1009 hPa  
Humidity: 35 %

| Op. Mode                       |                                   |                          |      |     | Setup          |                | Port           |                      |                      |
|--------------------------------|-----------------------------------|--------------------------|------|-----|----------------|----------------|----------------|----------------------|----------------------|
| op-mode 1                      |                                   |                          |      |     | Setup_01       |                | Enclosure      |                      |                      |
| Measuring Antenna Polarisation | Spurious Emission Frequency [MHz] | Corrected value [dBµV/m] |      |     | Limit [dBµV/m] | Limit [dBµV/m] | Limit [dBµV/m] | Margin to limit [dB] | Margin to limit [dB] |
|                                |                                   | QP                       | Peak | AV  | QP             | Peak           | AV             | QP/Peak              | AV                   |
| 0°                             | ---                               | ---                      | ---  | --- | ---            | ---            | ---            | ---                  | ---                  |
| 90°                            | ---                               | ---                      | ---  | --- | ---            | ---            | ---            | ---                  | ---                  |

Remark: In step 1 no spurious emissions above the limit were found using a peak detector, therefore step 2 (using a QP-detector) was not performed. For this test the EUT was sending a continuously modulated signal. Please see the measurement plots.

The EUT is tested in horizontal position, as it is normally pointed to the vehicle's door.

##### 4.2.3.2 MEASUREMENT ABOVE 30 MHz TO 6 GHz

Temperature: 24 °C  
Air Pressure: 1006 hPa  
Humidity: 32 %

| Op. Mode  | Setup    | Port      |
|-----------|----------|-----------|
| op-mode 1 | Setup_01 | Enclosure |
| op-mode 1 | Setup_02 | Enclosure |

| Polarisation of the antenna and the EUT | Spurious Emission Frequency [MHz] | Corrected value [dBµV/m] |      |     | Limit [dBµV/m] | Limit [dBµV/m] | Limit [dBµV/m] | Margin to limit [dB] | Margin to limit [dB] |
|-----------------------------------------|-----------------------------------|--------------------------|------|-----|----------------|----------------|----------------|----------------------|----------------------|
|                                         |                                   | QP                       | Peak | AV  | QP             | Peak           | AV             | QP/Peak              | AV                   |
| ---                                     | ---                               | ---                      | ---  | --- | ---            | ---            | ---            | ---                  | ---                  |

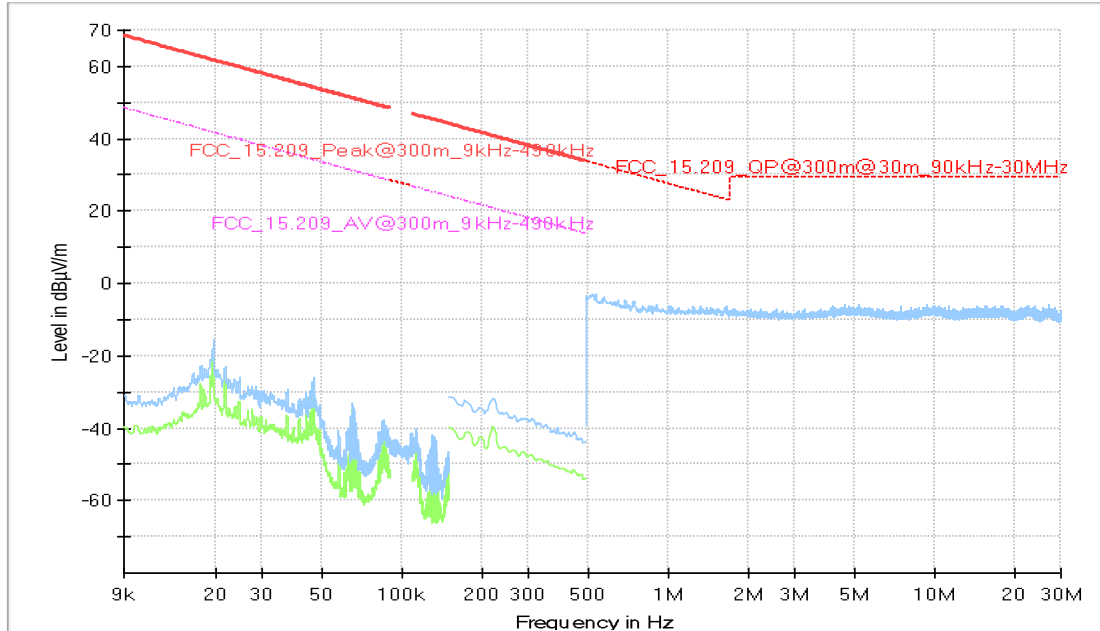
Remarks: - No spurious emissions in the range 15 dB below the limit were found. The test was performed in the frequency range from 30 MHz to 6 GHz. For this test the EUT was sending a continuously modulated signal.  
- Please see the measurement plots.  
- The EUT is tested in horizontal position, as it is normally pointed to the vehicle's door.

#### 4.2.4 TEST RESULT: SPURIOUS RADIATED EMISSIONS

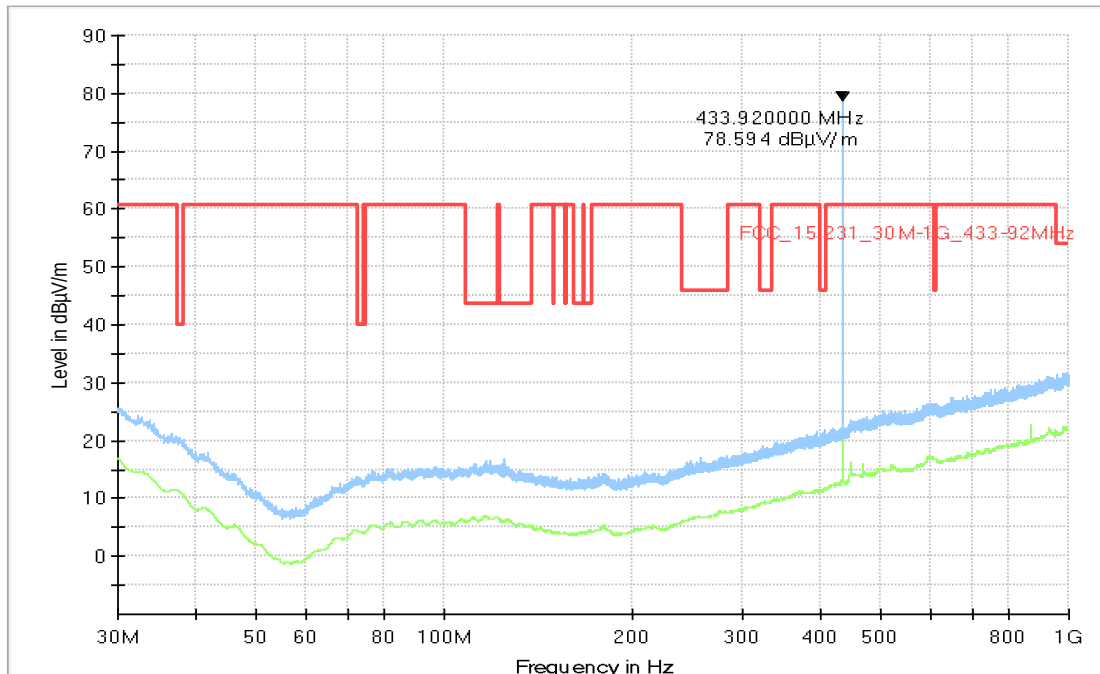
| FCC Part 15, Subpart C | Op. Mode  | Result |
|------------------------|-----------|--------|
|                        | op-mode 1 | passed |

## 4.2.5 MEASUREMENT PLOTS

### 4.2.5.1 RADIATED EMISSIONS ( $f < 30$ MHz)



### 4.2.5.2 RADIATED EMISSIONS ( $30 \text{ MHz} < f < 1 \text{ GHz}$ )



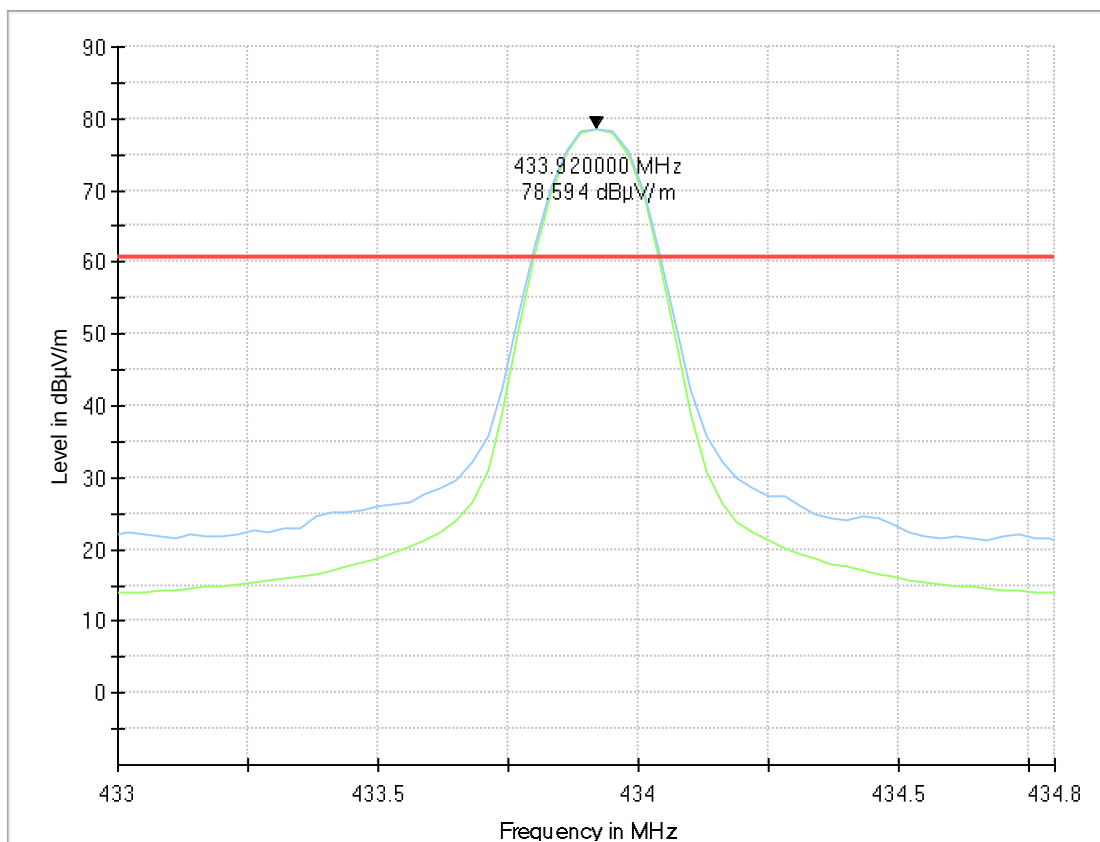
### Final Result

| Frequency (MHz) | QuasiPeak (dBμV/m) | Limit (dBμV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Comment |
|-----------------|--------------------|----------------|-------------|-----------------|-----------------|-------------|-----|---------------|---------|
| -               | -                  | -              | -           | -               | -               | -           | -   | -             | -       |

Note: The values over the limit line are from modulated carrier and are entirely in the EUT Occupied BW measured in clause 4.3.

#### 4.2.5.3 RADIATED EMISSIONS (30 MHz < f < 1GHz) Exclusion band (Zoomed)

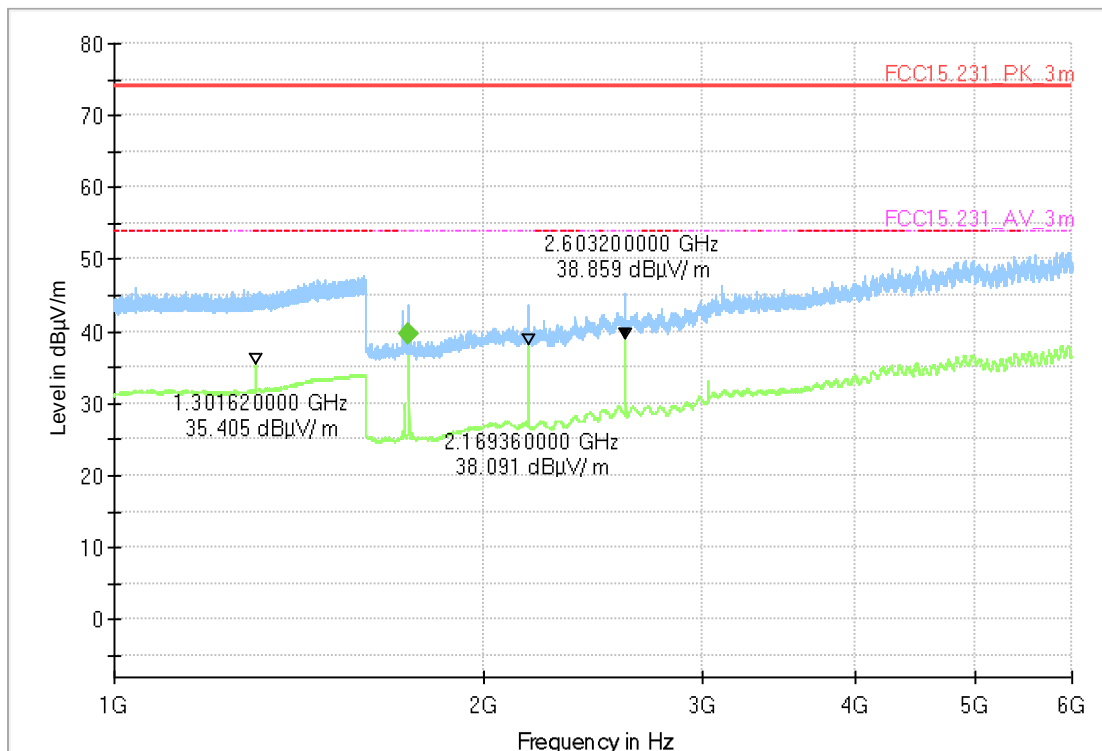
Test Description: Radiated Emissions, Test Site: Semi Anechoic Chamber @ 3 m  
 Test Standard: FCC §15.231  
 EUT / Setup Code: DE1307004ab01  
 Operating Conditions: SRD (433.92MHz)  
 Operator Name: MER  
 Comment: EUT: vertical  
 Legend: Trace: blue = PK, green = QP; Star: red or blue = critical frequency;  
 Rhombus: blue = final QP



#### Final\_Result

| Frequency (MHz) | QuasiPeak (dBμV/m) | Limit (dBμV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Comment |
|-----------------|--------------------|----------------|-------------|-----------------|-----------------|-------------|-----|---------------|---------|
| -               | -                  | -              | -           | -               | -               | -           | -   | -             | -       |

#### 4.2.5.4 RADIATED EMISSIONS (1 GHz < f < 6GHz)



Legend: Trace: blue = PK, green = QP; Rhombus: green = final QP

#### Critical frequencies

| Frequency (MHz) | MaxPeak (dBμV/m) | Average (dBμV/m) | Limit (dBμV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Elevation (deg) |
|-----------------|------------------|------------------|----------------|-------------|-----------------|-----------------|-------------|-----|---------------|-----------------|
| 1735.520        | ---              | 39.8             | 53.98          | 14.22       | ---             | ---             | 150.0       | H   | -11.0         | -12.0           |

#### Final result

| Frequency (MHz) | MaxPeak (dBμV/m) | CAverage (dBμV/m) | Limit (dBμV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Elevation (deg) |
|-----------------|------------------|-------------------|----------------|-------------|-----------------|-----------------|-------------|-----|---------------|-----------------|
| 1735.520        | ---              | 39.6              | 53.98          | 14.39       | 1000.0          | 1000.000        | 150.0       | H   | -11.0         | -10.0           |



### 4.3 MAXIMUM RADIATED FIELD STRENGTH AT FUNDAMENTAL FREQUENCY

Standard FCC Part 15, Subpart C

The test was performed according to:  
ANSI C63.10-2013

#### 4.3.1 TEST DESCRIPTION

Please refer to sub-clause 4.1.1

#### 4.3.2 TEST LIMITS

Please refer to sub-clause 4.1.2

#### 4.3.3 TEST PROTOCOL

Temperature: 24 °C  
Air Pressure: 1009 hPa  
Humidity: 38 %

| Op. Mode  | Setup    | Port      |
|-----------|----------|-----------|
| op-mode 2 | Setup_02 | Enclosure |

| Frequency<br>[MHz] | Output power<br>[dBμV/m] | Limit<br>[dBμV/m] | Margin to Limit<br>[dB] | Remarks                                                  |
|--------------------|--------------------------|-------------------|-------------------------|----------------------------------------------------------|
| 433.470            | 79.69                    | 80.81             | 1.12                    | Maximum radiated field strength at fundamental frequency |
| 433.920            | 79.88                    | 80.83             | 0.94                    |                                                          |
| 434.370            | 79.53                    | 80.84             | 1.31                    |                                                          |

- Notes: 1) The EUT transmitted continuously not modulated carrier at  $f_u = f_c - \Delta f/2$   
Where  $\Delta f$  is FSK deviation of channel frequency declared by the customer.  
2) The Duty Cycle correction factor calculated in clause 4.1 is not used, because it is negligible.

#### 4.3.4 TEST RESULT:

#### MAXIMUM RADIATED FIELD STRENGTH AT FUNDAMENTAL FREQUENCY

| FCC Part 15, Subpart C | Op. Mode  | Result |
|------------------------|-----------|--------|
|                        | op-mode 2 | passed |

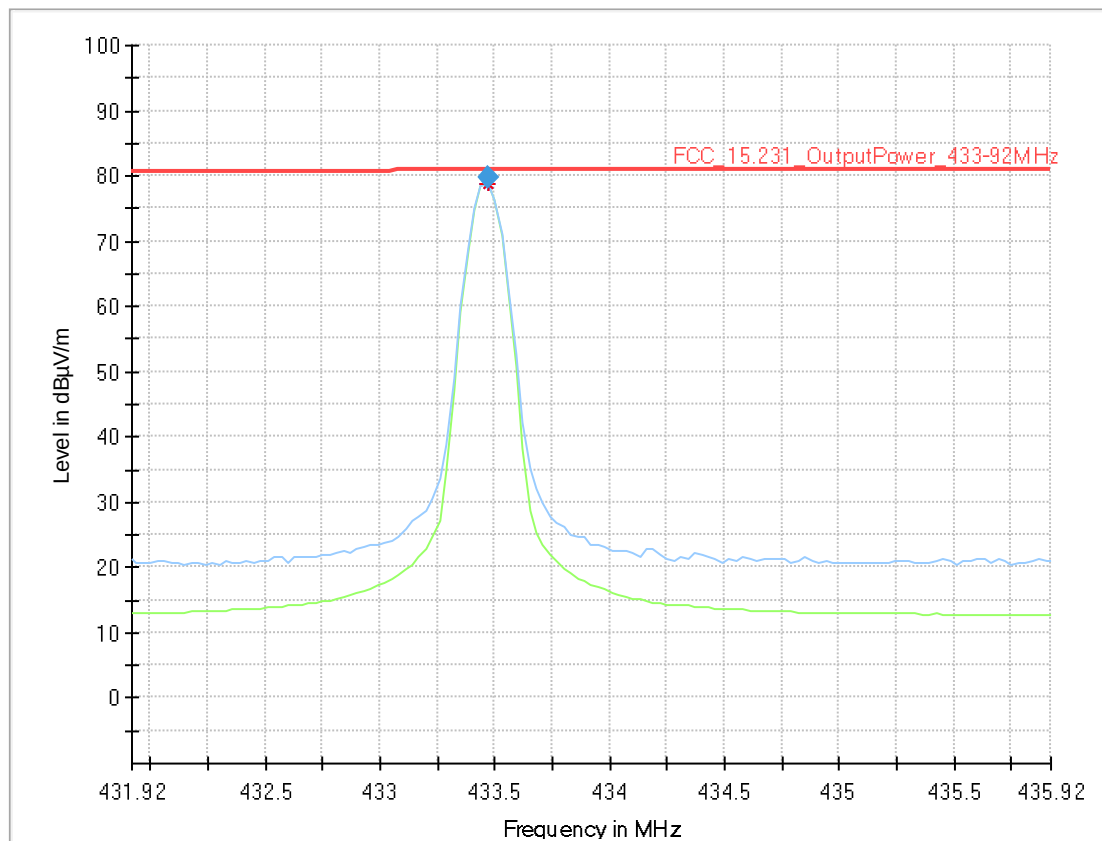
#### 4.3.5 MEASUREMENT PLOT

##### MAXIMUM RADIATED FIELD STRENGTH AT FUNDAMENTAL FREQUENCY

###### Common information

|                       |                                                                                                   |
|-----------------------|---------------------------------------------------------------------------------------------------|
| Test Description:     | Radiated Emissions, Test Site: Semi Anechoic Chamber @ 3 m                                        |
| Test Standard:        | FCC §15.231                                                                                       |
| EUT / Setup Code:     | DE1307005ab01                                                                                     |
| Operating Conditions: | SRD (433.47MHz)                                                                                   |
| Operator Name:        | MER                                                                                               |
| Comment:              | EUT: vertical                                                                                     |
| Legend:               | Trace: blue = PK, green = QP; Star: red or blue = critical frequency;<br>Rhombus: blue = final QP |

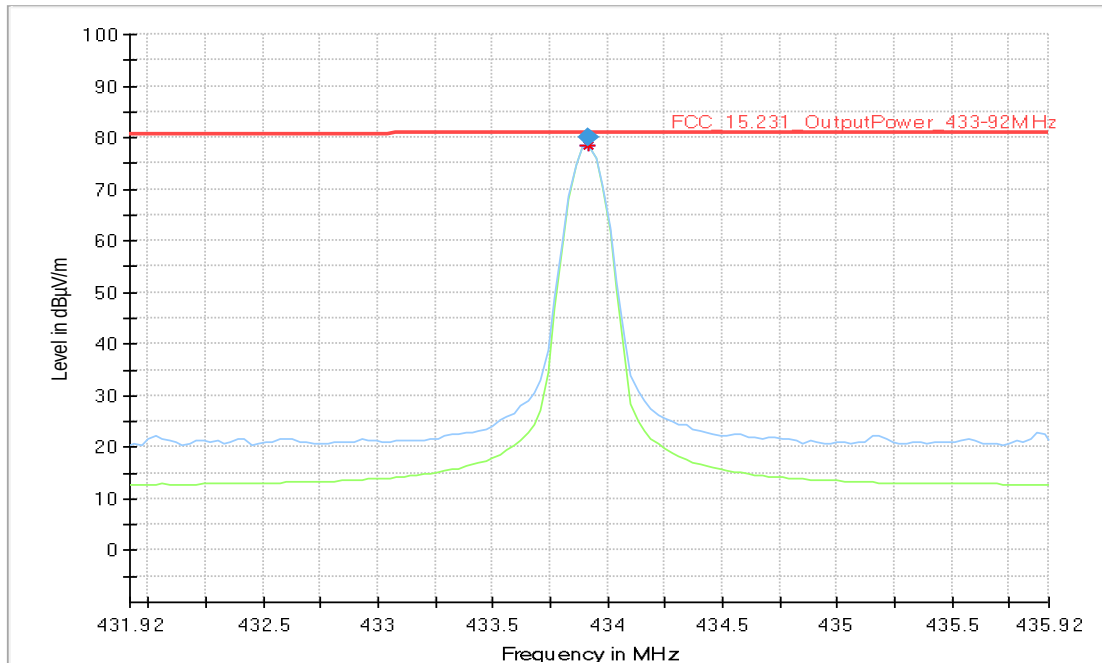
Channel 1  $f_c = 433.47$  MHz



###### Final Result

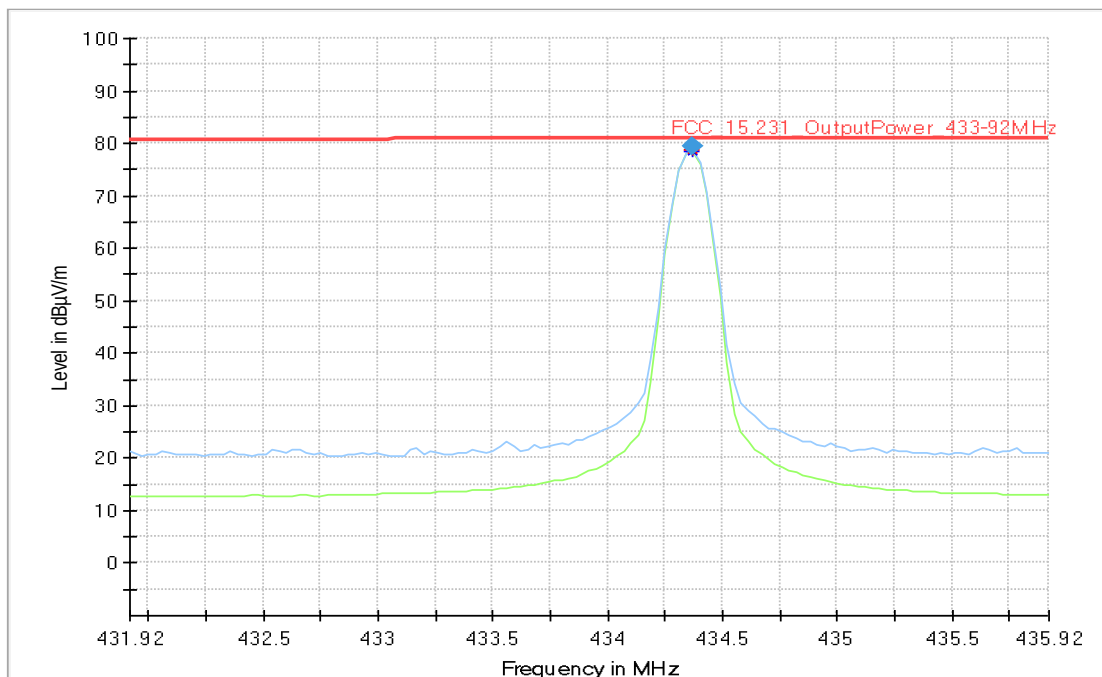
| Frequency (MHz) | QuasiPeak (dBμV / m) | Limit (dBμV / m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) |
|-----------------|----------------------|------------------|-------------|-----------------|-----------------|-------------|-----|---------------|
| 433.470000      | 79.69                | 80.81            | 1.12        | 1000.0          | 120.000         | 119.0       | V   | -111.0        |

Channel 2  $f_c = 433.92$  MHz



### Final Result

| Frequency (MHz) | QuasiPeak (dBμV/m) | Limit (dBμV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) |
|-----------------|--------------------|----------------|-------------|-----------------|-----------------|-------------|-----|---------------|
| 433.920000      | 79.88              | 80.83          | 0.94        | 1000.0          | 120.000         | 119.0       | V   | -65.0         |



### Final Result

| Frequency (MHz) | QuasiPeak (dBμV/m) | Limit (dBμV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) |
|-----------------|--------------------|----------------|-------------|-----------------|-----------------|-------------|-----|---------------|
| 434.370000      | 79.53              | 80.84          | 1.31        | 1000.0          | 120.000         | 119.0       | V   | -106.0        |

#### 4.4 OCCUPIED BANDWIDTH

Standard FCC Part 15 Subpart C

The test was performed according to: ANSI C63.10–2013

##### 4.4.1 TEST DESCRIPTION

The Equipment Under Test (EUT) was setup in a shielded room to perform the occupied bandwidth measurements.

For analyzer settings please see the measurement plots.

##### 4.4.2 TEST LIMITS

FCC Part 15, Subpart C, §15.231(c)

The maximum 20 dB bandwidth of a transmitter operating at a frequency range:

70 to 900 MHz is 0.25% of the centre frequency

above 900 MHz is 0.5% of the centre frequency

##### 4.4.3 TEST PROTOCOL

Temperature: 23 °C

Air Pressure: 1009 hPa

Humidity: 42 %

|           |          |           |
|-----------|----------|-----------|
| Op. Mode  | Setup    | Port      |
| op-mode 1 | Setup_01 | Enclosure |

| Cannel Frequency [MHz] | 20 dB bandwidth [kHz] | 99 % bandwidth [kHz] | Limit [kHz] | Remarks                                                  |
|------------------------|-----------------------|----------------------|-------------|----------------------------------------------------------|
| 433.47                 | 82.85                 | 81.042               | 1083.7      | The limit is calculated as:<br>Channel frequency X 0.25% |
| 433.92                 | 83.22                 | 81.404               | 1084.8      |                                                          |
| 434.37                 | 82.85                 | 81.404               | 1085.9      |                                                          |

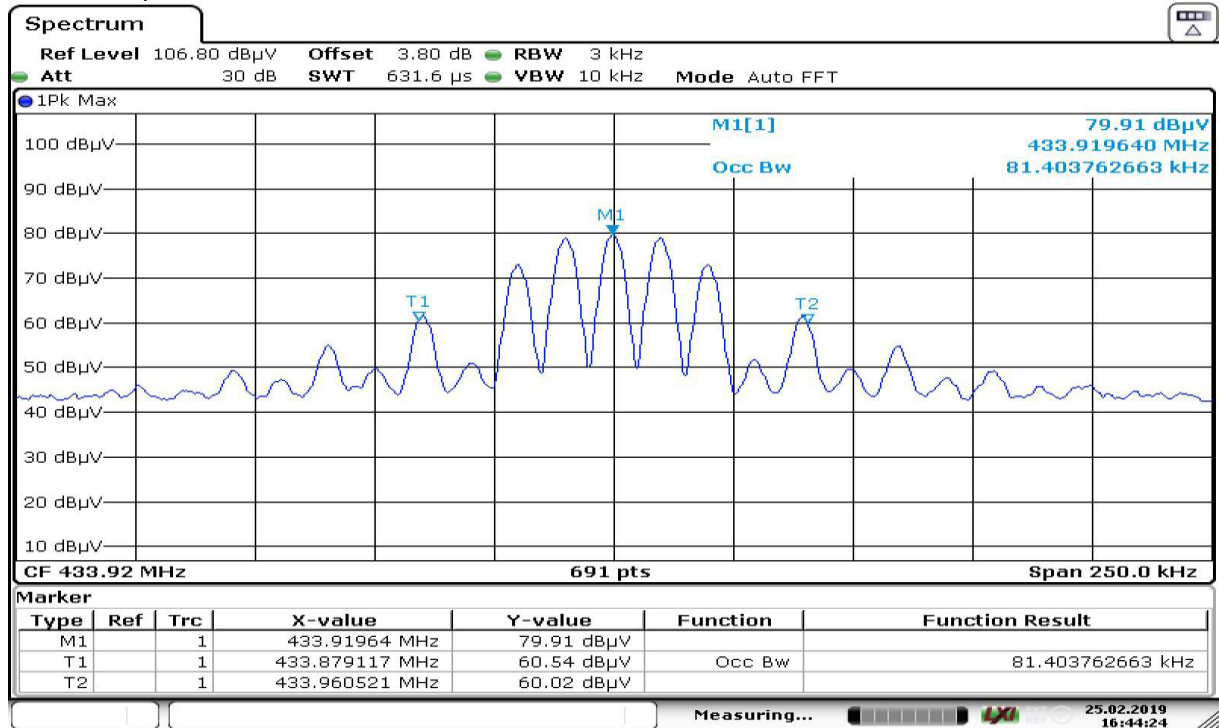
Remark: Please see the measurement plots.

##### 4.4.4 TEST RESULT: OCCUPIED BANDWIDTH

|                        |           |        |
|------------------------|-----------|--------|
| FCC Part 15, Subpart C | Op. Mode  | Result |
|                        | op-mode 1 | passed |

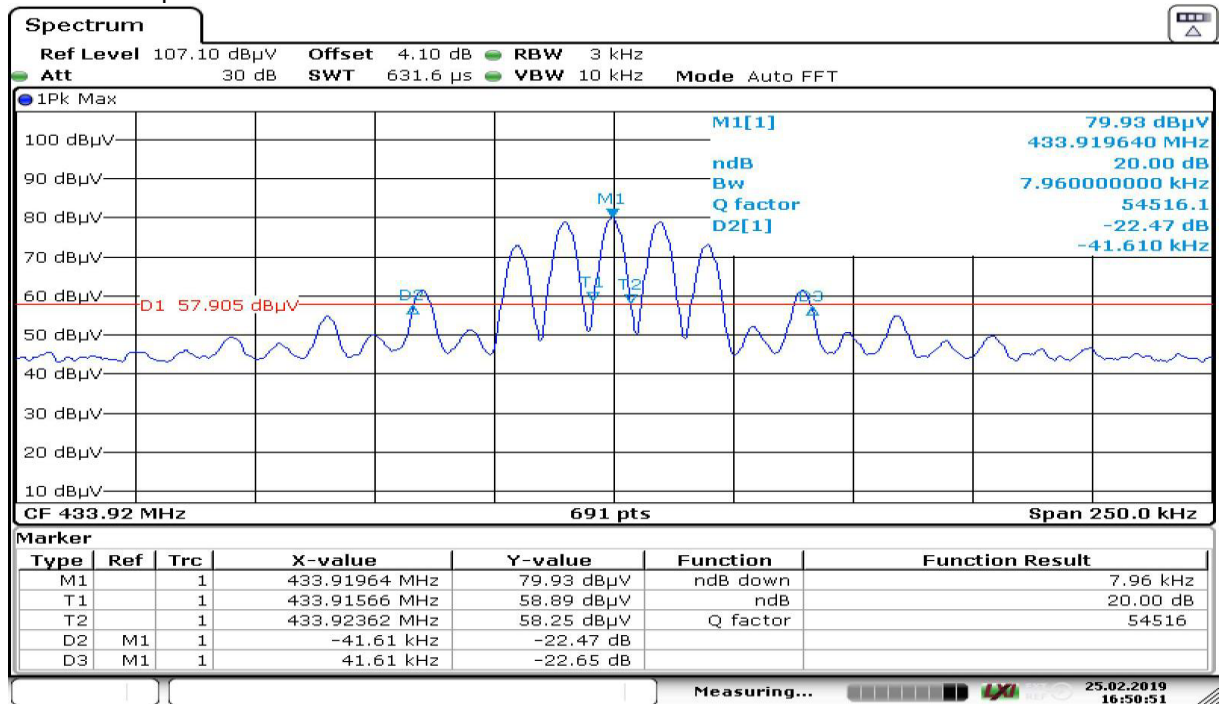
#### 4.4.5 MEASUREMENT PLOTS OCCUPIED BANDWIDTH WORST CASES

99% occupied bandwidth between T2 and T1 = 114.689 kHz on ch3



Date: 25.FEB.2019 16:44:25

20 DB occupied bandwidth between Markers D2 and D3 = 81.04 kHz on ch1



Date: 25.FEB.2019 16:50:51

## 5 TEST EQUIPMENT

### 1 Radiated Emissions

#### Lab to perform radiated emission tests

| Ref.No. | Device Name          | Description                                            | Manufacturer                       | Serial Number      | Last Calibration | Calibration Due |
|---------|----------------------|--------------------------------------------------------|------------------------------------|--------------------|------------------|-----------------|
| 1.1     | NRV-Z1               | Sensor Head A                                          | Rohde & Schwarz GmbH & Co. KG      | 827753/005         |                  |                 |
| 1.2     | MFS                  | Rubidium Frequency Normal MFS                          | Datum GmbH                         | 002                | 2018-10          | 2020-10         |
| 1.3     | Opus10 TPR (8253.00) | ThermoAirpressure Datalogger 13 (Environ)              | Lufft Mess- und Regeltechnik GmbH  | 13936              | 2017-04          | 2019-04         |
| 1.4     | ESW44                | EMI Test Receiver                                      | Rohde & Schwarz GmbH & Co. KG      | 101603             | 2018-05          | 2019-05         |
| 1.5     | Anechoic Chamber     | 10.58 x 6.38 x 6.00 m <sup>3</sup>                     | Frankonia                          | none               |                  |                 |
| 1.6     | FS-Z60               | Harmonic Mixer 40 - 60 GHz                             | Rohde & Schwarz Messgerätebau GmbH | 100178             | 2016-12          | 2019-12         |
| 1.7     | FS-Z220              | Harmonic Mixer 140 - 220 GHz                           | Rohde & Schwarz Messgerätebau GmbH | 101005             | 2017-03          | 2020-03         |
| 1.8     | SGH-05               | Standard Gain / Pyramidal Horn Antenna (140 - 220 GHz) |                                    | 075                |                  |                 |
| 1.9     | HL 562               | Ultralog new biconicals                                | Rohde & Schwarz                    | 830547/003         | 2018-07          | 2021-07         |
| 1.10    | 5HC2700/12750-1.5-KK | High Pass Filter                                       | Trilithic                          | 9942012            |                  |                 |
| 1.11    | ASP 1.2/1.8-10 kg    | Antenna Mast                                           | Maturo GmbH                        | -                  |                  |                 |
| 1.12    | Fully Anechoic Room  | 8.80m x 4.60m x 4.05m (l x w x h)                      | Albatross Projects                 | P26971-647-001-PRB | 2018-06          | 2020-06         |
| 1.13    | Fluke 177            | Digital Multimeter 03 (Multimeter)                     | Fluke Europe B.V.                  | 86670383           | 2018-04          | 2020-04         |
| 1.14    | NRVD                 | Power Meter                                            | Rohde & Schwarz GmbH & Co. KG      | 828110/016         |                  |                 |
| 1.15    | HF 906               | Double-ridged horn                                     | Rohde & Schwarz                    | 357357/002         | 2018-06          | 2021-06         |
| 1.16    | JS4-18002600-32-5P   | Broadband Amplifier 18 GHz - 26 GHz                    | Miteq                              | 849785             |                  |                 |
| 1.17    | 3160-09              | Standard Gain / Pyramidal Horn Antenna 26.5 GHz        | EMCO Elektronik GmbH               | 00083069           |                  |                 |
| 1.18    | SGH-19               | Standard Gain / Pyramidal Horn Antenna (40 - 60 GHz)   |                                    | 093                |                  |                 |
| 1.19    | WHKX 7.0/18G-8SS     | High Pass Filter                                       | Wainwright                         | 09                 |                  |                 |
| 1.20    | 4HC1600/12750-1.5-KK | High Pass Filter                                       | Trilithic                          | 9942011            |                  |                 |
| 1.21    | Chroma 6404          | AC Power Source                                        | Chroma ATE INC.                    | 64040001304        |                  |                 |

|      |                               |                                                        |                                       |                        |         |         |
|------|-------------------------------|--------------------------------------------------------|---------------------------------------|------------------------|---------|---------|
| 1.22 | JS4-00102600-42-5A            | Broadband Amplifier 30 MHz - 26 GHz                    | Miteq                                 | 619368                 |         |         |
| 1.23 | TT 1.5 WI                     | Turn Table                                             | Maturo GmbH                           | -                      |         |         |
| 1.24 | HL 562 Ultralog               | Log.-per. Antenna                                      | Rohde & Schwarz                       | 100609                 | 2016-04 | 2019-04 |
| 1.25 | HF 906                        | Double-ridged horn                                     | Rohde & Schwarz                       | 357357/001             | 2018-03 | 2021-03 |
| 1.26 | FS-Z325                       | Harmonic Mixer 220 - 325 GHz                           | Rohde & Schwarz<br>Messgerätebau GmbH | 101006                 | 2017-03 | 2020-03 |
| 1.27 | 3160-10                       | Standard Gain / Pyramidal Horn Antenna 40 GHz          | EMCO Elektronik GmbH                  | 00086675               |         |         |
| 1.28 | SGH-08                        | Standard Gain / Pyramidal Horn Antenna (90 - 140 GHz)  |                                       | 064                    |         |         |
| 1.29 | SGH-12                        | Standard Gain / Pyramidal Horn Antenna (60 - 90 GHz)   |                                       | 326                    |         |         |
| 1.30 | 5HC3500/18000-1.2-KK          | High Pass Filter                                       | Trilithic                             | 200035008              |         |         |
| 1.31 | FS-Z140                       | Harmonic Mixer 90 - 140 GHz                            | Rohde & Schwarz<br>Messgerätebau GmbH | 101007                 | 2017-02 | 2020-02 |
| 1.32 | HFH2-Z2                       | Loop Antenna                                           | Rohde & Schwarz                       | 829324/006             | 2018-01 | 2021-01 |
| 1.33 | Opus10 THI (8152.00)          | ThermoHygro Datalogger 12 (Environ)                    | Lufft Mess- und Regeltechnik GmbH     | 12482                  | 2017-03 | 2019-03 |
| 1.34 | ESR 7                         | EMI Receiver / Spectrum Analyzer                       | Rohde & Schwarz                       | 101424                 | 2016-11 | 2019-01 |
| 1.35 | JS4-00101800-35-5P            | Broadband Amplifier 30 MHz - 18 GHz                    | Miteq                                 | 896037                 |         |         |
| 1.36 | AS 620 P                      | Antenna mast                                           | HD GmbH                               | 620/37                 |         |         |
| 1.37 | Tilt device Maturo (Rohacell) | Antrieb TD1.5-10kg                                     | Maturo GmbH                           | TD1.5-10kg/024/3790709 |         |         |
| 1.38 | SGH-03                        | Standard Gain / Pyramidal Horn Antenna (220 - 325 GHz) |                                       | 060                    |         |         |
| 1.39 | FS-Z90                        | Harmonic Mixer 60 - 90 GHz                             | Rohde & Schwarz<br>Messgerätebau GmbH | 101686                 | 2017-03 | 2020-03 |
| 1.40 | ESIB 26                       | Spectrum Analyzer                                      | Rohde & Schwarz                       | 830482/004             | 2018-01 | 2020-01 |
| 1.41 | PAS 2.5 - 10 kg               | Antenna Mast                                           | Maturo GmbH                           | -                      |         |         |
| 1.42 | AFS42-00101800-25-S-42        | Broadband Amplifier 25 MHz - 18 GHz                    | Miteq                                 | 2035324                |         |         |
| 1.43 | AM 4.0                        | Antenna mast                                           | Maturo GmbH                           | AM4.0/180/11920513     | 2018-07 | 2021-07 |
| 1.44 | HF 907                        | Double-ridged horn                                     | Rohde & Schwarz                       | 102444                 |         |         |
| 1.45 | FSW43                         | Spectrum analyzer                                      | Rohde & Schwarz                       | 103779                 | 2019-02 | 2021-02 |

## 2 Conducted and Radiated Emissions

### Conducted and Radiated, Radio Test Lab

| Ref.No. | Device Name          | Description                           | Manufacturer                      | Serial Number  | Last Calibration | Calibration Due |
|---------|----------------------|---------------------------------------|-----------------------------------|----------------|------------------|-----------------|
| 2.1     | SMB100A              | Signal Generator 9 kHz - 6 GHz        | Rohde & Schwarz                   | 107695         | 2017-07          | 2020-07         |
| 2.2     | MFS                  | Rubidium Frequency Standard           | Datum-Beverly                     | 5489/001       | 2018-10          | 2020-10         |
| 2.3     | FSV30                | Signal Analyzer 10 Hz - 30 GHz        | Rohde & Schwarz                   | 103005         | 2018-04          | 2020-04         |
| 2.4     | Fluke 177            | Digital Multimeter 03 (Multimeter)    | Fluke Europe B.V.                 | 86670383       | 2018-04          | 2020-04         |
| 2.5     | SMP03                | Signal Generator 2 GHz - 27 GHz       | Rohde & Schwarz                   | 833680/003     | 2017-09          | 2020-09         |
| 2.6     | FSIQ26               | Signal Analyser                       | Rohde & Schwarz                   | 840061/005     | 2017-05          | 2019-05         |
| 2.7     | Chroma 6404          | AC Power Source                       | Chroma ATE INC.                   | 64040001304    |                  |                 |
| 2.8     | VT 4002              | Temperature Chamber                   | Vötsch                            | 58566002150010 | 2018-04          | 2020-04         |
| 2.9     | WA1515               | Broadband Power Divider SMA           | Weinschel Associates              | A855           |                  |                 |
| 2.10    | A8455-4              | 4 Way Power Divider (SMA)             |                                   | -              |                  |                 |
| 2.11    | Opus10 THI (8152.00) | ThermoHygro Datalogger 03 (Environ)   | Lufft Mess- und Regeltechnik GmbH | 7482           | 2019-01          | 2020-01         |
| 2.12    | SMBV100A             | Vector Signal Generator 9 kHz - 6 GHz | Rohde & Schwarz                   | 259291         | 2016-10          | 2019-10         |



## 6 ANTENNA FACTORS, CABLE LOSS AND SAMPLE CALCULATIONS

This chapter contains the antenna factors with their corresponding path loss of the used measurement path for all antennas as well as the insertion loss of the LISN.

## 6.1 ANTENNA R&S HFH2-Z2 (9 KHZ – 30 MHZ)

| Frequency | AF<br>HFH-Z2) | Corr. |
|-----------|---------------|-------|
| MHz       | dB (1/m)      | dB    |
| 0.009     | 20.50         | -79.6 |
| 0.01      | 20.45         | -79.6 |
| 0.015     | 20.37         | -79.6 |
| 0.02      | 20.36         | -79.6 |
| 0.025     | 20.38         | -79.6 |
| 0.03      | 20.32         | -79.6 |
| 0.05      | 20.35         | -79.6 |
| 0.08      | 20.30         | -79.6 |
| 0.1       | 20.20         | -79.6 |
| 0.2       | 20.17         | -79.6 |
| 0.3       | 20.14         | -79.6 |
| 0.49      | 20.12         | -79.6 |
| 0.490001  | 20.12         | -39.6 |
| 0.5       | 20.11         | -39.6 |
| 0.8       | 20.10         | -39.6 |
| 1         | 20.09         | -39.6 |
| 2         | 20.08         | -39.6 |
| 3         | 20.06         | -39.6 |
| 4         | 20.05         | -39.5 |
| 5         | 20.05         | -39.5 |
| 6         | 20.02         | -39.5 |
| 8         | 19.95         | -39.5 |
| 10        | 19.83         | -39.4 |
| 12        | 19.71         | -39.4 |
| 14        | 19.54         | -39.4 |
| 16        | 19.53         | -39.3 |
| 18        | 19.50         | -39.3 |
| 20        | 19.57         | -39.3 |
| 22        | 19.61         | -39.3 |
| 24        | 19.61         | -39.3 |
| 26        | 19.54         | -39.3 |
| 28        | 19.46         | -39.2 |
| 30        | 19.73         | -39.1 |

| cable<br>loss 1<br>(inside<br>chamber) | cable<br>loss 2<br>(outside<br>chamber) | cable<br>loss 3<br>(switch<br>unit) | cable<br>loss 4<br>(to<br>receiver) | distance<br>corr.<br>(-40 dB/<br>decade) | d <sub>Limit</sub><br>(meas.<br>distance<br>(limit)) | d <sub>used</sub><br>(meas.<br>distance<br>(used)) |
|----------------------------------------|-----------------------------------------|-------------------------------------|-------------------------------------|------------------------------------------|------------------------------------------------------|----------------------------------------------------|
| dB                                     | dB                                      | dB                                  | dB                                  | dB                                       | m                                                    | m                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -80                                      | 300                                                  | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.1                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.1                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.2                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.2                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.3                                    | 0.1                                     | 0.3                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |
| 0.4                                    | 0.1                                     | 0.3                                 | 0.1                                 | -40                                      | 30                                                   | 3                                                  |

### Sample calculation

$$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + AF \text{ (dB 1/m)} + \text{Corr. (dB)}$$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

$$\text{distance correction} = -40 * \text{LOG} (d_{\text{Limit}}/ d_{\text{used}})$$

Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values

## 6.2 ANTENNA R&S HL562 (30 MHZ – 1 GHZ)

( $d_{Limit} = 3 \text{ m}$ )

| Frequency | AF<br>R&S<br>HL562 | Corr. |
|-----------|--------------------|-------|
| MHz       | dB (1/m)           | dB    |
| 30        | 18.6               | 0.6   |
| 50        | 6.0                | 0.9   |
| 100       | 9.7                | 1.2   |
| 150       | 7.9                | 1.6   |
| 200       | 7.6                | 1.9   |
| 250       | 9.5                | 2.1   |
| 300       | 11.0               | 2.3   |
| 350       | 12.4               | 2.6   |
| 400       | 13.6               | 2.9   |
| 450       | 14.7               | 3.1   |
| 500       | 15.6               | 3.2   |
| 550       | 16.3               | 3.5   |
| 600       | 17.2               | 3.5   |
| 650       | 18.1               | 3.6   |
| 700       | 18.5               | 3.6   |
| 750       | 19.1               | 4.1   |
| 800       | 19.6               | 4.1   |
| 850       | 20.1               | 4.4   |
| 900       | 20.8               | 4.7   |
| 950       | 21.1               | 4.8   |
| 1000      | 21.6               | 4.9   |

| cable<br>loss 1<br>(inside<br>chamber) | cable<br>loss 2<br>(outside<br>chamber) | cable<br>loss 3<br>(switch<br>unit) | cable<br>loss 4<br>(to<br>receiver) | distance<br>corr.<br>(-20 dB/<br>decade) | $d_{Limit}$<br>(meas.<br>distance<br>(limit)) | $d_{used}$<br>(meas.<br>distance<br>(used)) |
|----------------------------------------|-----------------------------------------|-------------------------------------|-------------------------------------|------------------------------------------|-----------------------------------------------|---------------------------------------------|
| dB                                     | dB                                      | dB                                  | dB                                  | dB                                       | m                                             | m                                           |
| 0.29                                   | 0.04                                    | 0.23                                | 0.02                                | 0.0                                      | 3                                             | 3                                           |
| 0.39                                   | 0.09                                    | 0.32                                | 0.08                                | 0.0                                      | 3                                             | 3                                           |
| 0.56                                   | 0.14                                    | 0.47                                | 0.08                                | 0.0                                      | 3                                             | 3                                           |
| 0.73                                   | 0.20                                    | 0.59                                | 0.12                                | 0.0                                      | 3                                             | 3                                           |
| 0.84                                   | 0.21                                    | 0.70                                | 0.11                                | 0.0                                      | 3                                             | 3                                           |
| 0.98                                   | 0.24                                    | 0.80                                | 0.13                                | 0.0                                      | 3                                             | 3                                           |
| 1.04                                   | 0.26                                    | 0.89                                | 0.15                                | 0.0                                      | 3                                             | 3                                           |
| 1.18                                   | 0.31                                    | 0.96                                | 0.13                                | 0.0                                      | 3                                             | 3                                           |
| 1.28                                   | 0.35                                    | 1.03                                | 0.19                                | 0.0                                      | 3                                             | 3                                           |
| 1.39                                   | 0.38                                    | 1.11                                | 0.22                                | 0.0                                      | 3                                             | 3                                           |
| 1.44                                   | 0.39                                    | 1.20                                | 0.19                                | 0.0                                      | 3                                             | 3                                           |
| 1.55                                   | 0.46                                    | 1.24                                | 0.23                                | 0.0                                      | 3                                             | 3                                           |
| 1.59                                   | 0.43                                    | 1.29                                | 0.23                                | 0.0                                      | 3                                             | 3                                           |
| 1.67                                   | 0.34                                    | 1.35                                | 0.22                                | 0.0                                      | 3                                             | 3                                           |
| 1.67                                   | 0.42                                    | 1.41                                | 0.15                                | 0.0                                      | 3                                             | 3                                           |
| 1.87                                   | 0.54                                    | 1.46                                | 0.25                                | 0.0                                      | 3                                             | 3                                           |
| 1.90                                   | 0.46                                    | 1.51                                | 0.25                                | 0.0                                      | 3                                             | 3                                           |
| 1.99                                   | 0.60                                    | 1.56                                | 0.27                                | 0.0                                      | 3                                             | 3                                           |
| 2.14                                   | 0.60                                    | 1.63                                | 0.29                                | 0.0                                      | 3                                             | 3                                           |
| 2.22                                   | 0.60                                    | 1.66                                | 0.33                                | 0.0                                      | 3                                             | 3                                           |
| 2.23                                   | 0.61                                    | 1.71                                | 0.30                                | 0.0                                      | 3                                             | 3                                           |

( $d_{Limit} = 10 \text{ m}$ )

|      |      |      |
|------|------|------|
| 30   | 18.6 | -9.9 |
| 50   | 6.0  | -9.6 |
| 100  | 9.7  | -9.2 |
| 150  | 7.9  | -8.8 |
| 200  | 7.6  | -8.6 |
| 250  | 9.5  | -8.3 |
| 300  | 11.0 | -8.1 |
| 350  | 12.4 | -7.9 |
| 400  | 13.6 | -7.6 |
| 450  | 14.7 | -7.4 |
| 500  | 15.6 | -7.2 |
| 550  | 16.3 | -7.0 |
| 600  | 17.2 | -6.9 |
| 650  | 18.1 | -6.9 |
| 700  | 18.5 | -6.8 |
| 750  | 19.1 | -6.3 |
| 800  | 19.6 | -6.3 |
| 850  | 20.1 | -6.0 |
| 900  | 20.8 | -5.8 |
| 950  | 21.1 | -5.6 |
| 1000 | 21.6 | -5.6 |

|      |      |      |      |       |    |   |
|------|------|------|------|-------|----|---|
| 0.29 | 0.04 | 0.23 | 0.02 | -10.5 | 10 | 3 |
| 0.39 | 0.09 | 0.32 | 0.08 | -10.5 | 10 | 3 |
| 0.56 | 0.14 | 0.47 | 0.08 | -10.5 | 10 | 3 |
| 0.73 | 0.20 | 0.59 | 0.12 | -10.5 | 10 | 3 |
| 0.84 | 0.21 | 0.70 | 0.11 | -10.5 | 10 | 3 |
| 0.98 | 0.24 | 0.80 | 0.13 | -10.5 | 10 | 3 |
| 1.04 | 0.26 | 0.89 | 0.15 | -10.5 | 10 | 3 |
| 1.18 | 0.31 | 0.96 | 0.13 | -10.5 | 10 | 3 |
| 1.28 | 0.35 | 1.03 | 0.19 | -10.5 | 10 | 3 |
| 1.39 | 0.38 | 1.11 | 0.22 | -10.5 | 10 | 3 |
| 1.44 | 0.39 | 1.20 | 0.19 | -10.5 | 10 | 3 |
| 1.55 | 0.46 | 1.24 | 0.23 | -10.5 | 10 | 3 |
| 1.59 | 0.43 | 1.29 | 0.23 | -10.5 | 10 | 3 |
| 1.67 | 0.34 | 1.35 | 0.22 | -10.5 | 10 | 3 |
| 1.67 | 0.42 | 1.41 | 0.15 | -10.5 | 10 | 3 |
| 1.87 | 0.54 | 1.46 | 0.25 | -10.5 | 10 | 3 |
| 1.90 | 0.46 | 1.51 | 0.25 | -10.5 | 10 | 3 |
| 1.99 | 0.60 | 1.56 | 0.27 | -10.5 | 10 | 3 |
| 2.14 | 0.60 | 1.63 | 0.29 | -10.5 | 10 | 3 |
| 2.22 | 0.60 | 1.66 | 0.33 | -10.5 | 10 | 3 |
| 2.23 | 0.61 | 1.71 | 0.30 | -10.5 | 10 | 3 |

### Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + AF \text{ (dB 1/m)} + Corr. \text{ (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

distance correction =  $-20 * \text{LOG} (d_{Limit} / d_{used})$

Linear interpolation will be used for frequencies in between the values in the table.

Tables show an extract of values.

### 6.3 ANTENNA R&S HF907 (1 GHZ – 18 GHZ)

| Frequency | AF<br>R&S<br>HF907 | Corr. |
|-----------|--------------------|-------|
| MHz       | dB (1/m)           | dB    |
| 1000      | 24.4               | -19.4 |
| 2000      | 28.5               | -17.4 |
| 3000      | 31.0               | -16.1 |
| 4000      | 33.1               | -14.7 |
| 5000      | 34.4               | -13.7 |
| 6000      | 34.7               | -12.7 |
| 7000      | 35.6               | -11.0 |

| cable<br>loss 1<br>(relay +<br>cable<br>inside<br>chamber) | cable<br>loss 2<br>(outside<br>chamber) | cable<br>loss 3<br>(switch<br>unit,<br>atten-<br>uator &<br>pre-amp) | cable<br>loss 4 (to<br>receiver) |  |  |
|------------------------------------------------------------|-----------------------------------------|----------------------------------------------------------------------|----------------------------------|--|--|
| dB                                                         | dB                                      | dB                                                                   | dB                               |  |  |
| 0.99                                                       | 0.31                                    | -21.51                                                               | 0.79                             |  |  |
| 1.44                                                       | 0.44                                    | -20.63                                                               | 1.38                             |  |  |
| 1.87                                                       | 0.53                                    | -19.85                                                               | 1.33                             |  |  |
| 2.41                                                       | 0.67                                    | -19.13                                                               | 1.31                             |  |  |
| 2.78                                                       | 0.86                                    | -18.71                                                               | 1.40                             |  |  |
| 2.74                                                       | 0.90                                    | -17.83                                                               | 1.47                             |  |  |
| 2.82                                                       | 0.86                                    | -16.19                                                               | 1.46                             |  |  |

| Frequency | AF<br>R&S<br>HF907 | Corr. |
|-----------|--------------------|-------|
| MHz       | dB (1/m)           | dB    |
| 3000      | 31.0               | -23.4 |
| 4000      | 33.1               | -23.3 |
| 5000      | 34.4               | -21.7 |
| 6000      | 34.7               | -21.2 |
| 7000      | 35.6               | -19.8 |

| cable<br>loss 1<br>(relay<br>inside<br>chamber) | cable<br>loss 2<br>(inside<br>chamber) | cable<br>loss 3<br>(outside<br>chamber) | cable<br>loss 4<br>(switch<br>unit,<br>atten-<br>uator &<br>pre-amp) | cable<br>loss 5 (to<br>receiver) | used<br>for<br>FCC<br>15.247 |
|-------------------------------------------------|----------------------------------------|-----------------------------------------|----------------------------------------------------------------------|----------------------------------|------------------------------|
| dB                                              | dB                                     | dB                                      | dB                                                                   | dB                               |                              |
| 0.47                                            | 1.87                                   | 0.53                                    | -27.58                                                               | 1.33                             |                              |
| 0.56                                            | 2.41                                   | 0.67                                    | -28.23                                                               | 1.31                             |                              |
| 0.61                                            | 2.78                                   | 0.86                                    | -27.35                                                               | 1.40                             |                              |
| 0.58                                            | 2.74                                   | 0.90                                    | -26.89                                                               | 1.47                             |                              |
| 0.66                                            | 2.82                                   | 0.86                                    | -25.58                                                               | 1.46                             |                              |

| Frequency | AF<br>R&S<br>HF907 | Corr. |
|-----------|--------------------|-------|
| MHz       | dB (1/m)           | dB    |
| 7000      | 35.6               | -57.3 |
| 8000      | 36.3               | -56.3 |
| 9000      | 37.1               | -55.3 |
| 10000     | 37.5               | -56.2 |
| 11000     | 37.5               | -55.3 |
| 12000     | 37.6               | -53.7 |
| 13000     | 38.2               | -53.5 |
| 14000     | 39.9               | -56.3 |
| 15000     | 40.9               | -54.1 |
| 16000     | 41.3               | -54.1 |
| 17000     | 42.8               | -54.4 |
| 18000     | 44.2               | -54.7 |

| cable<br>loss 1<br>(relay<br>inside<br>chamber) | cable<br>loss 2<br>(High<br>Pass) | cable<br>loss 3<br>(pre-<br>amp) | cable<br>loss 4<br>(inside<br>chamber) | cable<br>loss 5<br>(outside<br>chamber) | cable<br>loss 6<br>(to<br>receiver) |
|-------------------------------------------------|-----------------------------------|----------------------------------|----------------------------------------|-----------------------------------------|-------------------------------------|
| dB                                              | dB                                | dB                               | dB                                     | dB                                      | dB                                  |
| 0.56                                            | 1.28                              | -62.72                           | 2.66                                   | 0.94                                    | 1.46                                |
| 0.69                                            | 0.71                              | -61.49                           | 2.84                                   | 1.00                                    | 1.53                                |
| 0.68                                            | 0.65                              | -60.80                           | 3.06                                   | 1.09                                    | 1.60                                |
| 0.70                                            | 0.54                              | -61.91                           | 3.28                                   | 1.20                                    | 1.67                                |
| 0.80                                            | 0.61                              | -61.40                           | 3.43                                   | 1.27                                    | 1.70                                |
| 0.84                                            | 0.42                              | -59.70                           | 3.53                                   | 1.26                                    | 1.73                                |
| 0.83                                            | 0.44                              | -59.81                           | 3.75                                   | 1.32                                    | 1.83                                |
| 0.91                                            | 0.53                              | -63.03                           | 3.91                                   | 1.40                                    | 1.77                                |
| 0.98                                            | 0.54                              | -61.05                           | 4.02                                   | 1.44                                    | 1.83                                |
| 1.23                                            | 0.49                              | -61.51                           | 4.17                                   | 1.51                                    | 1.85                                |
| 1.36                                            | 0.76                              | -62.36                           | 4.34                                   | 1.53                                    | 2.00                                |
| 1.70                                            | 0.53                              | -62.88                           | 4.41                                   | 1.55                                    | 1.91                                |

#### Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + \text{AF (dB 1/m)} + \text{Corr. (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)  
Linear interpolation will be used for frequencies in between the values in the table.

Tables show an extract of values.

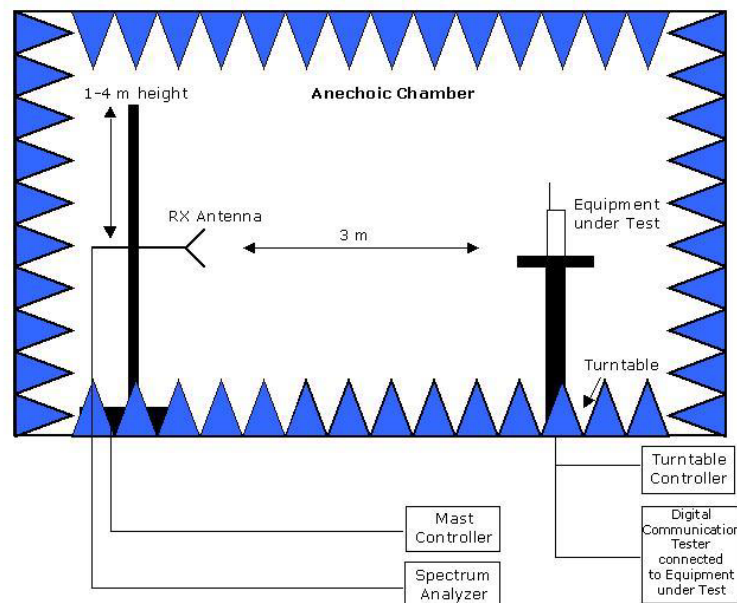
## 7 MEASUREMENT UNCERTAINTIES

| Parameter                                                     | Uncertainty   |
|---------------------------------------------------------------|---------------|
| Radio frequency                                               | $\pm 0.5$ ppm |
| RF power, conducted                                           | $\pm 1.0$ dB  |
| Conducted spurious emission of transmitter, valid up to 6 GHz | $\pm 2.0$ dB  |
| Conducted emission of receivers                               | $\pm 2.0$ dB  |
| Radiated emission of transmitter, valid up to 6 GHz           | $\pm 4.5$ dB  |
| Radiated emission of receiver, valid up to 6 GHz              | $\pm 4.5$ dB  |
| RF level uncertainty for a given BER                          | $\pm 1.5$ dB  |
| Occupied Bandwidth                                            | $\pm 4.5\%$   |
| Temperature                                                   | $\pm 0.3$ °C  |
| Humidity                                                      | $\pm 3\%$     |

## 8 PHOTO REPORT

Photos are included in an external report.

## 9 SETUP DRAWINGS



Remark: Depending on the frequency range suitable antenna types, attenuators or preamplifiers are used.

Drawing 1: Setup in the Anechoic chamber. For measurements below 1 GHz the ground was replaced by a conducting ground plane.