Validation report

Customer:

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RF test report

160162-AU01+W01

Hottinger Baldwin Messtechnik GmbH

Torque meter

T40
S10, S11

EMV TESTHAUS

DAkkS Deutsche Akkreditierungsstelle D-PL-12155-01-00

EMV **TESTHAUS** GmbH

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Accreditation:

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-12155-01-00

FCC facility registration number: 221458
Test Firm Type “2.948 listed”: Valid until 2017-04-22
Test Firm Type “accredited”: Valid until 2017-06-09
MRA US-EU, FCC designation number: DE0010
BnetzA-CAB-02/21-02/04 Valid until 2018-11-27

Industry Canada test site numbers with registration expiry date:
3472A-1, expiring 2018-11-09
3472A-2, expiring 2018-11-12

Location of Testing:

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94315 Straubing

The technical accuracy is guaranteed through the quality management of the EMV **TESTHAUS** GmbH.

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1 Summary

1.1 Purpose of testing

According to 47 CFR Part 15, §15.31 (d) and KDB Publication no. 937606 measurements at a distance less than the limit distance at an alternate test site are acceptable if measurements on an open field test site are performed to show that the results of the alternate test site correlate with those of an open field test site (see clause 3.1 for further details).

Therefore test site correlation for H-field measurements in Compact Diagnostic Chamber (CDC) with open field test site is documented in this validation report.

1.2 Scope of testing

This report supports tests referring to section §15.209 of the rules with test results recorded at approximately

472.3 kHz
522.9 kHz
1.22 MHz.

1.3 Conclusion

Testing in Compact Diagnostic Chamber (CDC) is performed at a distance of 3 meters using an extrapolation factor of -40 dB per decade to calculate emissions at the test distance specified in section §15.209 of the rules (approach no. 1).
Testing in open field test site is performed at distances of 3 meters and 10 m to determine the proper extrapolation factor to calculate emissions at the test distance specified in section §15.209 of the rules (approach no. 2).
As shown in this document for the frequencies listed in clause 1.2 approach no. 1 gives higher emission results than approach no. 2 irrespective of the use of a correlation factor so that compliance with the emission limits of section §15.209 is ensured if approach no. 1 is applied.

Straubing, March 4, 2016

Rainer Heller	Rudolf Klein
Head of EMC/Radio Department	Managing Director
EMV **TESTHAUS** GmbH	EMV **TESTHAUS** GmbH

2 Referenced publications

In this report any reference to publications without stating the issue date explicitly refers to the versions as listed below.

Publication	*Title*
47 CFR Part 15 October 2015	Code of Federal Regulations of the Federal Communication Commission (FCC) - Title 47, Part 15 - Radio Frequency Devices
ANSI C63.10 June 2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
KDB Publication no. 937606 October 10, 2014	Test Site Requirements for Part 15 and 18 Devices Operating Below 30 MHz

3 Test Procedure

3.1 Normative requirements

The measurement standards for testing according to section §15.209 are described in section §15.31 of the rules.

§15.31 (d):
Field strength measurements shall be made, to the extent possible, on an open field site. Test sites other than open field sites may be employed if they are properly calibrated so that the measurement results correspond to what would be obtained from an open field site. In the case of equipment for which measurements can be performed only at the installation site, such as perimeter protection systems, carrier current systems, and systems employing a ‘‘leaky’’ coaxial cable as an antenna, measurements for verification or for obtaining a grant of equipment authorization shall be performed at a minimum of three installations that can be demonstrated to be representative of typical installation sites.

§15.31 (f) (2):
At frequencies below 30 MHz, measurements may be performed at a distance closer than that specified in the regulations; however, an attempt should be made to avoid making measurements in the near field. Pending the development of an appropriate measurement procedure for measurements performed below 30 MHz, when performing measurements at a closer distance than specified, the results shall be extrapolated to the specified distance by either making measurements at a minimum of two distances on at least one radial to determine the proper extrapolation factor or by using the square of an inverse linear distance extrapolation factor (40 dB/decade).

KDB Publication no. 937606 refers to these sections and summarizes the test site requirements for Part 15 and 18 devices operating below 30 MHz. As there are no standards for validation of test sites below 30 MHz, calibration must be obtained by other means such as performing measurements at an alternate test site and comparing to measurements obtained on an open field site. How these comparative measurements are performed and which results they give is subject to this validation report.

3.2 Technical implementation

For comparative tests a programmable function generator with well-defined settings and stable output voltage connected to a loop antenna is used as the reference source for both test sites. At the distance(s) specified for the appropriate test site a calibrated test receiver connected to a calibrated loop antenna is placed to measure the radiated magnetic field (H-field) depending on the test distance.
Special care is taken to minimize influence of cables necessary to operate source and measurement equipment. As far as possible cables connected to the source are placed orthogonal to the appropriate plane of the loop antenna. For the connection between functional generator and loop antenna a cable with ferrites is used.

4 Test Results

4.1 Approach no. 1: Compact Diagnostic Chamber (CDC)

4.1.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*	*Last calibration*	*Next calibration*	*Note*
☒	Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026	n. a.	n. a.	1
☒	EMI test receiver	ESCI 3	Rohde & Schwarz	E00552	2014-07	2016-07	
☒	Loop antenna (for measurement)	HFH2-Z2	Rohde & Schwarz	E00060	2014-07	2016-07	
☒	Programmable function generator	HM 8130	Hameg	E00077	n. a.	n. a.	2
☒	Loop antenna (reference source)	HFLA	EMV **TESTHAUS**	E00178	n. a.	n. a.	3

Table 1: Test equipment used for measurement in Compact Diagnostic Chamber (CDC)

Notes:

1 Although not calibrated for testing below 30 MHz chamber complies with NSA free space requirements for fully anechoic rooms (30 MHz to 1 GHz) according to CISPR 16-1-4 (last verified 2015-07).
2 As function generator is used for both tests calibration is not required. However, tests have been carried out to ensure that signal stability is sufficient for the duration of the tests.
3 Loops of antenna are wrapped around a wooden ring with 48 cm diameter mounted in a height of 101 cm (center). The number of loops is 20.

4.1.2 Test procedure

The measurement is performed in a Compact Diagnostic Chamber (CDC) at a distance of 3 m.
A calibrated active loop antenna as specified in clause 4.3.2 of ANSI C63.10 is used to measure absolute values of the H-field. It is oriented in the vertical plane and set up in a height of 1 m above the ground. It is rotated about its vertical axis to find the maximum emission.
As the reference source a second loop antenna mounted on a wooden support and oriented in the vertical plane is used. It is rotated by 360° around its vertical axis by using a turntable.
For each frequency the maximum of the emission is recorded. The maximum is obtained if both antennas are oriented in parallel (face to face).
In order to minimize the influence of environmental disturbances when measuring in the open field test site the average detector is selected with measuring bandwidth set to 200 Hz for all frequencies to be tested. As the source signal is sinusoidal the average detector with a smaller bandwidth gives same results for the wanted signal but reduces ambient noise.

4.1.3 Test setup

Picture 1: Setup for test at 3 m distance in Compact Diagnostic Chamber (CDC)

4.1.4 Test results

Performed by:	Rainer Heller	Date of test:	February 12, 2016
Climatic conditions:	Ambient temperature 21.4 °C	Relative humidity 34.6 %	Barometric pressure 958 hPa

Frequency f (kHz)	Detector (200 Hz)	Distance d (m)	Field strength measured FS_{meas} (dBµV/m)	Extrapolation factor EPF_{dec1} (dB/dec)	λ/(2π) d_{nf} (m)	Extrapolation factor EPF (dB)	Reference distance d_{ref} (m)	Field strength at d_{ref} FS_{ref} (dBµV/m)
472.3	AV	3	90.5	-40.0	101	-80.0	300	10.5
522.9	AV	3	89.5	-40.0	91	-40.0	30	49.5
1220.0	AV	3	81.9	-40.0	39	-40.0	30	41.9

Table 2: Extrapolation from the measurement of a single point according to §15.31 (f) (2)

Frequency f (kHz)	Detector (200 Hz)	Distance d (m)	Field strength measured FS_{meas} (dBµV/m)	Extrapolation factor EPF_{dec1} (dB/dec)	λ/(2π) d_{nf} (m)	Extrapolation factor EPF (dB)	Reference distance d_{ref} (m)	Field strength final result FS_{fin} (dBµV/m)
472.3	AV	3	90.5	-40.0	101	-70.6	300	20.0
522.9	AV	3	89.5	-40.0	91	-40.0	30	49.5
1220.0	AV	3	81.9	-40.0	39	-40.0	30	41.9

Table 3: Extrapolation from the measurement of a single point according to §15.31 (f) (2) and ANSI C63.10 section 6.4.4.2

Approach no. 1:

Field strength is measured in a Compact Diagnostic Chamber (CDC) at a distance of 3 m.
To calculate the field strength value of the emission at the reference distance an extrapolation factor of 40 dB per decade is used.

Without reference to ANSI C63.10 section 6.4.4.2 (see Table 2) the relation between test distance d and reference distance d_{ref} multiplied by -40 dB/decade results in an extrapolation factor in dB which is added to the field strength value measured to get the final result at the reference distance.

$$FS_{ref} = FS_{meas} - 40 \log\left(\frac{d_{ref}}{d_{meas}}\right)$$

With reference to ANSI C63.10 section 6.4.4.2 (see Table 3) the relation between near field distance d_{nf} and test distance d multiplied by -40 dB/decade results in the first part of the extrapolation factor in dB and the relation between reference distance d_{ref} and near field distance d_{nf} multiplied by -20 dB/decade results in the second part. Both parts are added to the field strength value measured to get the final result at the reference distance d_{ref}.

$$FS_{ref} = FS_{meas} - 40\log\left(\frac{d_{nf}}{d_{meas}}\right) - 20\log\left(\frac{d_{ref}}{d_{nf}}\right)$$

4.2 Approach no. 2: Open field test site

4.2.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*	*Last calibration*	*Next calibration*	*Note*
☒	Open field test site	---	EMV **TESTHAUS**		n. a.	n. a.	
☒	EMI test receiver	ESCI 3	Rohde & Schwarz	E00552	2014-07	2016-07	
☒	Loop antenna (for measurement)	HFH2-Z2	Rohde & Schwarz	E00060	2014-07	2016-07	
☒	Programmable function generator	HM 8130	Hameg	E00077	n. a.	n. a.	1
☒	Loop antenna (reference source)	HFLA	EMV **TESTHAUS**	E00178	n. a.	n. a.	2

Table 4: Test equipment used for measurement in open field test site

Notes:

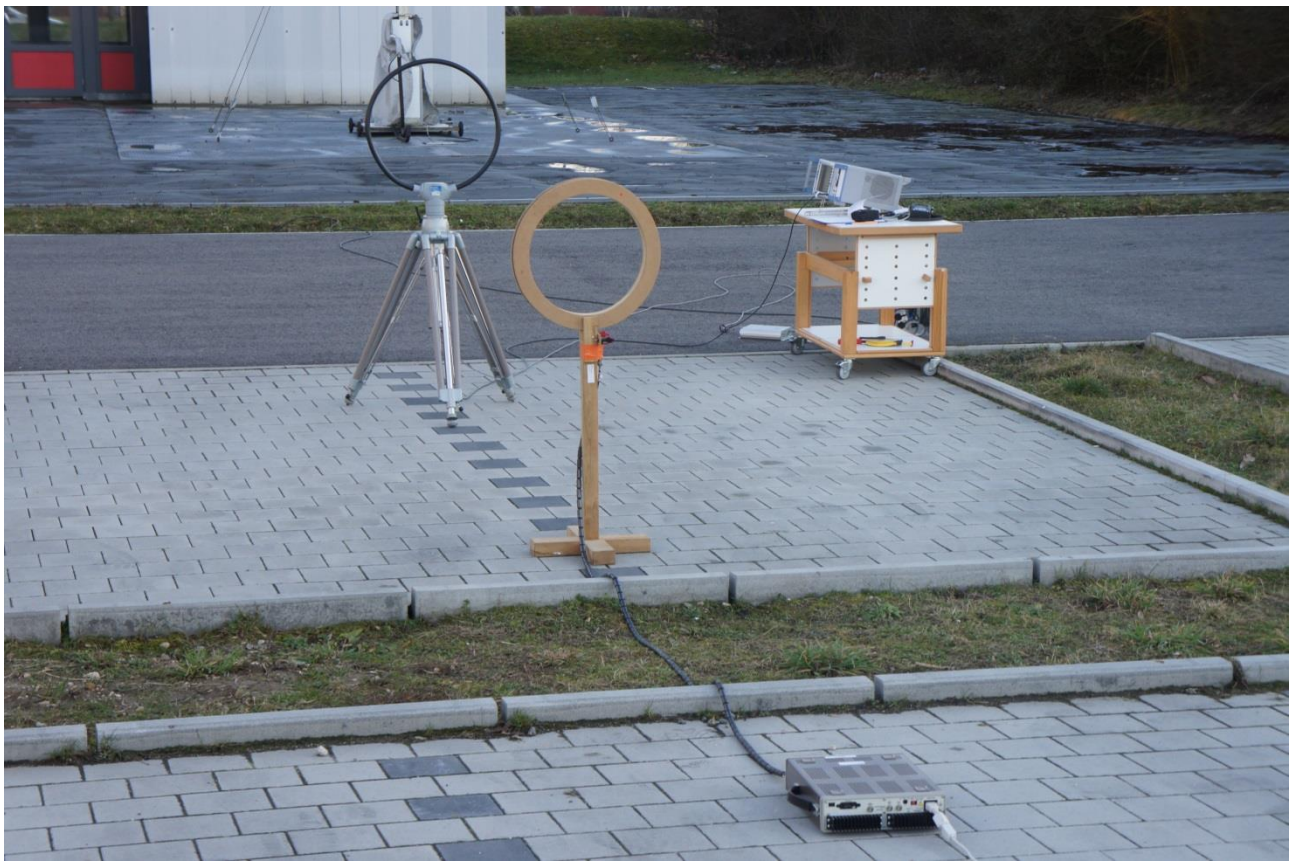
1 As function generator is used for both tests calibration is not required. However, tests have been carried out to ensure that signal stability is sufficient for the duration of the tests.
2 Loops of antenna are wrapped around a wooden ring with 48 cm diameter mounted in a height of 101 cm (center). The number of loops is 20.

4.2.2 Test procedure

The measurement is performed on an open field test site at distances of 3 m and 10 m. Due to environmental disturbances testing at 30 m distance is not possible.
A calibrated active loop antenna as specified in clause 4.3.2 of ANSI C63.10 is used to measure absolute values of the H-field. It is oriented in the vertical plane and set up in a height of 1 m above the ground. It is rotated about its vertical axis to find the maximum emission.
As the reference source a second loop antenna mounted on a wooden support and oriented in the vertical plane is used. It is rotated by 360° around its vertical axis.

For each frequency the maximum of the emission is recorded. The maximum is obtained if both antennas are oriented in parallel (face to face).
In order to minimize the influence of environmental disturbances the average detector is selected with measuring bandwidth set to 200 Hz for all frequencies to be tested. As the source signal is sinusoidal the average detector with a smaller bandwidth gives same results for the wanted signal but reduces ambient noise.

4.2.3 Test setup



Picture 2: Setup for test at 3 m distance in open field test site

4.2.4 Test results

Performed by:	Rainer Heller	Date of test:	February 12, 2016
Climatic conditions:	Ambient temperature 6.2°C	Relative humidity 62.6 %	Barometric pressure 958 hPa

Frequency f (kHz)	Detector (200 Hz)	Distance d (m)	Field strength measured FS_{meas} (dBµV/m)	Extrapolation factor EPF_{dec1} (dB/dec)	λ/(2π) d_{nf} (m)	Extrapolation factor EPF (dB)	Reference distance d_{ref} (m)	Field strength final result FS_{ref} (dBµV/m)
472.3	AV	3	92.3	-55.6	101	-111.3	300	-18.9
472.3	AV	10	63.3			-82.2		-18.9
522.9	AV	3	91.3	-54.4	91	-54.4	30	36.9
522.9	AV	10	62.8			-25.9		36.9
1220.0	AV	3	83.9	-53.9	39	-53.9	30	30.0
1220.0	AV	10	55.7			-25.7		30.0

Table 5: Extrapolation from the measurement of two points according to §15.31 (f) (2)

Frequency f (kHz)	Detector (200 Hz)	Distance d (m)	Field strength measured FS_{meas} (dBµV/m)	Extrapolation factor EPF_{dec1} (dB/dec)	λ/(2π) d_{nf} (m)	Extrapolation factor EPF (dB)	Reference distance d_{ref} (m)	Field strength final result FS_{ref} (dBµV/m)
472.3	AV	3	92.3	-55.6	101	-94.4	300	-2.1
472.3	AV	10	63.3			-65.3		-2.1
522.9	AV	3	91.3	-54.4	91	-54.4	30	36.9
522.9	AV	10	62.8			-25.9		36.9
1220.0	AV	3	83.9	-53.9	39	-53.9	30	30.0
1220.0	AV	10	55.7			-25.7		30.0

Table 6: Extrapolation from the measurement of a single point according to §15.31 (f) (2) and ANSI C63.10 section 6.4.4.6

Approach no. 2:

Field strength is measured on an open field test site at distances of 3 m and 10 m. Due to environmental disturbances testing at 30 m is not possible.

As described in ANSI C63.10 section 6.4.4.4 the first part of the extrapolation factor is defined as a function of the measurement distances d_1 = 3 m and d_2 = 10 m and the appropriate measured field strength values $FS_{meas(d1)}$ and $FS_{meas(d2)}$:

$$EPF_{dec1} = 20 \frac{\log\left(\frac{E_1}{E_2}\right)}{\log\left(\frac{d_1}{d_2}\right)} = \frac{FS_{meas(d1)} - FS_{meas(d2)}}{\log(d_1) - \log(d_2)}$$

Without reference to ANSI C63.10 section 6.4.4.6 (see Table 5) the relation between test distance d and reference distance d_{ref} multiplied by the extrapolation factor EPF_{dec1} in dB/decade results in an extrapolation factor in dB which is added to the field strength value measured to get the final result at the reference distance.

$$FS_{ref} = FS_{meas} + EPF_{dec1} \log\left(\frac{d_{ref}}{d_{meas}}\right)$$

With reference to ANSI C63.10 section 6.4.4.6 (see Table 6) the relation between near field distance d_{nf} and test distance d multiplied by the extrapolation factor EPF_{dec} in dB/decade results in the first part of the extrapolation factor in dB and the relation between reference distance d_{ref} and near field distance d_{nf} multiplied by -20 dB/decade results in the second part of the extrapolation factor. Both parts are added to the field strength value measured to get the final result at the reference distance d_{ref}.

$$FS_{ref} = FS_{meas} + EPF_{dec1} \log\left(\frac{d_{nf}}{d_{meas}}\right) - 20 \log\left(\frac{d_{ref}}{d_{nf}}\right)$$

4.3 Correlation of test sites

Correlation between Compact Diagnostic Chamber (CDC) and open field test site is determined at test distance 3 m. The correlation factor f_c is calculated according to:

$$f_c = FS_{meas\ OFTS} - FS_{meas\ CDC}$$

The correlation factors are listed in Table 7 and shall be added to the field strength values measured in CDC if field strength value at reference distance is calculated.

Frequency f (kHz)	Detector (200 Hz)	Distance d (m)	Field strength measured in CDC $FS_{meas\ CDC}$ (dBµV/m)	Field strength measured in open field test site $FS_{meas\ OFTS}$ (dBµV/m)	Correlation factor f_c (dB)
472.3	AV	3	90.5	92.3	1.8
522.9	AV	3	89.5	91.3	1.8
1220.0	AV	3	81.9	83.9	2.1

Table 7: Correlation of test sites

4.4 Discussion of test results

Although field strength measured at 3 m distance in Compact Diagnostic Chamber (CDC) is about 2 dB lower than in open test site due to extrapolation method used field strength levels at reference distance are considerably higher. This effect would even be more distinct if the imperfections of the open field test site would not prevent a closer approximation to the theoretical extrapolation factor of 60 dB up to about 1 MHz.
In all cases approach no. 1 with testing in CDC gives significantly higher field strength levels at reference distance than approach no. 2 in open field test site. Since ANSI C63.10 has replaced ANSI C63.4 as the measurement standard for intentional radiators as noted in 47 CFR Part 15, section §15.31 (a) (3), the calculation methods of section 6.4 of ANSI C63.10 shall be applied.

4.5 Calculation of EUT results

To show that approach no. 1 gives higher levels for radiated emission below 30 MHz even if correlation factor f_c is not taken into account the maximum emissions at reference distance d_{ref} calculated from the maximum emissions measured in Compact Diagnostic Chamber (CDC) recorded at test distance 3 m are listed using

1. Extrapolation factor -40 dB/decade without correlation factor
2. Extrapolation factor -40 dB/decade with correlation factor f_c
3. Extrapolation factor determined from two distances in open field test site with correlation factor f_c

The field strength level at reference distance d_{ref} is calculated according to

$$FS_{ref} = FS_{meas} + f_c + EPF$$

Table 8 contains the tests results of maximum radiated emission below 30 MHz of torque meter T40S10 as collected in test report no. 150866-AU01+W02. All levels are measured with quasi-peak detector. Significant emissions are measured at carrier frequency 523 kHz of wireless power transfer only. Emissions at carrier frequency 1.22 MHz of wireless data transfer could not be observed.

Frequency f (kHz)	Distance d (m)	Field strength measured FS_{meas} (dBµV/m)	Correlation factor f_c (dB)	λ/(2π) d_{nf} (m)	Extra-polation factor EPF (dB)	Reference distance d_{ref} (m)	Field strength final result FS_{ref} (dBµV/m)	Limit L_{ref} (dBµV/m)	Margin (dB)
523.0	3	58.1		91	-40.0	30	18.1	33.2	15.1
523.0	3	58.1	1.8	91	-40.0	30	19.9	33.2	13.3
523.0	3	58.1	1.8	91	-54.4	30	5.5	33.2	27.7

Table 8: Calculation of test results for T40S10

Table 9 contains the tests results of maximum radiated emission below 30 MHz of torque meter T40S11 as collected in test report no. 150866-AU01+W02. All levels are measured with quasi-peak detector. Significant emissions are measured at carrier frequency 523 kHz of wireless power transfer only. Emissions at carrier frequency 1.22 MHz of wireless data transfer could not be observed.

Frequency f (kHz)	Distance d (m)	Field strength measured FS_{meas} (dBµV/m)	Correlation factor f_c (dB)	λ/(2π) d_{nf} (m)	Extra-polation factor EPF (dB)	Reference distance d_{ref} (m)	Field strength final result FS_{ref} (dBµV/m)	Limit L_{ref} (dBµV/m)	Margin (dB)
523.4	3	53.2		91	-40.0	30	13.2	33.2	20.1
523.4	3	53.2	1.8	91	-40.0	30	14.9	33.2	18.3
523.4	3	53.2	1.8	91	-54.4	30	0.5	33.2	32.7

Table 9: Calculation of test results for T40S11

5 Revision history

Revision	*Date*	*Issued by*	*Description of modifications*
0	2016-03-04	Rainer Heller	First edition