TEST REPORT # EMCC-931028NBB, 2019-10-07

- This Test Report supersedes Test Report # EMCC-931028NB, 2019-08-08 -

EQUIPMENT UNDER TEST:

Trade Name:	FSC
Type/Model:	FSC 1/7
Serial Number(s):	none
Application:	Paint thickness gauge
FCC ID:	2AMBGMEMW02
Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Address:	Königbacher Str. 15 94496 Ortenburg GERMANY
Name:	Maik Richter
Phone:	+49 8542 168-673
E-Mail:	Maik.Richter@micro-epsilon.de
RELEVANT STANDARD(S) :	47 CFR § 15.107 47 CFR § 15.109
MEASUREMENT PROCEDURE: :	ANSI C63.4-2014

TEST REPORT PREPARED BY:

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Tested:

Patrick Reusch

Ludwig Kraft

Checked:

Reinhard Sauerschell
-Head of Laboratory –

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0 REVISION HISTORY

Project number	Issue date	Chapter	Description
931028NB	2019-08-08	n.a.	Initial issue
931028NBB	2019-10-07	Title page; 2.1; Annex 1; Annex 2; Annex 3; Annex 4	FCC ID changed

1 GENERAL INFORMATION

1.1 Purpose

The purpose of this report is to show compliance with the 47 CFR §15.107 and 47 CFR §15.109 requirements applicable to intentional radiators (subpart C).

1.2 Limits and Reservations

The test results in this report apply only to the particular equipment under test (EUT) as declared in this report. This test report shall not be reproduced except in full without the written permission of EMCCons DR. RAŠEK GmbH & Co. KG.

1.3 Test Laboratory

Test Laboratory:	EMCCons DR. RAŠEK GmbH & Co. KG
Accreditation No.:	D-PL-12067-01-04
Address of Labs I, II, III and Head Office:	EMCCons DR. RAŠEK GmbH & Co. KG Boelwiese 8 91320 Ebermannstadt GERMANY
Address of Labs IV and V:	EMCCons DR. RAŠEK GmbH & Co. KG Stoernhofer Berg 15 91364 Unterleinleiter GERMANY
Phone:	+49 9194 7262-0
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E-Mail:	info@emcc.de
Web:	www.emcc.de

1.4 Customer

Company Name:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Street:	Königbacher Str. 15
City:	94496 Ortenburg
Country:	GERMANY
Name:	Mr Maik Richter
Phone:	+49 8542 168-673
Fax:	+49 8542 168-90
E-Mail:	Maik.Richter@micro-epsilon.de

1.5 Manufacturer

Company Name:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Street:	Königbacher Str. 15
City:	94496 Ortenburg
Country:	GERMANY
Phone:	+49 8542 168-673
E-Mail:	Maik.Richter@micro-epsilon.de

1.6 Dates and Test Location

Date of receipt of EUT: 2019-05-16
Test Date: CW 20 to 21/2019
Test Location: Lab IV

1.7 Ordering Information

Purchase Order: B154425
Date: 2019-03-26
Vendor-Number: 74586

1.8 Climatic Conditions

Date	Temperature	Relative Humidity	Air Pressure	Lab	Customer attended tests
--	°C	%	hPa	--	--
2019-05-16	23	32	974	IV	Yes, Mr Richter
2019-05-17	23	35	967	IV	Yes, Mr Richter
2019-05-20	24	42	961	IV	Yes, Mr Richter
2019-05-21	24	44	964	IV	Yes, Mr Richter

2 PRODUCT DESCRIPTION

2.1 Equipment Under Test (EUT)

The following data is based on customer's information.

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type, EUT No, Serial No(s):	FSC 1/7, none
Application:	Paint thickness gauge
No of variants:	1, FSC 1000 is a variant of FSC 1/7 with a different measurement range due to a different resonator dimension.
Firmware version:	8010182
Hardware version:	Gen2
FCC ID:	2AMBGMEMW02
Highest internal frequency:	24.245 GHz
TX operating frequency range:	24.005 ... 24.245 GHz
No of operating channels:	n/a
Used channels during test:	Fmin: 24.012 GHz Fmid: 24.125 GHz Fmax: 24.238 GHz
Power source:	External DC (5 V_{DC})
Voltage for testing:	5 V_{DC} (from USB-Connector connected to FSC1)
Ports:	USB Connector
Antenna:	Internal
Max. antenna gain:	n/a
Remarks:	None

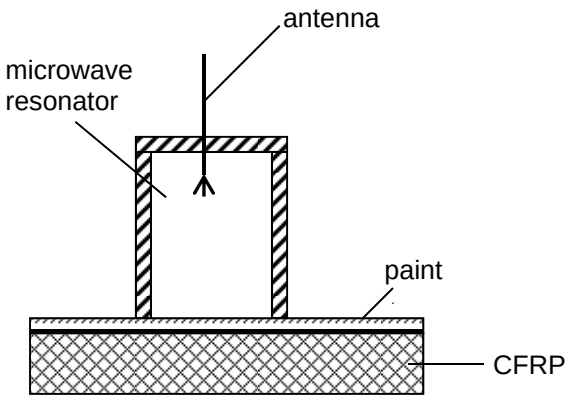
The following information was delivered by the customer:

"

The FSC1/7 and FSC1000 are suitable to measure the paint thickness (dielectric layer) on CFRP with and without lightning protection as well as on metal.

The system consists of a sensor module (Sensor) and a control and display module (Controller).

The Sensor includes microwave circuit components. It is intended for measuring a resonant frequency which is determined by a dielectric layer on a base substrate. The main part of the measure system, the resonator, and its application is shown in the picture below.



- *A resonant cavity having a rotationally symmetrical wall and a plane wall on one end thereof, wherein the opposite end is open to be placed up on the dielectric layer on the substrate to form a wall of the resonant cavity on the opposite end.*
- *An antenna located within said resonant cavity and adapted to excite an electromagnetic field in the resonant cavity.*
- *A reflection meter connected to said antenna and adapted to measure the resonance frequency of the resonant cavity. The device operates in "frequency stepped continuous wave" (FSCW) mode. The measurements of all individual frequency steps are performed under steady state conditions. At the measurements no intermediate frequencies are generated. The receiver output signal is a dc signal at each individual frequency point.*
- *The Transceiver is driven in a way that frequencies only in the range from 24.010 to 24.240 GHz are adjustable.*
- *The output power of the transceiver is less than -15dBm. The output signal of the internal generator is only active during the measurement process, after that it is turned off.*
- *A processor connected to said reflection meter and adapted to determine the resonance frequency of the resonant cavity.*

"

2.2 Intended Use

The following information was delivered by the customer.

The FSC1/7 and FSC1000 are suitable to measure the paint thickness (dielectric layer) on CFRP with and without lightning protection as well as on metal.

2.3 EUT Peripherals/Simulators

The EUT was tested being connected via USB cable to an FSC1 Controller, 4112002, serial number 0113. The FSC1 Controller was connected to a power charger V-Charge ECO NIMH 2000.

2.4 Mode of operation during testing and test setup

The equipment under test (EUT) was operated during the tests under the following conditions:

For the test the EUT was connected to the controller FSC1 with the charger V-Charge ECO NIMH 200.
The RF transmitter on the EUT is off. This test was done with the normal operation software. The EUT does one measurement and switches then the RF off.

2.5 Modifications required for compliance

None.

3 TEST RESULTS SUMMARY

Summary of test results for the following EUT:

Manufacturer: MICRO-EPSILON Messtechnik GmbH & Co. KG
Type, Serial No.: FSC 1/7, none

Requirement	47 CFR Section	Report Section	Result
AC Power Line Conducted Emissions	§ 15.107	4.1	Passed
Radiated Emissions 30 MHz – 1000 MHz	§ 15.109	4.2.4	Passed
Radiated Emissions 1 GHz – 40 GHz	§ 15.109	4.2.5	Passed

N.A. – not applicable; N.T. – Not tested acc. to applicant's order.

The client has made the determination that EUT Condition, Characterization, and Mode of Operation are representative of production units and meet the requirements of the specifications referenced herein.
Consistent with Industry practice, measurement and test equipment not directly involved in obtaining measurement results but having an impact on measurements (such as cable loss, antenna factors, etc.) are factored into the "Correction Factor" documented in certain test results. Instrumentation employed for testing meets tolerances consistent with known Industry Standards and Regulations.
The measurements contained in this report were made in accordance with the procedures described in ANSI C63.4-2014 and all applicable Public Notices received prior to the date of testing.All requirements were found to be within the limits outlined in this report.

The test results in this report apply only to the particular equipment under test (EUT) as declared in this report.

Test personnel: Ludwig Kraft
Issuance date: 2019-10-07

4 DETAILED TEST RESULTS

4.1 AC Power Line Conducted Emissions

4.1.1 Regulation

47 CFR § 15.107 Conducted limits

(a) Except for Class A digital devices, for equipment that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50 µH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the band edges.

Frequency of emission (MHz)	Conducted limit (dBµV)	
	Quasi-peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

*Decreases with the logarithm of the frequency.

4.1.2 Test Procedures

Testing is performed acc. to ANSI C63.4-2014.

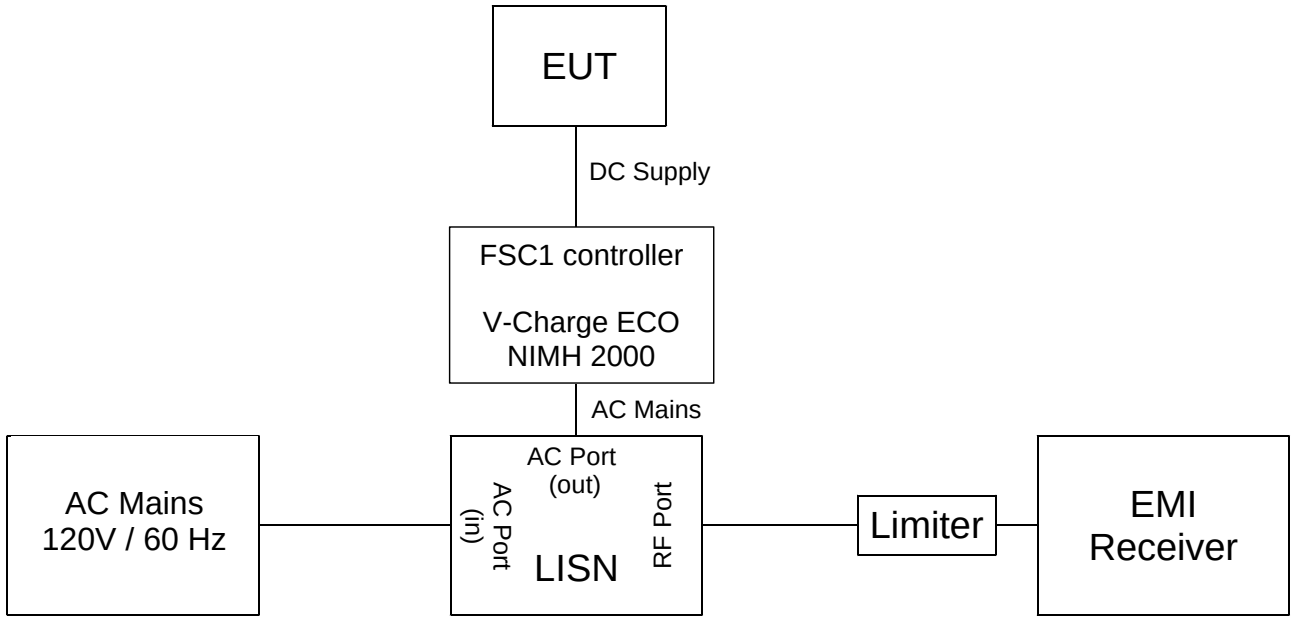
Tabletop and their ancillary devices are placed on a nonconducting table with nominal dimension of 1.0 m by 1.5 m, height 0.8 m above the ground plane. The EUT is centered laterally (left to right facing the tabletop) on the tabletop and its rear is flush with the rear of the table. Accessories or peripherals that are part of a system tested on a tabletop are being placed in a test arrangement on one or both sides of the host with a 10 cm separation between the nearest points of the cabinets.

Interconnecting cables that hang closer than 40 cm to the ground plane are folded back and forth in the center forming a bundle 30 cm to 40 cm long.

The EUT's DC port was connected to a laboratory DC power supply (EMCC-ID#4721), which was connected to a LISN.

The measurement receiver is connected to the 50 Ω RF port of the LISN.

4.1.3 Test Setup

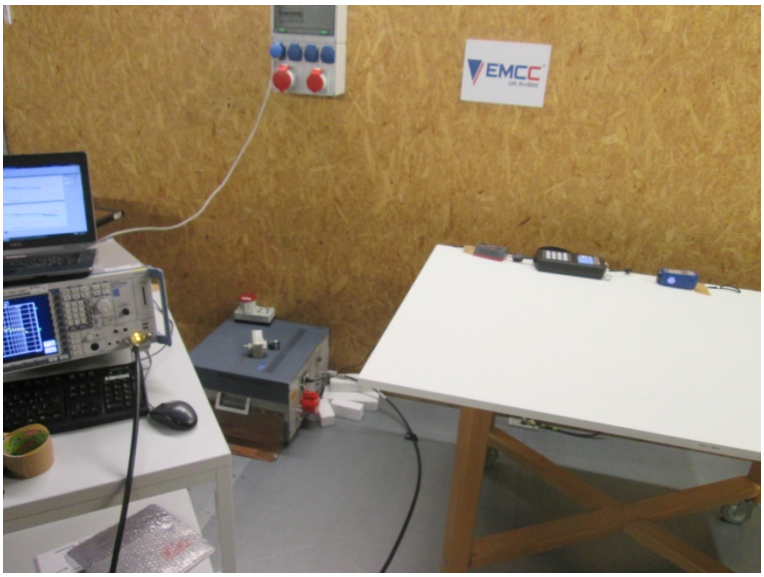


SCHEMATIC TEST SETUP

Requirement: 47 CFR, § 15.107
Procedure: ANSI C63.4-2014

Power Source: #001
Receiver: #3846
LISN: #1901

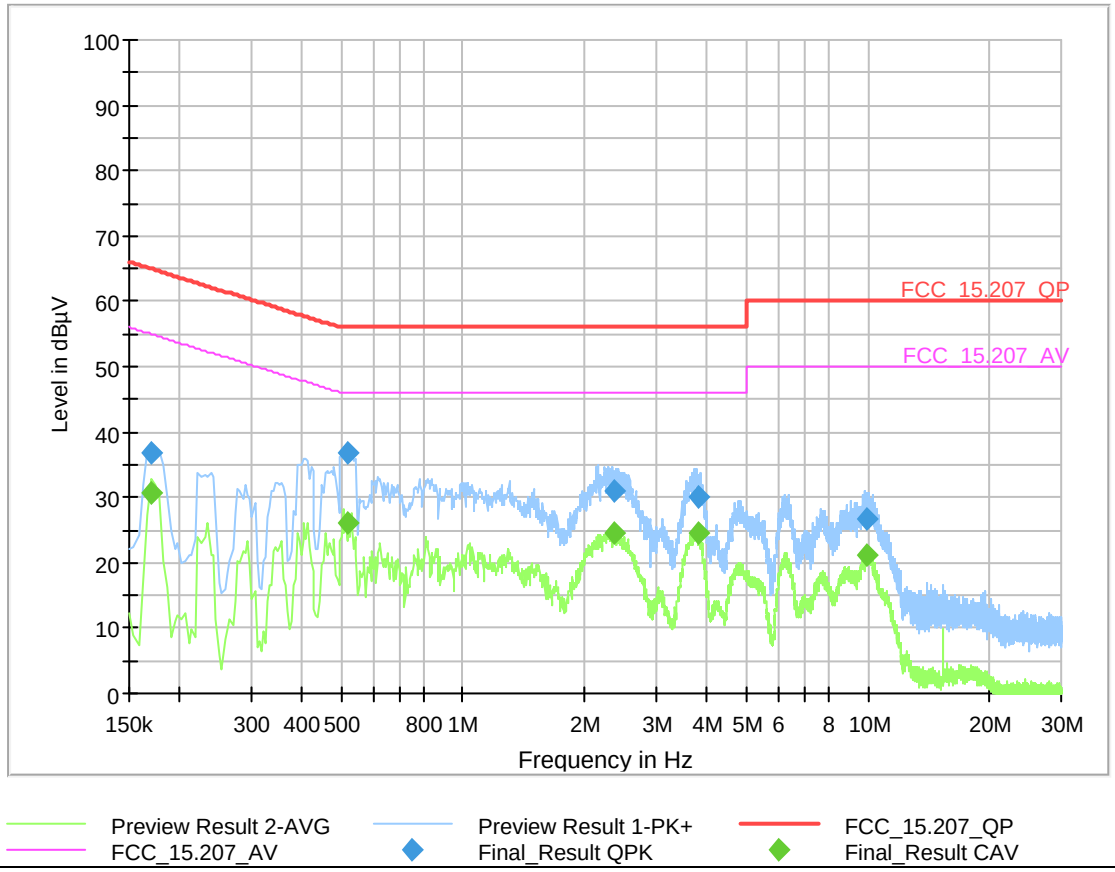
TEST EQUIPMENT USED:
Refer to chapter 5 of this document.
001, 1890, 1901, 3148, 3846, 3880, 4524, 4597, 4717, 5392, 5551



Sample photo of setup

4.1.4 Detailed Test Data

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
Line:	L and N (max hold)



Final Result:

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.517500	---	26.09	46.00	19.91	1000	9	L1	GND	0.0
0.517500	36.92	---	56.00	19.08	1000	9	L1	GND	0.0
2.353500	---	24.51	46.00	21.49	1000	9	L1	GND	0.0
2.353500	30.96	---	56.00	25.04	1000	9	L1	GND	0.0
3.797500	---	24.52	46.00	21.48	1000	9	L1	GND	0.0
3.797500	30.13	---	56.00	25.87	1000	9	L1	GND	0.0

Worst case results listed, only.

4.1.5 Test Result

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No.:	none
Test date:	2019-05-21
Test personnel:	Patrick Reusch

The EUT meets the requirements of this section.

4.2 Radiated Emissions

4.2.1 Regulation

47CFR § 15.33 Frequency range of radiated measurements

(b) For unintentional radiators:
(1) Except as otherwise indicated in paragraphs (b)(2) or (b)(3) of this section, for an unintentional radiator, including a digital device, the spectrum shall be investigated from the lowest radio frequency signal generated or used in the device, without going below the lowest frequency for which a radiated emission limit is specified, up to the frequency shown in the following table:
(3) Except for a CB receiver, a receiver employing superheterodyne techniques shall be investigated from 30 MHz up to at least the second harmonic of the highest local oscillator frequency generated in the device. If such receiver is controlled by a digital device, the frequency range shall be investigated up to the higher of the second harmonic of the highest local oscillator frequency generated in the device or the upper frequency of the measurement range specified for the digital device in paragraph (b)(1) of this section.

Highest frequency generated or used in the device or on which the device operates or tunes / MHz	Upper frequency of measurement range / MHz
Below 1.705	30
1.705-108	1000
108-500	2000
500-1000	5000
Above 1000	5th harmonic of the highest frequency or 40 GHz, whichever is lower.

47 CFR § 15.35 Measurement detector functions and bandwidths.

(a) On any frequency or frequencies below or equal to 1000 MHz, the limits shown are based on measuring equipment employing a CISPR quasi-peak detector function and related measurement bandwidths, unless otherwise specified. The specifications for the measuring instrumentation using the CISPR quasi-peak detector can be found in ANSI C63.4-2014, clause 4 (incorporated by reference, see §15.38). As an alternative to CISPR quasi-peak measurements, the responsible party, at its option, may demonstrate compliance with the emission limits using measuring equipment employing a peak detector function as long at the same bandwidth as indicated for CISPR quasi-peak measurements are employed.

47 CFR § 15.109 Radiated emission limits; general requirements.

(a) Except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values:

Frequency of emission / MHz	Field strength / µV/m
30 – 88	100
88 – 216	150
216 – 960	200
Above 960	500

(c) In the emission tables above, the tighter limit applies at the band edges. Sections 15.33 and 15.35 which specify the frequency range over which radiated emissions are to be measured and the detector functions and other measurement standards apply.

4.2.2 Calculation of Field Strength Limits

E.g. radiated emissions field strength limits for the frequency band 30 - 88 MHz:

100 µV/m at 3 meters

Using the equation:

$E_{dB\mu V/m} = 20 \log (E_{\mu V/m})$

where

$E_{dB\mu V/m}$ = Field Strength in logarithmic units (in dBµV/m)

$E_{\mu V/m}$ = Field Strength in linear units (in µV/m)

A field strength limit of 100 µV/m corresponds with 40.0 dBµV/m.

Distance correction (limit)
Remark: The preferred method is the correction of the measured field strength (refer to 4.2.3) instead of limit correction. Only one correction method shall be applied to a particular measurement.

In case of testing being performed in a distance other than specified, the limit may be adjusted by a Distance Extrapolation Factor DF of 20 dB per decade, which is calculated by the following equation:

$DF = 20 \log (D_{test}/D_{specification})$
where

DF = Distance Extrapolation Factor (in dB)

D_{test} = Distance, where measurement was performed (in m)

$D_{specification}$ = Distance acc. to specification (in m)

Example: Assume a limit specified in 3 m and a measurement performed at 1 m: The distance correction factor is 20 log (3 / 1) = 9.5. This factor is mathematically added to the limit by the following equation:
$E_{dB\mu V/m\_new} = E_{dB\mu V/m} + DF$
where

$E_{dB\mu V/m}$ = Field Strength limit in logarithmic units (in dBµV/m)

$E_{dB\mu V/m\_new}$ = Corrected Field Strength limit in logarithmic units (in dBµV/m)

DF = Distance Extrapolation Factor (in dB)

Example: Assume a limit of 40.0 dBµV/m specified in 3 m distance and the measurement performed at 1 m. The limit is adjusted by the distance correction factor of 9.5 dB to the new limit of 49.5 dBµV/m.

4.2.3 Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor. The basic equation with a sample calculation is as follows:

FS = RA + AF + CF
where
FS = Field Strength (in dBµV/m)
RA = Receiver Amplitude (in dBµV)
AF = Antenna Factor (in dB (1/m))
CF = Cable Attenuation Factor (in dB)

Assume a receiver reading of 30 dBµV is obtained. The Antenna Factor of 10 dB(1/m) and a Cable Factor of 1.2 dB are added, giving a field strength of 41.2 dBµV/m in the measurement distance. The field strength of 41.2 dBµV/m value can be mathematically converted to its corresponding level in µV/m.

FS = 30 + 10 + 1.2 = 41.2
Level (in µV/m) = Common Antilogarithm (41.2/20) = 114.8

Distance correction (field strength)
Remark: The preferred method is the correction of the measured field strength instead of limit correction (refer to 4.2.2). Only one correction method shall be applied to a particular measurement..

If a measurement is performed at a different distance other than specified, the field strength at the specified distance can be obtained by the following equation:

$FS_{Dspecified} = FS_{Dtest} + 20 \log (D_{test}/D_{specified})$
where
$FS_{Dspecified}$ = Field Strength at specified distance $D_{specified}$ (in dBµV/m)
FS_{DTest} = Field Strength at specified distance D_{Test} (in dBµV/m)
D_{test} = Measurement distance where test was performed (in m)
$D_{specified}$ = Measurement distance as specified by the rules (in m)

Assuming a recorded field strength of 41.2 dBµV/m in a distance of 1 m. If the rules are specifying a limit in a distance of 3 m, the field strength recorded in 1 m is corrected by the distance. Therefore, the field strength $FS_{Dspecified}$ is 41.2 + 20 log (1 / 3) = 31.7 (in dBµV/m).
Remark: Using EMC32 software corrections are combined in the Corr. Factor as listed in the results' table.
"Result" represents the FS Result), "Corr." is the combined correction factor.

4.2.4 Radiated Emissions 30 MHz – 1000 MHz

4.2.4.1 Test Procedures

ANSI C63.4-2014, 8.2.3 Electric field radiated emissions (30 MHz to 1 GHz)

Electric field measurements are made in the frequency range of 30 MHz to 1000 MHz using a calibrated linearly polarized antenna as specified in 4.5.4, which shall be positioned at the specified distance from the periphery of the EUT. The specified distance is the distance between the horizontal projection onto the ground plane of the closest periphery of the EUT and the projection onto the ground plane of the center of the axis of the elements of the receiving antenna. However, if the receiving antenna is an LPDA antenna, the specified distance shall be the distance between the closest periphery of the EUT and the front-to-back center (midpoint along boom/feeder transmission line) of the array of elements.
Measurements shall be made with the antenna positioned in both the horizontal and vertical planes of polarization. The measurement antenna shall be varied in height above the reference ground plane to obtain the maximum signal strength. Unless otherwise specified, the measurement distance shall be 3 m or 10 m. At either measurement distance, the antenna height shall be varied from 1 m to 4 m.
These height scans apply for both horizontal and vertical polarizations, except that for vertical polarization, the minimum height of the center of the antenna shall be increased so that the lowest point of the bottom of the lowest antenna element clears the site reference ground plane by at least 25 cm. For a tuned dipole, the minimum heights as measured from the center of the antenna are shown in Table D.3.

ANSI C63.4-2014, 8.3.1.1 Exploratory radiated emission measurements (9 kHz to 1 GHz)

a) Exploratory radiated measurements shall be performed at the measurement distance or at a closer distance than that specified for compliance to determine the emission characteristics of the EUT (see also 10.2.8 and Annex E) and recorded in tabular or graphical form. Significant emissions are identified using a remote-controlled turntable and antenna positioner and monitoring the spectrum while changing the EUT (turntable) azimuth, antenna polarity, and height. This spectrum exploratory monitoring can also be performed by manually moving the receiving antenna around the EUT to pick up significant emissions. A shielded room may be used for exploratory testing, but care must be taken to account for shielded room reflections that can lead to significant errors in amplitude measurements.
b) Broadband antennas and a spectrum analyzer or an EMI receiver with a panoramic display are most often used in this type of testing. It is recommended that either a headset or loudspeaker be connected as an aid in detecting ambient signals and finding frequencies of significant emission from the EUT when the exploratory and final testing is performed at an OATS with strong ambient signals. Caution should be taken if either antenna heights between 1 m and 4 m or EUT azimuth is not fully explored. Not fully exploring these parameters during exploratory testing may require complete testing at the OATS or semi-anechoic chamber when the final full spectrum testing is conducted.
c) The EUT should be set up in its typical configuration and arrangement and operated in its various modes. For tabletop systems, cables or wires not bundled in the initial setup shall be manipulated within the range of likely arrangements. For floor-standing equipment, the cables or wires should be located in the same manner as the user would install them and no further manipulation is made. For combination EUTs, the tabletop and floor-standing portions of the EUT shall follow the procedures for their respective setups and cable manipulation. If the manner of cable installation is not known, or if it changes with each installation, cables or wires for floor-standing equipment shall be manipulated to the extent possible to reduce the maximum level of emissions.
d) Exploratory radiated emissions testing of handheld and/or body-worn devices shall include rotation of the EUT through three orthogonal axes to determine the orientation (attitude) that maximizes the emissions. Subclause 6.3.6 applies for exploratory radiated emissions testing of ceiling-mounted devices. This equipment arrangement shall be used in the final measurements of radiated emission from the EUT.
e) For each mode of operation required to be tested, the frequency spectrum shall be monitored. Variations in antenna height between 1 m and 4 m, antenna polarization, EUT azimuth, and cable or wire placement (each variable within bounds specified elsewhere) shall be explored to produce the emission that has the highest amplitude relative to the limit. A suggested step-by-step technique for determining maximum radiated emission is given in Annex E.

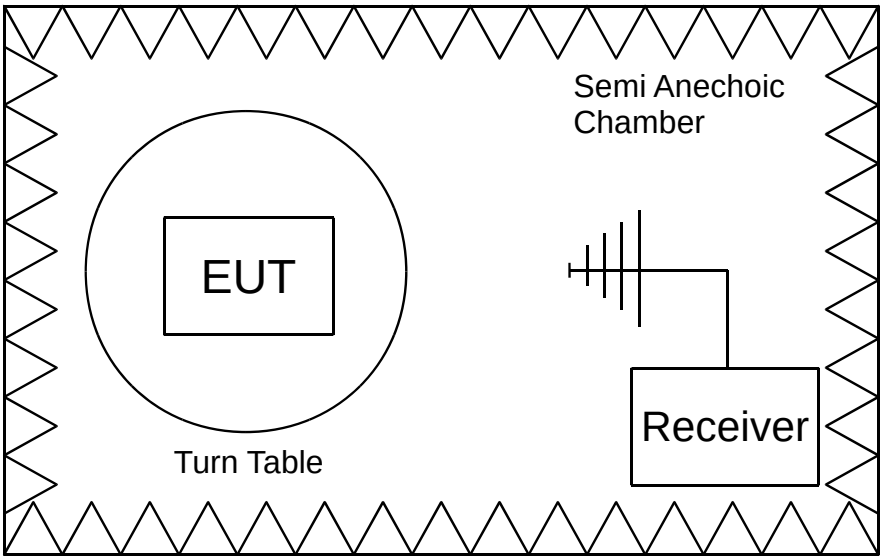
ANSI C63.4-2014, 8.3.2.1 Final radiated emission measurements (9 kHz to 1 GHz)

Based on the exploratory radiated emissions measurement results (i.e., see 8.3.1.1), the single EUT, cable and wire arrangement, and mode of operation that produces the emission that has the highest amplitude relative to the limit are selected for the final measurement. The final measurements are then performed on a site meeting the requirements of 5.3 or 5.4, as appropriate. If the EUT is relocated from an exploratory test site to a final test site, the highest emission relative to the limit shall be remaximized at the final test location before final radiated emissions measurements are performed. However, antenna height and polarization and EUT azimuth are to be varied. In addition, the full frequency range to be checked for meeting compliance shall be investigated.

This investigation is performed with the EUT rotated 360°, the antenna height scanned between 1 m and 4 m, and the antenna rotated by 90° relative to the ground plane to repeat the measurements for both the horizontal and vertical antenna polarizations. During the full frequency range investigation, particular focus should be made on the frequencies found in exploratory testing that were used to find the final test configuration, mode of operation, and arrangement (associated with achieving the least margin with respect to the limit). This full range test constitutes the compliance measurement.

Radiated Emissions Test Characteristics	
Frequency range	30 MHz – 1000 MHz
Test distance	3 m
Test instrumentation resolution bandwidth	120 kHz
Receive antenna height	1 m - 4 m
Angular steps size during prescan:	90 °
Receive antenna polarization	Vertical/Horizontal
Measurement location	Semi Anechoic Chamber (SAC)

4.2.4.2 Test Setup



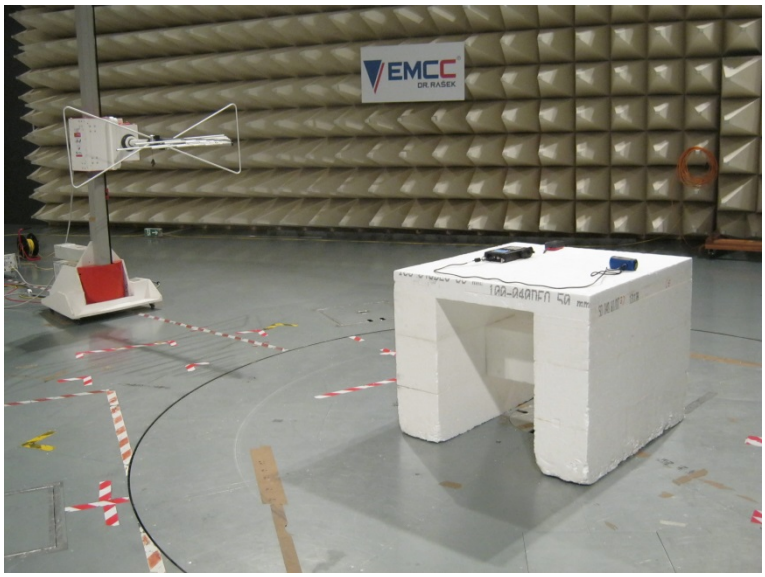
SCHEMATIC TEST SETUP

Requirement: 47 CFR, § 15.109
Procedure: ANSI C63.4-2014

Receiver: #3846
Antenna: #6041

Test distance: 3 m

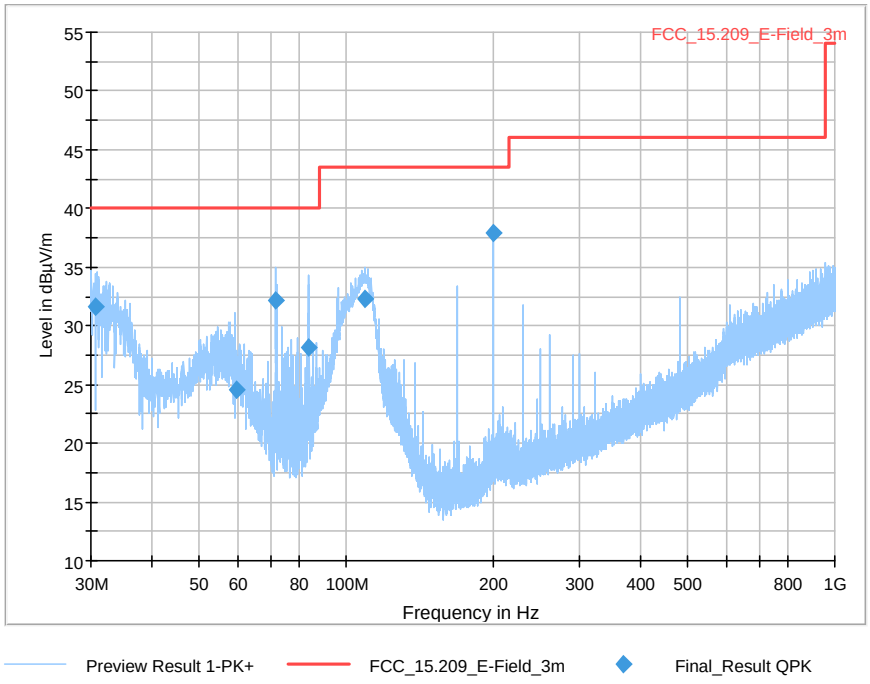
TEST EQUIPMENT USED:
Refer to chapter 5 of this document.
001, 54, 553, 554, 1291, 1292, 1889, 2724, 3846, 4075, 4717, 5392, 6041



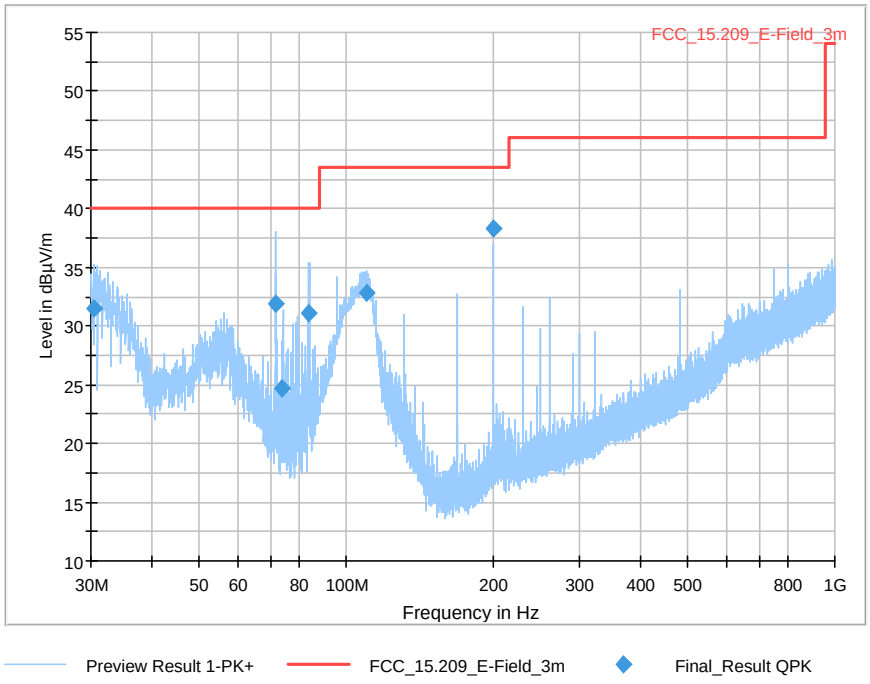
Sample photo of setup

4.2.4.3 Detailed Test Data

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	1 (hor)



Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	2 (vert)



Final Result:

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
30.56	31.6	40.0	8.4	1000	120.0	101.0	V	29	16.5
59.70	24.5	40.0	15.5	1000	120.0	100.0	V	70	18.0
71.82	32.1	40.0	7.9	1000	120.0	328.0	H	-71	14.5
83.90	31.2	40.0	8.8	1000	120.0	260.0	H	-90	14.2
109.82	32.9	43.5	10.6	1000	120.0	274.0	H	83	17.4
200.02	38.3	43.5	5.2	1000	120.0	136.0	H	75	17.5

All tests performed at the distance of d = 3m.

The table above contains worst-case emissions, only. For further details refer to the pre-scan test plot above.

4.2.4.4 Test Result

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No.:	none
Test date:	2018-05-16
Test personnel:	Ludwig Kraft

The EUT meets the requirements of this section.

4.2.5 Radiated Emissions 1 – 6 GHz

4.2.5.1 Test Procedures

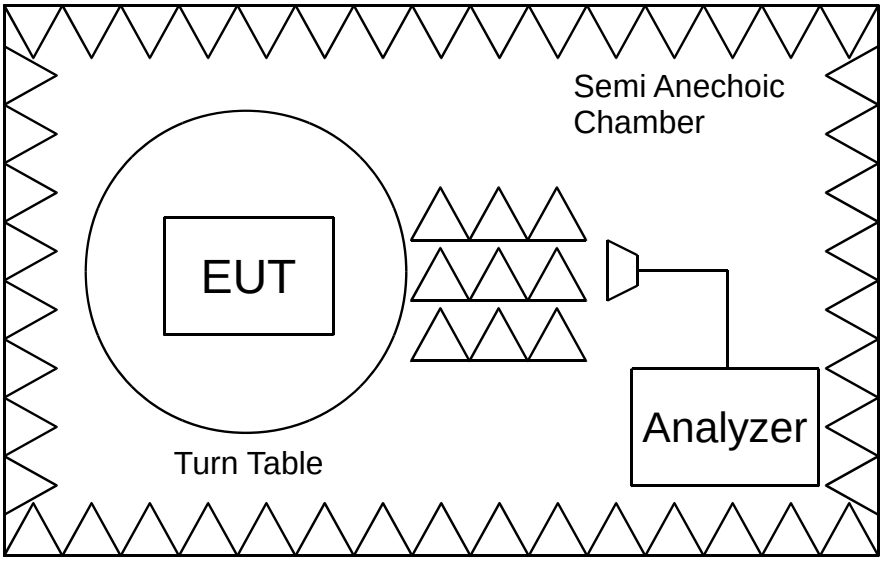
ANSI C63.4-2014, 8.2.4 Electric field radiated emissions (1 GHz to 40 GHz)
Radiated emission measurements above 1 GHz are made using calibrated linearly polarized antennas as specified in 4.5.5, which may have a smaller beamwidth (main lobe) than do the antennas used for frequencies below 1 GHz. Because the source of emissions from the EUT is generally limited to relatively small-angle cones of radiation in any elevation above the ground plane including angles above the height of the EUT, the antenna beamwidth shall be known so that when EUT emissions are measured, the area of coverage of the EUT emissions can be determined. Moving the measurement antenna over the surfaces of the four sides of the EUT or another method of scanning of the EUT is required when the EUT is larger than the area covered by the beamwidth of the measuring antenna at the specified distance.
For any EUT, the frequencies of emission should first be detected. Then the amplitudes of the emissions are measured at the specified measurement distance using the required antenna height, polarization, and detector characteristics.
In performing these measurements, the sensitivity of the complete measurement system relative to the limit shall be determined before the test. If the overall measurement sensitivity is inadequate, then low-noise preamplifiers, closer measurement distances, higher gain antennas, and/or narrower bandwidths may be used. Also, measurement system overload levels shall be determined to be adequate when preamplifiers are used. The effects of using bandwidths different from those specified shall also be determined. Any changes from the specific measurement conditions shall be described in the report of the measurements. (See also 10.2.4 and 10.2.9.)

ANSI C63.4-2014, 8.3.1.2 Exploratory radiated emissions measurements (1 GHz to 40 GHz)
When measuring emissions above 1 GHz, the frequencies of maximum emission shall be determined by manually (or with an articulated antenna positioner) positioning the antenna close to the EUT and then moving the measurement antenna over the surfaces of the EUT while observing a spectral display. It will be advantageous to have prior knowledge of the frequencies of emissions above 1 GHz to help in the search for emissions at those frequencies.

ANSI C63.4-2014, 8.3.2.2 Final radiated emission measurements (1 GHz to 40 GHz)
The final measurements are performed on a site meeting the requirements of 5.5. For measurements above 1 GHz, use the cable, EUT arrangement, and mode of operation determined in the exploratory testing to produce the emission that has the highest amplitude relative to the limit. Place the measurement antenna away from each area of the EUT determined to be a source of emissions at the specified measurement distance, while keeping the measurement antenna aimed at the source of emissions at each frequency of significant emissions, with polarization oriented for maximum response. The measurement antenna may have to be higher or lower than the EUT, depending on the radiation pattern of the emission and staying aimed at the emission source for receiving the maximum signal. The final measurement antenna elevation shall be that which maximizes the emissions. The measurement antenna elevation for maximum emissions shall be restricted to a range of heights of from 1 m to 4 m above the ground or reference ground plane. The data collected shall satisfy the report requirements of Clause 10.

Radiated Emissions Test Characteristics	
Frequency range	1 GHz – 6 GHz
Test distance	3 m
Test instrumentation resolution bandwidth	1 MHz
Receive antenna height	1 m – 4 m
Receive antenna polarization	Vertical/Horizontal
Measurement chamber	Semi anechoic chamber (SAC) with rf absorbers on the floor

4.2.5.2 Test Setup



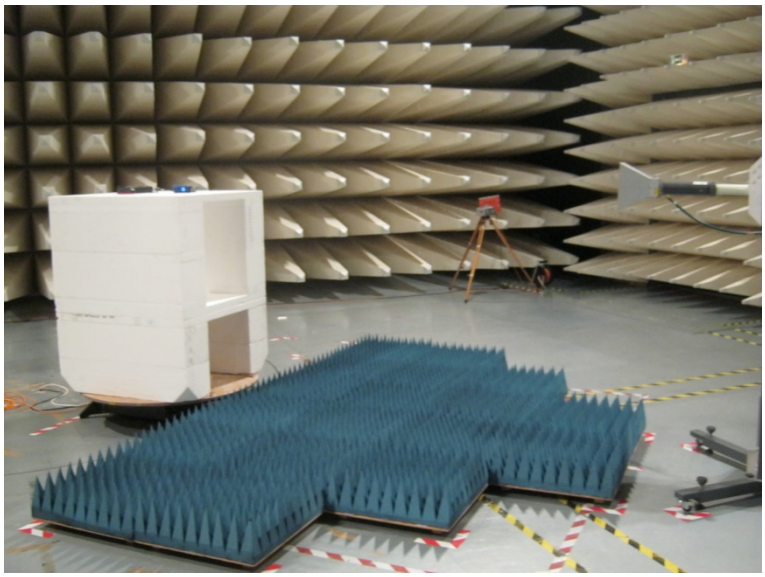
SCHEMATIC TEST SETUP

Requirement: 47 CFR, § 15.109
Procedure: ANSI C63.4-2014

Receiver: #3846
Antenna: #3235

Test distance: 3 m

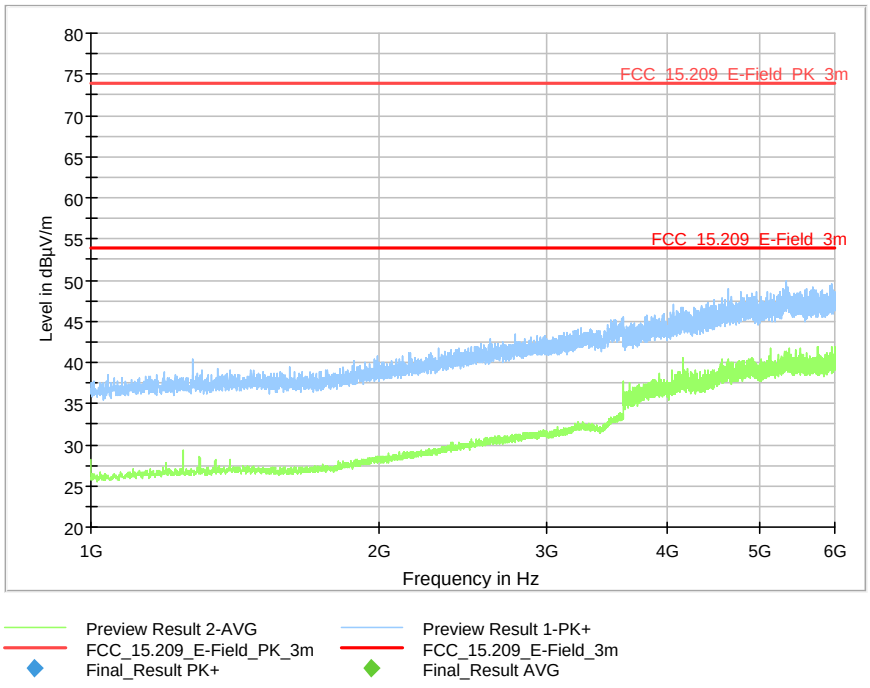
TEST EQUIPMENT USED:
Refer to chapter 5 of this document.
001, 553, 554, 1889, 3235, 4075, 4717, 5392, 5535, 5536, 5544, 5545, 5615



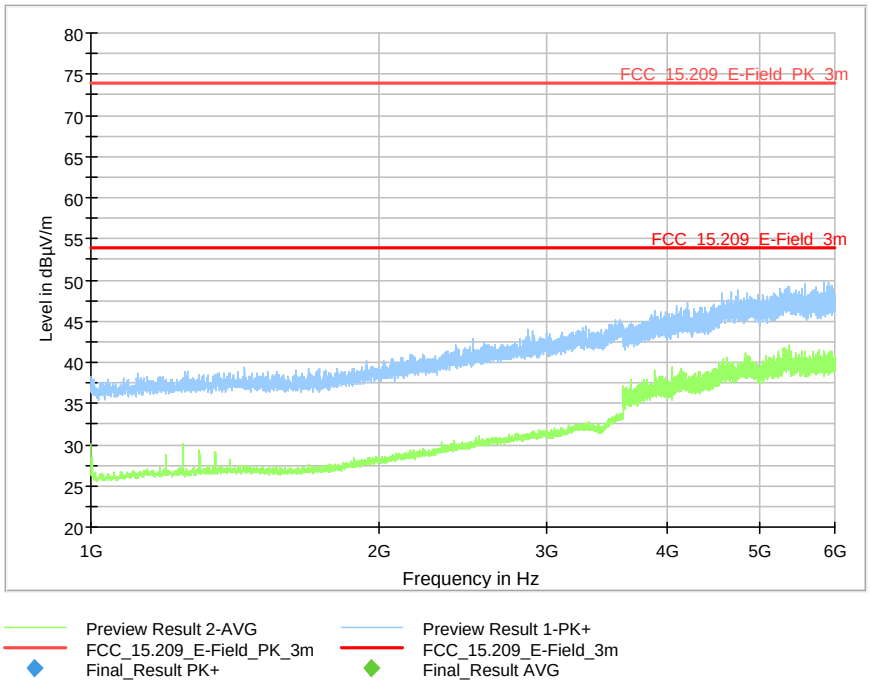
Sample photo of setup

4.2.5.3 Detailed Test Data

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	1 (hor)



Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	2 (vert)



Final Result:

Frequency MHz	MaxPeak dBµV/m	Average dBµV/m	Limit dBµV/m	Margin dB	Meas. Time ms	Bandwidth kHz	Height cm	Pol --	Azimuth deg	Corr. dB/m

All peak emissions were below the average limit.
Therefore, no final measurement performed.

All tests performed at the distance of d = 3 m.

The table above contains worst-case emissions, only. For further details refer to the pre-scan test plot above.

4.2.5.4 Test Result

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No.:	none
Test date:	2019-05-17
Test personnel:	Ludwig Kraft

The EUT meets the requirements of this section.

4.2.6 Radiated Emissions 6 – 40 GHz

4.2.6.1 Test Procedures

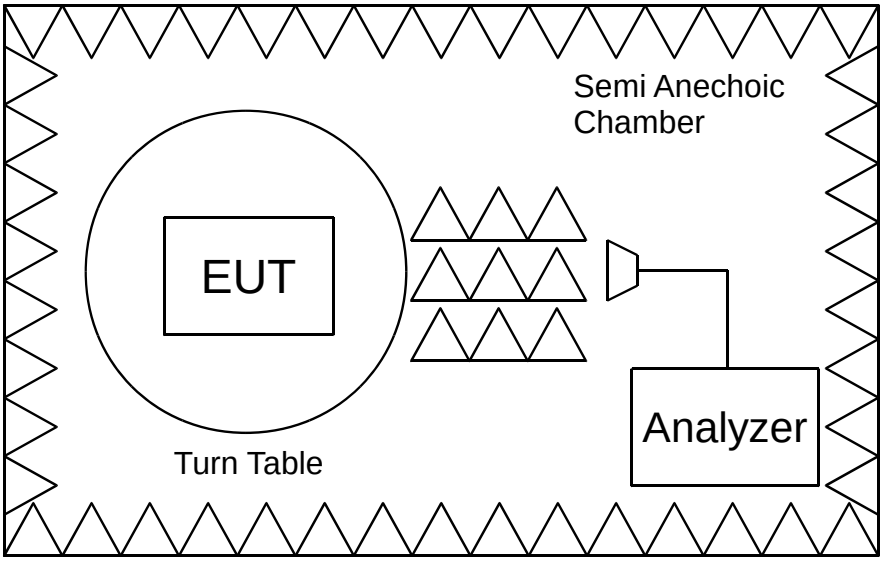
ANSI C63.4-2014, 8.2.4 Electric field radiated emissions (1 GHz to 40 GHz)
Radiated emission measurements above 1 GHz are made using calibrated linearly polarized antennas as specified in 4.5.5, which may have a smaller beamwidth (main lobe) than do the antennas used for frequencies below 1 GHz. Because the source of emissions from the EUT is generally limited to relatively small-angle cones of radiation in any elevation above the ground plane including angles above the height of the EUT, the antenna beamwidth shall be known so that when EUT emissions are measured, the area of coverage of the EUT emissions can be determined. Moving the measurement antenna over the surfaces of the four sides of the EUT or another method of scanning of the EUT is required when the EUT is larger than the area covered by the beamwidth of the measuring antenna at the specified distance.
For any EUT, the frequencies of emission should first be detected. Then the amplitudes of the emissions are measured at the specified measurement distance using the required antenna height, polarization, and detector characteristics.
In performing these measurements, the sensitivity of the complete measurement system relative to the limit shall be determined before the test. If the overall measurement sensitivity is inadequate, then low-noise preamplifiers, closer measurement distances, higher gain antennas, and/or narrower bandwidths may be used. Also, measurement system overload levels shall be determined to be adequate when preamplifiers are used. The effects of using bandwidths different from those specified shall also be determined. Any changes from the specific measurement conditions shall be described in the report of the measurements. (See also 10.2.4 and 10.2.9.)

ANSI C63.4-2014, 8.3.1.2 Exploratory radiated emissions measurements (1 GHz to 40 GHz)
When measuring emissions above 1 GHz, the frequencies of maximum emission shall be determined by manually (or with an articulated antenna positioner) positioning the antenna close to the EUT and then moving the measurement antenna over the surfaces of the EUT while observing a spectral display. It will be advantageous to have prior knowledge of the frequencies of emissions above 1 GHz to help in the search for emissions at those frequencies.

ANSI C63.4-2014, 8.3.2.2 Final radiated emission measurements (1 GHz to 40 GHz)
The final measurements are performed on a site meeting the requirements of 5.5. For measurements above 1 GHz, use the cable, EUT arrangement, and mode of operation determined in the exploratory testing to produce the emission that has the highest amplitude relative to the limit. Place the measurement antenna away from each area of the EUT determined to be a source of emissions at the specified measurement distance, while keeping the measurement antenna aimed at the source of emissions at each frequency of significant emissions, with polarization oriented for maximum response. The measurement antenna may have to be higher or lower than the EUT, depending on the radiation pattern of the emission and staying aimed at the emission source for receiving the maximum signal. The final measurement antenna elevation shall be that which maximizes the emissions. The measurement antenna elevation for maximum emissions shall be restricted to a range of heights of from 1 m to 4 m above the ground or reference ground plane. The data collected shall satisfy the report requirements of Clause 10.

Radiated Emissions Test Characteristics	
Frequency range	6 GHz – 40 GHz
Test distance	1 m
Test instrumentation resolution bandwidth	1 MHz
Receive antenna height	1.5 m
Receive antenna polarization	Vertical/Horizontal
Measurement chamber	Semi anechoic chamber (SAC) with rf absorbers on the floor

4.2.6.2 Test Setup



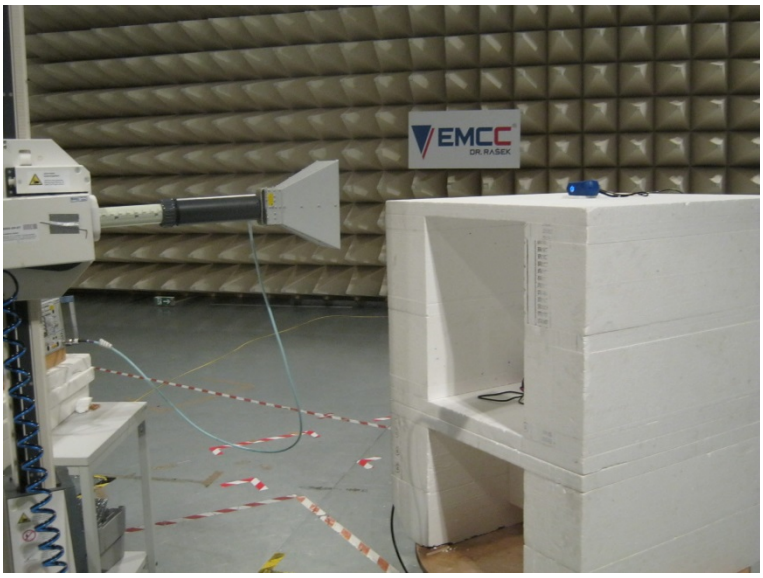
SCHEMATIC TEST SETUP

Requirement: 47 CFR, § 15.109
Procedure: ANSI C63.4-2014

Receiver: #3831
Antenna: #3235 (1 - 18GHz)
#1300 (18 - 26.5 GHz)
#1229 (26.5 – 40 GHz)

Test distance: 1 m

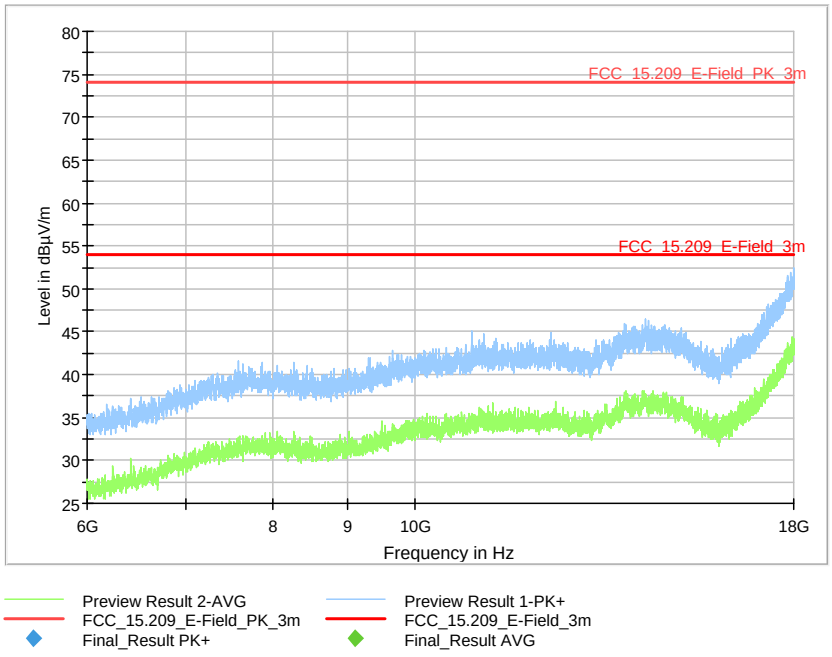
TEST EQUIPMENT USED:
Refer to chapter 5 of this document.
001, 553, 554, 1229, 1300, 1889, 3235, 3831, 4075, 4717, 5392, 5535, 5536, 5544, 5545, 5620



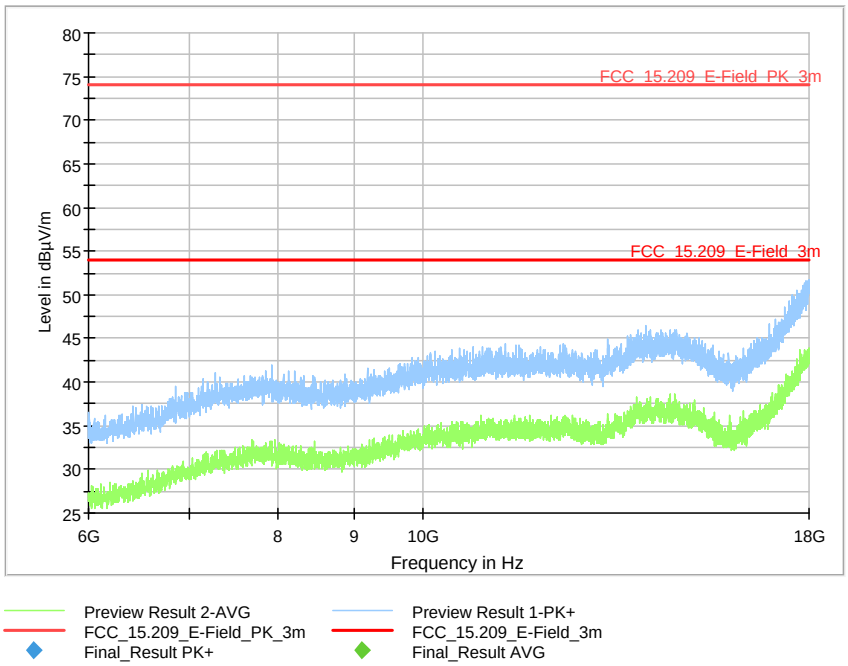
Sample photo of setup

4.2.6.3 Detailed Test Data

Manufacturer: Type: Serial No: EUT Orientation: Frequency range:	MICRO-EPSILON Messtechnik GmbH & Co. KG FSC 1/7 none 1 (hor) 6 -18 GHz

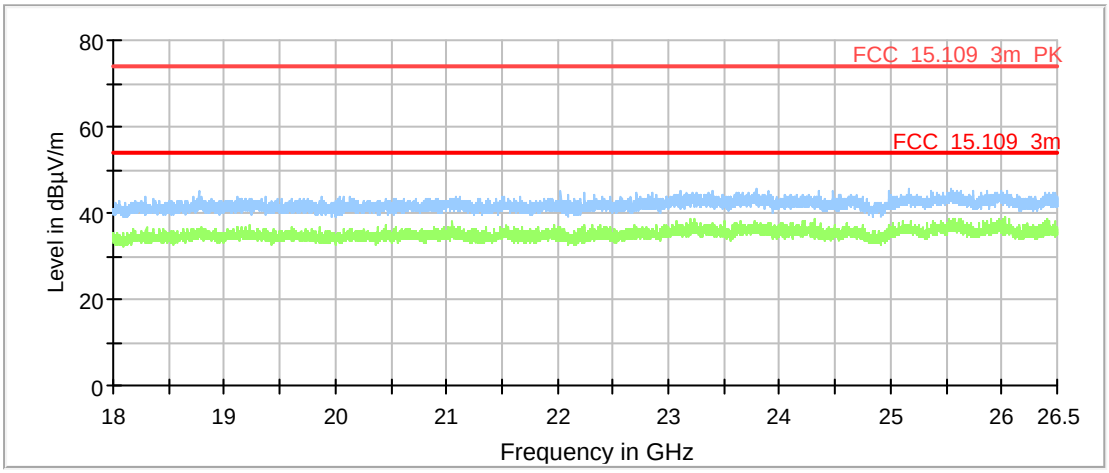


Manufacturer: Type: Serial No: EUT Orientation: Frequency range:	MICRO-EPSILON Messtechnik GmbH & Co. KG FSC 1/7 none 2 (vert) 6 -18 GHz



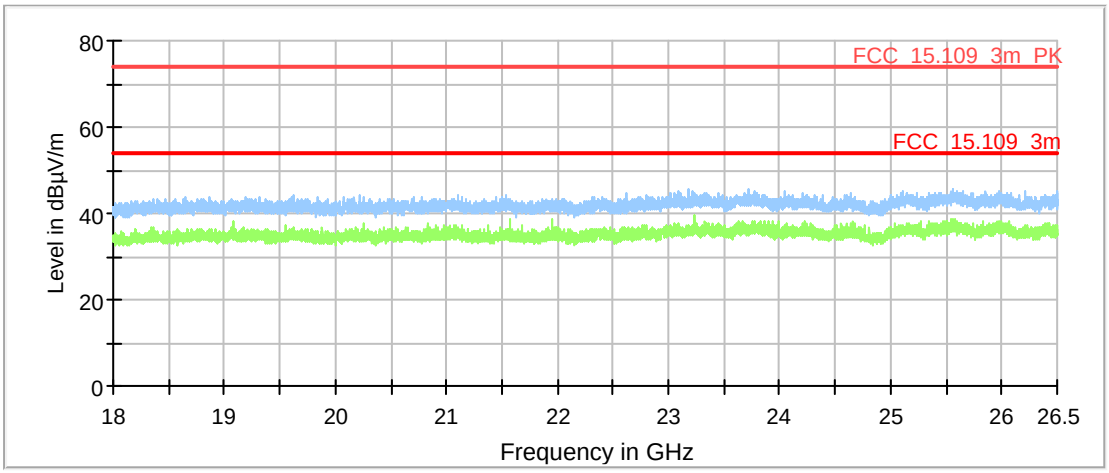
Test on MICRO-EPSILON Messtechnik GmbH & Co. KG FSC 1/7 to 47 CFR § 15.107 / 47 CFR § 15.109

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	1 (hor)
Frequency range:	18 -26.5 GHz



Preview Result 2-AVG
Preview Result 1-PK+
Critical_Freqs AVG
Critical_Freqs PK+
FCC_15.209_3m_PK
FCC_15.209_3m
Final_Result PK+
Final_Result AVG

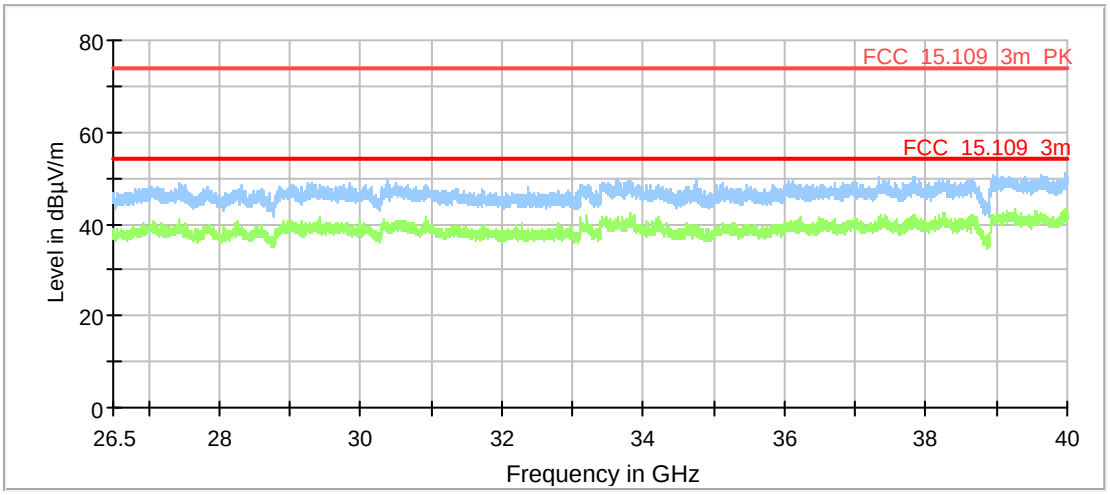
Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	2 (vert)
Frequency range:	18 -26.5 GHz



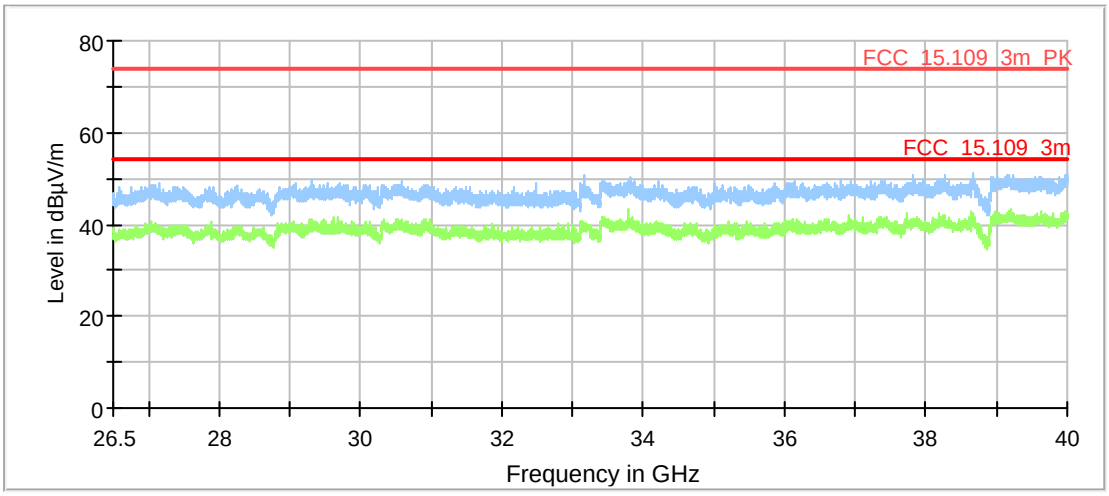
Preview Result 2-AVG
Preview Result 1-PK+
Critical_Freqs AVG
Critical_Freqs PK+
FCC_15.209_3m_PK
FCC_15.209_3m
Final_Result PK+
Final_Result AVG

Test on MICRO-EPSILON Messtechnik GmbH & Co. KG FSC 1/7 to 47 CFR § 15.107 / 47 CFR § 15.109

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	1 (hor)
Frequency range:	26.5 -40 GHz



Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No:	none
EUT Orientation:	2 (vert)
Frequency range:	26.5 - 40 GHz



Final Result:

Frequency MHz	MaxPeak dBµV/m	Average dBµV/m	Limit dBµV/m	Margin dB	Meas. Time ms	Bandwidth kHz	Height cm	Pol --	Azimuth deg	Corr. dB/m

All peak emissions were below the average limit.
Therefore, no final measurement performed.

All tests performed at the distance of d = 1 m.

The table above contains worst-case emissions, only. For further details refer to the pre-scan test plot above.

4.2.6.4 Test Result

Manufacturer:	MICRO-EPSILON Messtechnik GmbH & Co. KG
Type:	FSC 1/7
Serial No.:	none
Test date:	2018-12-19
Test personnel:	Patrick Reusch

The EUT meets the requirements of this section.

5 TEST INSTRUMENTS

EMCC Ident#	Instrument	Manufacturer	Model No.	Last Calibration	Calibration valid until
54	N-Cable N/50	Rohde & Schwarz	HFU2-Z5	n/a	n/a
553	GPIB-140A	National Instruments	186135C-31	n/a	n/a
554	GPIB-140A	National Instruments	186135C-31	n/a	n/a
1229	Standard Gain Horn Antenna	Mid Century	MC 22/31B	2014-07	2024-07
1291	Antenna Mast	Frankonia	FAM4	n/a	n/a
1292	Multi Device Controller	Frankonia	FC02	n/a	n/a
1300	Standard Gain Horn Antenna	Mid Century	MC 20/31B	2014-07	2024-07
1889	SR-ULL-01, Semi-Anechoic Chamber (SAC)	EMCC/FRANK.	SAC-10	n/a	n/a
1890	SR-ULL-05, Absorber-Lined Shielded Chamber	EMCC / SIEM / FRANK	SC2-ULL	n/a	n/a
1901	V-LISN 50 ohms//(50 uH + 5 ohms)	Rohde & Schwarz	ESH2-Z5	2018-11	2019-11
2724	5 W Attenuator 6dB	Weinschel	2	2019-07	2021-07
3148	8 W Termination	EMCC DR. RASEK	3V150	2017-11	2019-11
3235	Double Ridged Guide Antenna	Schwarzbeck	BBHA 9120D	2019-01	2021-01
3831	Spectrum Analyzer	Rohde & Schwarz	FSU50	2018-10	2019-10
3846	EMI Test Receiver	Rohde & Schwarz	ESU8	2019-02	2020-02
3880	Digital Multimeter	Agilent	U1241B	2018-07	2020-07
4075	Workstation	Dell	Optiplex 7010	n/a	n/a
4524	Notebook	Dell	Latitude E6430	n/a	n/a
4597	USB to GPIB adapter	National Instruments	GPIB-USB-HS with NI-488.2; 187965H-01L	n/a	n/a
4717	Web-Thermo-Hygrobarograph	Wiesemann & Theis GmbH WUT	57613 Web-T/Rh/P	2018-01	2020-01
5392	EMC Measurement Software V10.38.2	Rohde & Schwarz	EMC32	n/a	n/a
5535	Positioning controller	Rohde & Schwarz	HCC	n/a	n/a
5536	Rotary table	Rohde & Schwarz	HCT12	n/a	n/a
5544	Antenna Mast	innco systems GmbH	MA 5000-XPET	n/a	n/a
5545	Antenna Mast Controller	innco systems GmbH	CO 3000-1D	n/a	n/a
5551	BNC cable	EMCC	BNC003m0	n/a	n/a
5615	RF cable assembly	Rosenberger	LA2-025-7000	n/a	n/a
5620	RF cable assembly	Rosenberger	LA2-001-2000	n/a	n/a
6041	TRILOG Broadband Antenna	Schwarzbeck	VULB 9163	2017-09	2019-09

6 MEASUREMENT UNCERTAINTY

Measurement	Measurement Uncertainty
Conducted Emissions, AC mains (150 kHz – 30 MHz)	±3.5 dB
Radiated Emissions below 1000 MHz	±5.6 dB
Radiated Emissions above 1 GHz	±5.3 dB

The reported uncertainty values are based on a standard uncertainty multiplied by a coverage factor of k=2, providing a level of confidence of 95%.

The given values have been calculated on the basis of the following documents:

CISPR 16-4-2:2011+A1:2014, Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-2: Uncertainties, statistics and limit modelling - Measurement instrumentation uncertainty.

JCGM 100:2008, Evaluation of measurement data - Guide to the expression of uncertainty in measurement.

7 LIST OF ANNEXES

The following annexes are separated parts from this test report.

Description	Pages
Annex 1: Photographs of test setup	5
Annex 2: External photographs of equipment under test	4
Annex 3: Internal photographs of equipment under test	5
Annex 4: Photographs of ancillary equipment	4