TEST REPORT

Testing Laboratory:
SK Tech Co., Ltd.
88, Geulgaeul-ro, 81beon-gil,
Wabu-eup, Namyangju-si,
Gyeonggi-do, Korea
TEL: +82-31-576-2204
FAX: +82-31-576-2205

Test Report Number: SKT-RFC-190004

Date of issue: June 17, 2019

Applicant:	**KYUNGWOO SYSTECH INC.** #401, Daeryung Post Tower 5, 68, Digital-ro 9, Geumcheon-gu, Seoul, South Korea
Manufacturer:	**KYUNGWOO SYSTECH INC.** #401, Daeryung Post Tower 5, 68, Digital-ro 9, Geumcheon-gu, Seoul, South Korea
Product:	SMART KEY READER
Model:	**SMK-HWF-01**
FCC ID:	ZE8-SMK-HWF-01
Project number:	SKTEU19-0287
EUT received:	April 3, 2019

Applied standards:	ANSI C63.10-2013 and ANSI C63.4-2014 558074 D01 DTS Meas Guidance v05
Rule parts:	FCC Part 15 Subpart C - Intentional radiators
Equipment Class:	**DTS - Part 15 Digital Transmission System**

Remarks to the standards: None

The above equipment has been tested by SK Tech Co., Ltd., and found compliance with the requirements set forth in the technical standards mentioned above. The results of testing in this report apply only to the product or system, which was tested.

Wonsik Ham **/ Testing Engineer**

Jongsoo Yoon **/ Technical Manager**

Revision History of Test Report

Rev.	Revisions	Effect page	Approved by	Date
-	Initial issue	All	Jongsoo Yoon	Jun. 17, 2019

TABLE OF CONTENTS

1 Summary of test results 4

2 Description of equipment under test (EUT) 5

3 Test and measurement conditions 6

3.1. Test configuration (arrangement of EUT) 6
3.2. Description of support units (accessory equipment) 6
3.3. Interconnection and I/O cables 6
3.4. Measurement Uncertainty (*U*) 7
3.5. Test date 7

4 Facilities and accreditations 8

4.1. Facilities 8
4.2. Accreditations 8
4.3. List of test and measurement instruments 8

5 Test and measurements 9

5.1. Antenna requirement 9
5.2. 6 dB bandwidth 10
5.3. Maximum peak output power 12
5.4. Spurious emissions, Band edge, and Restricted bands 14
5.5. Peak power spectral density 31

1 Summary of test results

Requirement	CFR 47 Section	Result
Antenna Requirement	15.203, 15.247(b)(4)	Meets the requirements
6dB Bandwidth	15.247(a)(2)	Meets the requirements
Maximum Peak Output Power	15.247(b)(3), (4)	Meets the requirements
Spurious Emission, Band Edge, and Restricted bands	15.247(d), 15.205(a), 15.209(a)	Meets the requirements
Peak Power Spectral Density	15.247(e)	Meets the requirements
AC power line Conducted emissions	15.207(a)	N/A

Note: *The EUT is operated from the battery (DC 12 V or DC 24 V) in a vehicle, and therefore the test suites related to AC Mains port were not applicable.*

2 Description of equipment under test (EUT)

Product:	SMART KEY READER
Model:	SMK-HWF-01
Serial number:	None (prototype)

Model differences:

Model name	Difference	Tested (checked)
SMK-HWF-01	fully tested model that was provided by the applicant	☒

Technical data:

Power source	DC 12 V / DC 24 V (powered from the battery in a vehicle)	
Local Oscillator or X-Tal	8 MHz, 32 MHz	
Transmit Frequency	2405 MHz transceiver	125 kHz transmitter*
Antenna Type	Integral chip antenna	Integral loop coil antenna
Type of Modulation	OQPSK (ZigBee)	ASK
RF Output power	-3.89 dBm (PEAK) (measured conducted RF power)	84.1 dBμV/m (PEAK) (measured @ 3m)

Note: ** The test report for Equipment Class of DCD was issued with other test report number.*
*** The test report for the compliance with FCC Part 15B as a digital device was issued with other test report number.*

I/O port	Type	Q'ty	Remark
Connector	12-pin connector (DC input, CAN, etc.)	1	

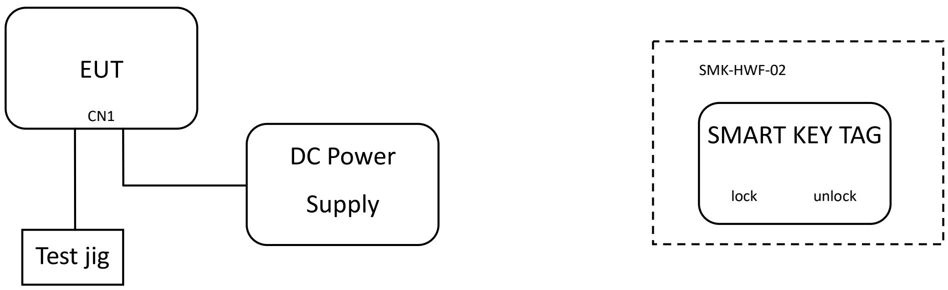
Modification of EUT during the compliance testing:

The firmware of the EUT was modified for the tests in order to transmit RF signals continuously with 100 % duty cycle when receiving RF signals from SMART KEY TAG (model SMK-HWF-02).

3 Test and measurement conditions

3.1. Test configuration (arrangement of EUT)

The EUT was operated from DC Power Supply (12 V/24 V). The measurements were taken in continuous transmitting mode provided by the applicant. In order to transmit RF signals, the LOCK button on the SMART KEY TAG was pressed one time.



NOTE: The Test jig was connected for the normal operation for the transceiver operating at 2405 MHz.

3.2. Description of support units (accessory equipment)

The following support units or accessories were used to form a representative test configuration during the tests.

#	Equipment	Manufacturer	Model No.	Serial No.
1	DC Power Supply	HP	6633A	2838A-01000
2	Test jig	N/A	N/A	N/A
3	SMART KEY TAG	KYUNGWOO SYSTECH INC.	SMK-HWF-02	N/A

Note: *For radiated spurious emission measurements, the measurements were performed without SMART KEY TAG after pressing the LOCK button on it.*

3.3. Interconnection and I/O cables

The following support units or accessories were used to form a representative test configuration during the tests.

#	Start		End		Cable	
	Name	I/O port	Name	I/O port	length (m)	shielded (Y/N)
1	EUT	DC IN(2-pin)	DC Power Supply	DC output	2.0	N
		IG(1-pin)	DC Power Supply	DC output(+)	2.0	N
		DOOR SW(1-pin)	Test jig #1	DOOR SW	2.0	N
		HORN RY(1-pin)	Test jig #1	HORN RY	2.0	N
		DOOR(3-pin)	Test jig #1	DOOR	2.0	N
		CAN(2-pin)	Test jig #2	CAN	2.0	N
		NC(2-pin)	-	-	-	-
2	DC Power Supply	AC input	AC Mains	AC Mains	1.8	N

Note: *1) All the equipment/cables were placed in the worst-case configuration to maximize the emission during the test.*
2) Grounding was established in accordance with the manufacturer's requirements and conditions for the intended use.

3.4. Measurement Uncertainty (U)

Measurement Item	Combined Standard Uncertainty *Uc*	Expanded Uncertainty $U = k \times Uc$ (k = 2)
Conducted RF power	±1.49 dB	±2.98 dB
Conducted emissions	±1.42 dB	±2.84 dB
Radiated emissions (9 kHz to 30 MHz)	±2.30 dB	±4.60 dB
Radiated emissions (30 MHz to 1000 MHz)	±2.53 dB	±5.06 dB
Radiated emissions (above 1 GHz)	±2.62 dB	±5.24 dB

3.5. Test date

Date Tested	April 24, 2019 – May 1, 2019

4 Facilities and accreditations

4.1. Facilities

All of the measurements described in this report were performed at SK Tech Co., Ltd
Site I: 88, Geulgaeul-ro 81beon-gil, Wabu-eup, Namyangju-si, Gyeonggi-do, Korea
Site II: 124-8, Geulgaeul-ro, Wabu-eup, Namyangju-si, Gyeonggi-do, Korea

The sites are constructed in conformance with the requirements of ANSI C63.4 and CISPR 16-1-4. The sites comply with the Normalized Site Attenuation requirements given in ANSI C63.4, and site VSWR requirements specified in CISPR 16-1-4. The measuring apparatus and ancillary equipment conform to CISPR 16-1 series.

4.2. Accreditations

The laboratory has been also notified to FCC by RRA as a Conformity Assessment Body, and designated to perform compliance testing on equipment subject to Declaration of Conformity (SDoC) and Certification under Parts 15 and 18 of the FCC Rules.

Designation No.	KR0007

4.3. List of test and measurement instruments

No	Description	Model	Manufacturer	Serial No.	Cal. due	Use
1	Spectrum Analyzer	E4405B	Agilent	US40520856	2020.02.25	
2	Spectrum Analyzer	E4440A	Agilent	MY46186322	2019.06.18	☒
3	EMI Test Receiver	ESR26	Rohde&Schwarz	101441	2019.08.29	☒
4	EMI Test Receiver	ESIB40	Rohde&Schwarz	100277	2020.02.26	☒
5	EMI Test Receiver	PMM9010F	Narda	020WW40105	2020.06.10	
6	Pulse limiter	ESH3-Z2	Rohde&Schwarz	100604	2020.06.10	
7	AMN (LISN)	ENV 216	Rohde&Schwarz	102047	2020.02.25	
8	AMN (LISN)	FCC-LISN-50-32-2-01-480V	FCC	141455	2020.06.10	
9	Pre-amplifier (30 MHz - 1 GHz)	MLA-10K01-B01-27	TSJ	2005350	2020.06.11	☒
10	Pre-amplifier (30 MHz - 1 GHz)	8447D	HP	2944A07994	2020.06.10	
11	Pre-amplifier (1 GHz - 18 GHz)	MLA-100M18-B02-38	TSJ	1539546	2020.02.25	
12	Attenuator (10dB)	8491B	HP	38072	2020.06.10	☒
13	Attenuator (6dB)	18N5W	API Technology	-	2020.06.10	☒
14	High Pass Filter	WHKX 3.0/18G-12SS	Wainwright	8	2019.06.10	☒
15	VHF Precision Dipole Antenna (TX/RX)	VHAP	Schwarzbeck	1014 / 1015	2020.09.17	
16	UHF Precision Dipole Antenna (TX/RX)	UHAP	Schwarzbeck	989 / 990	2020.09.17	
17	Loop Antenna	HFH2-Z2	Schwarzbeck	863048/019	2019.12.18	☒
18	BILOG Broadband Antenna	VULB9168	Schwarzbeck	9168-230	2019.07.20	☒
19	Horn Antenna (1 GHz - 18 GHz)	BBHA 9120D	Schwarzbeck	9120D-816	2021.06.10	☒
20	Horn Antenna (15 GHz - 40 GHz)	BBHA9170	Schwarzbeck	BBHA9170318	2020.07.23	
21	Vector Signal Generator	E4438C	Agilent	MY42080359	2020.02.26	
22	PSG analog signal generator	E8257D	Agilent	MY45141255	2020.06.10	
23	DC Power Supply	6633A	HP	2838A-01000	2020.06.10	☒
24	DC Power Supply	6633A	HP	3325A04972	2020.06.10	
25	Digital Thermo-Hygrometer	608-H1	Testo	-	2020.06.17	☒
26	Temperature/Humidity Chamber	DJ-THC02	DAE JIN ENG	06071	2020.02.27	
27	Pre-Amplifier (15 GHz - 40 GHz)	AFS44-00101800-25-10P-44	MITEQ	1116321	2019-06-19	☒

5 Test and measurements

5.1. Antenna requirement

5.1.1 Regulation

According to §15.203, an intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited.
And according to §15.247(b)(4), the conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

5.1.2 Result: PASS

The EUT has the integral chip antenna with the directional gain 2.2 dBi, and meets the requirements of this section.

5.2. 6 dB bandwidth

5.2.1 Regulation

According to §15.247(a)(2), systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz bands. The minimum 6dB bandwidth shall be at least 500 kHz.

5.2.2 Test Procedure

1. Set RBW = 100 kHz.
2. Set the video bandwidth (VBW) ≥ 3 × RBW.
3. Detector = Peak.
4. Trace mode = max hold.
5. Sweep = auto couple.
6. Allow the trace to stabilize.
7. Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

5.2.3 Test Results: PASS

Table 1: Measured values of the 6dB Bandwidth

(Operated from DC 12 V)

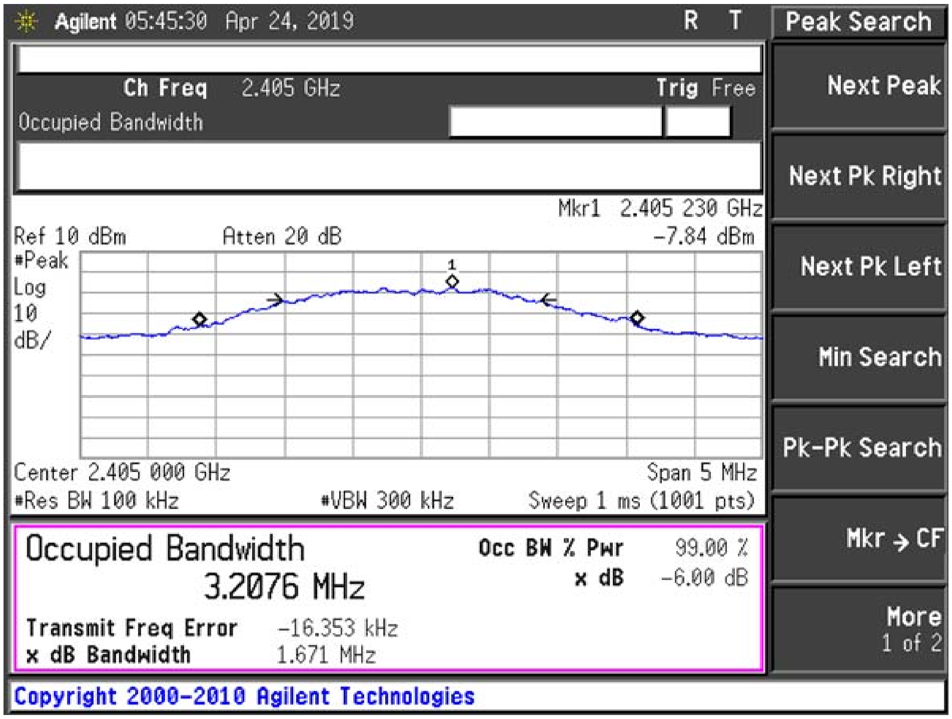
Operating frequency	Occupied Bandwidth (99 %)	6 dB Bandwidth	Limit
2405 MHz	3.2076 MHz	1.671 MHz	≥ 500 kHz

(Operated from DC 24 V)

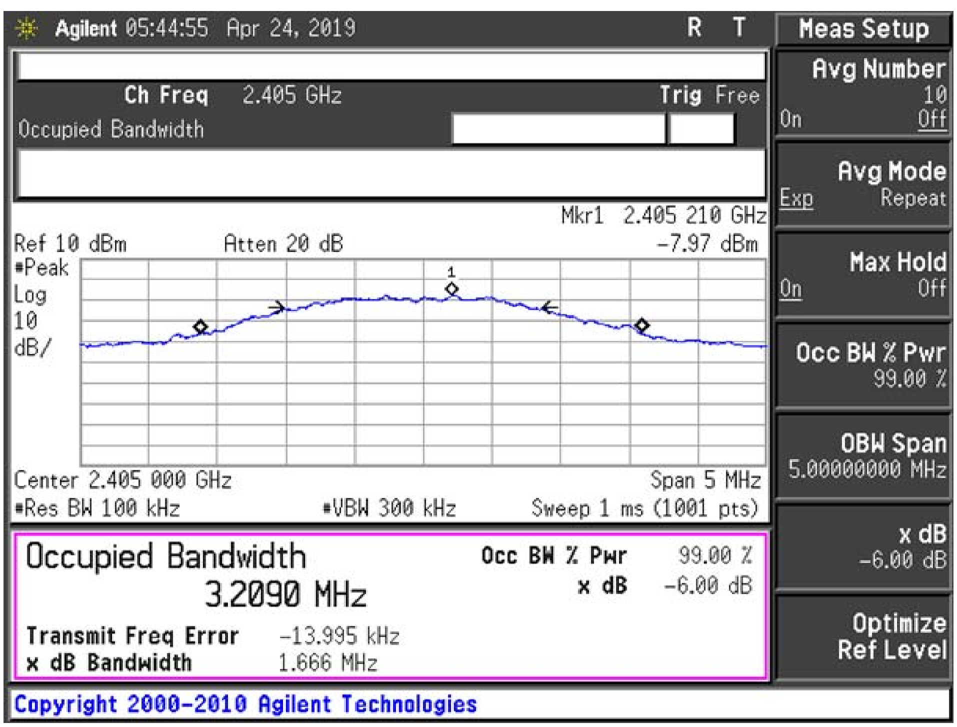
Operating frequency	Occupied Bandwidth (99 %)	6 dB Bandwidth	Limit
2405 MHz	3.2090 MHz	1.666 MHz	≥ 500 kHz

Figure 1. Plot of the 6dB Bandwidth & Occupied Bandwidth (99%)

(Operated from DC 12 V)



(Operated from DC 24 V)



5.3. Maximum peak output power

5.3.1 Regulation

According to §15.247(b)(3), for systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

According to §15.247(b)(4), the conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

5.3.2 Test Procedure

1. Set the RBW ≥ DTS bandwidth.
2. Set the VBW ≥ 3 x RBW.
3. Set the span ≥ 3 x RBW.
4. Sweep time = auto couple.
5. Detector = peak.
6. Trace mode = max hold.
7. Allow trace to fully stabilize.
8. Use peak marker function to determine the peak amplitude level.

5.3.3 Test Results: PASS

Table 2: Measured values of the Maximum Peak Conducted Output Power

(Operated from DC 12 V)

Operating frequency	PEAK POWER		Limit
	[dBm]	[W]	
2405 MHz	-3.97	0.000 40	1 W

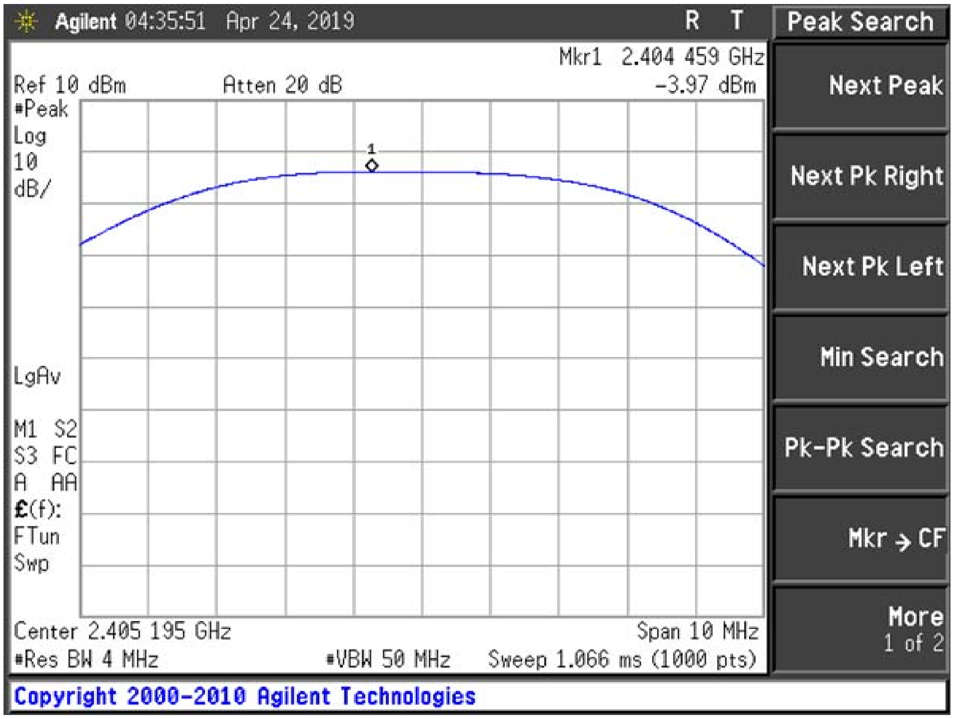
(Operated from DC 24 V)

Operating frequency	PEAK POWER		Limit
	[dBm]	[W]	
2405 MHz	-3.89	0.000 41	1 W

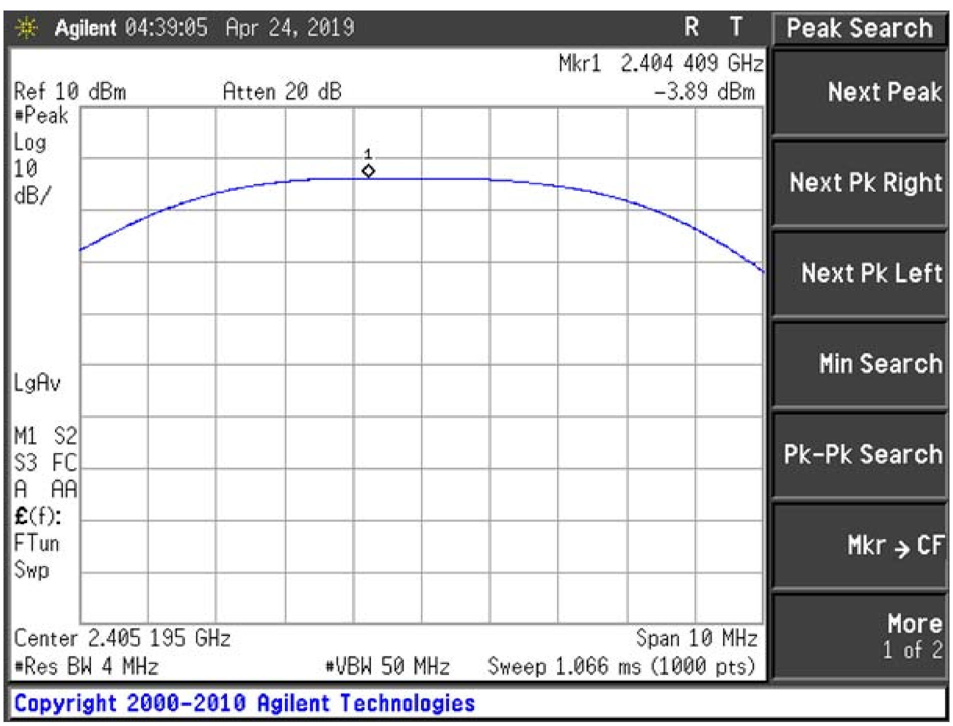
Figure 2. Plot of the Maximum Peak Conducted Output Power

During the measurements, the insertion loss of the cable loss and the external attenuator (10 dB) was corrected in the spectrum analyzer.

(Operated from DC 12 V)



(Operated from DC 24 V)



5.4. Spurious emissions, Band edge, and Restricted bands

5.4.1 Regulation

According to §15.247(d), In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)), the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field strength limit (μV/m)	Field strength limit (dBμV/m)	Measurement distance (m)
0.009 - 0.490	2400/F (kHz)	48.5 - 13.8	300
0.490 - 1.705	24000/F (kHz)	33.6 - 23.0	30
1.705 - 30.0	30	29.5	30
30 – 88	100	40.0	3
88 – 216	150	43.5	3
216 – 960	200	46.0	3
Above 960	500	54.0	3

***Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.*

5.4.2 Test Procedure

<u>1) Band-edge measurements for RF conducted emissions</u>

1. Set the spectrum analyzer as follows:

   Span = wide enough to capture the peak level of the emission operating on the channel closest to the band-edge, as well as any modulation products which fall outside of the authorized band of operation

   RBW ≥ 1 % of spectrum analyzer display span

   VBW ≥ 3 x RBW

   Sweep = auto

   Detector function = peak

   Trace = max hold

2. Allow the trace to stabilize. Set the marker on the emission at the band-edge, or on the highest modulation product outside of the band, if this level is greater than that at the band-edge. Enable the marker-delta function, and then use the marker-to-peak function to move the marker to the peak of the in-band emission.
3. Now, using the same instrument settings, enable the hopping function of the EUT. Allow the trace to stabilize. Follow the same procedure listed above to determine if any spurious emissions caused by the hopping function also comply with the specified limit.

2) Spurious RF Conducted Emissions:

1. Set the spectrum analyzer as follows:
   Span = wide enough to capture the peak level of the in-band emission and all spurious emissions (e.g., harmonics) from the lowest frequency generated in the EUT up through the 10th harmonic. Typically, several plots are required to cover this entire span.
   RBW = 100 kHz
   VBW ≥ 3 x RBW
   Sweep = auto
   Detector function = peak
   Trace = max hold
2. Allow the trace to stabilize. Set the marker on the peak of any spurious emission recorded.

3) Spurious Radiated Emissions:

1. The preliminary radiated measurements were performed to determine the frequency producing the maximum emissions in an anechoic chamber at a distance of 3 meters or 1 meter if applicable.
2. The EUT was placed on the top of the 0.8-meter height (or 1.5 meter height for above 1 GHz). To find the maximum emission levels, the height of a measuring antenna was changed and the turntable was rotated (0º to 360º).
3. The antenna polarization was also changed from vertical to horizontal. The spectrum was scanned from 9 kHz to 30 MHz using the loop antenna, from 30 to 1000 MHz using the Bilog broadband antenna, and from 1 GHz to tenth harmonic of the highest fundamental frequency using the horn antenna.
4. To increase the overall measurement sensitivity, the closer test distances and/or narrower bandwidths may be used. If the closer measurement distance (1 meter) were used, the beamwidth of the measuring antenna versus size of the EUT was taken into account.
5. To obtain the final measurement data, each frequency found during preliminary measurements was re-examined and investigated. The test receiver was set up to average, peak, and quasi-peak detector function with specified bandwidth. It was attempted to maximize the emission, by varying the configuration of the EUT and the cables routing.
6. The EUT is situated in three orthogonal planes (if appropriate)
7. If the emission on which a radiated measurement must be made is located at the edge of the authorized band of operation, then the alternative “marker-delta” method may be employed.

4) Marker-Delta Method at the edge of the authorized band of operation:

1. Perform an in-band field strength measurement of the fundamental emission using the RBW and detector function specified in 6.3 and 6.4, 6.5, or 6.6, as applicable, and the appropriate regulatory requirements for the frequency being measured.
2. Choose a spectrum analyzer span that encompasses both the peak of the fundamental emission and the band-edge emission under investigation. Set the analyzer RBW to approximately 1 % to 5 % of the total span, unless otherwise specified, with a video bandwidth equal to or greater than the RBW.
   Record the peak levels of the fundamental emission and the relevant band-edge emission (i.e., run several sweeps in peak hold mode). Observe the stored trace and measure the amplitude delta between the peak of the fundamental and the peak of the band-edge emission. This is not an absolute field strength measurement; it is only a relative measurement to determine the amount by which the emission drops at the band edge relative to the highest fundamental emission level.
3. Subtract the delta measured in b) from the field strengths measured in a). The resultant field strengths (CISPR QP, average, or peak, as appropriate) are then used to determine band-edge compliance of the restricted bands, described in 5.9.
4. The above “delta” measurement technique may be used for measuring emissions that are up to two “standard” bandwidths away from the band edge, where a “standard” bandwidth is the bandwidth specified by 4.2.3.2 for the frequency being measured. For example, band-edge measurements in the restricted band that begins at 2483.5 MHz require a measurement bandwidth of at least 1 MHz.
   Therefore the “delta” technique for measuring emissions up to 2 MHz removed from the band edge may be used. Radiated emissions that are removed by more than two “standard” bandwidths shall be measured in the conventional manner.

5.4.3 Test Results: PASS

Table 3: Measured values of the Field strength (below 30 MHz)

Freq. (kHz)	RBW (kHz)	Reading (dBμV)			AF (dB/m)	CL (dB)	Actual (dBμV/m)			Limit (at 3m) (dBμV/m)			Margin (dB)			Remark
		PK	AV	QP			PK	AV	QP	PK	AV	QP	PK	AV	QP	

No Radiated Spurious Emissions Found

AF and CL: antenna factor and cable loss
Actual (dBμV/m) = Reading + AF + CL
Margin (dB) = Limit – Actual
Note: These test results were measured at the 3 m distance

Table 4: Measured values of the Field strength (30 MHz to 1 GHz)

(Operated from DC 12 V)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)	AMP (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Remark
32.190	V	1.00	38.3	30.7	18.3	0.8	26.7	40.0	13.3	X-axis
61.482	V	1.00	36.9	30.5	18.8	1.1	26.3	40.0	13.7	
75.746	V	2.05	41.9	30.4	15.9	1.2	28.6	40.0	11.4	
383.990	H	1.01	36.5	30.1	21.3	2.7	30.4	46.0	15.6	
400.008	H	1.01	32.7	30.2	21.7	2.7	26.9	46.0	19.1	
415.997	H	1.00	32.6	30.2	22.0	2.8	27.2	46.0	18.8	
31.323	V	1.00	37.5	30.7	18.2	0.8	25.8	40.0	14.2	Y-axis
66.383	V	1.00	37.6	30.5	18.0	1.1	26.2	40.0	13.8	
75.742	V	2.05	40.9	30.4	15.9	1.2	27.6	40.0	12.4	
384.006	H	1.00	36.7	30.1	21.3	2.7	30.6	46.0	15.4	
399.998	H	1.00	32.3	30.2	21.7	2.7	26.5	46.0	19.5	
416.015	H	1.00	32.9	30.2	22.0	2.8	27.5	46.0	18.5	
31.800	V	1.00	38.5	30.7	18.3	0.8	26.9	40.0	13.1	Z-axis
55.410	V	1.00	34.9	30.5	19.5	1.0	24.9	40.0	15.1	
75.766	V	2.08	41.8	30.4	15.9	1.2	28.5	40.0	11.5	
384.003	H	1.00	35.7	30.1	21.3	2.7	29.6	46.0	16.4	
399.985	H	1.00	31.7	30.2	21.7	2.7	25.9	46.0	20.1	
416.015	H	1.00	30.2	30.2	22.0	2.8	24.8	46.0	21.2	

V/H: Vertical / Horizontal polarization
AMP, AF and CL: pre-amplifier gain, antenna factor and cable loss
Actual = Reading - AMP + AF + CL
Margin = Limit - Actual

(Operated from DC 24 V)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)	AMP (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Remark
32.452	V	1.00	38.3	30.7	18.3	0.8	26.7	40.0	13.3	X-axis
59.497	V	1.00	36.5	30.5	19.1	1.1	26.2	40.0	13.8	
75.763	V	2.05	41.7	30.4	15.9	1.2	28.4	40.0	11.6	
383.998	H	1.00	36.5	30.1	21.3	2.7	30.4	46.0	15.6	
415.998	H	1.00	32.5	30.2	22.0	2.8	27.1	46.0	18.9	
919.502	H	1.27	24.1	30.3	29.6	4.1	27.5	46.0	18.5	
31.335	V	1.01	38.1	30.7	18.2	0.8	26.4	40.0	13.6	Y-axis
66.387	V	1.01	37.4	30.5	18.0	1.1	26.0	40.0	14.0	
75.745	V	2.08	41.7	30.4	15.9	1.2	28.4	40.0	11.6	
376.001	H	1.00	33.1	30.1	21.2	2.6	26.8	46.0	19.2	
383.995	H	1.00	36.8	30.1	21.3	2.7	30.7	46.0	15.3	
415.982	H	1.00	32.8	30.2	22.0	2.8	27.4	46.0	18.6	
32.352	V	1.00	38.5	30.7	18.3	0.8	26.9	40.0	13.1	Z-axis
55.436	V	1.01	35.1	30.5	19.5	1.0	25.1	40.0	14.9	
75.747	V	2.08	42.2	30.4	15.9	1.2	28.9	40.0	11.1	
384.001	H	1.00	35.8	30.1	21.3	2.7	29.7	46.0	16.3	
399.998	H	1.00	31.9	30.2	21.7	2.7	26.1	46.0	19.9	
415.985	H	1.00	30.5	30.2	22.0	2.8	25.1	46.0	20.9	

V/H: Vertical / Horizontal polarization
AMP, AF and CL: pre-amplifier gain, antenna factor and cable loss
Actual = Reading - AMP + AF + CL
Margin = Limit - Actual

Table 5: Measured values of the Field strength (above 1 GHz)

(Operated from DC 12 V, for X-axis)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)		AMP (dB)	ATT (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			PK	AV					PK	AV	PK	AV	PK	AV
4811.623	H	1.50	48.62	40.51	44.42	1.19	31.16	6.90	43.45	35.34	74.00	54.00	30.55	18.66
4811.623	V	1.00	47.14	38.61	44.42	1.19	31.16	6.90	41.97	33.44	74.00	54.00	32.03	20.56
7207.415	H	1.00	41.58	29.81	43.82	1.09	36.39	9.17	44.41	32.64	74.00	54.00	29.59	21.36
7207.415	V	2.00	39.76	26.64	43.82	1.09	36.39	9.17	42.59	29.47	74.00	54.00	31.41	24.53

(Operated from DC 12 V, for Y-axis)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)		AMP (dB)	ATT (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			PK	AV					PK	AV	PK	AV	PK	AV
4811.623	H	1.00	48.14	39.19	44.42	1.19	31.16	6.90	42.97	34.02	74.00	54.00	31.03	19.98
4811.623	V	1.00	47.61	39.78	44.42	1.19	31.16	6.90	42.44	34.61	74.00	54.00	31.56	19.39
7207.415	H	1.00	43.60	32.63	43.82	1.09	36.39	9.17	46.43	35.46	74.00	54.00	27.57	18.54
7207.415	V	1.00	44.59	33.09	43.82	1.09	36.39	9.17	47.42	35.92	74.00	54.00	26.58	18.08

(Operated from DC 12 V, for Z-axis)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)		AMP (dB)	ATT (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			PK	AV					PK	AV	PK	AV	PK	AV
4811.623	H	1.00	48.76	41.70	44.42	1.19	31.16	6.90	43.59	36.53	74.00	54.00	30.41	17.47
4811.623	V	1.00	42.61	30.21	44.42	1.19	31.16	6.90	37.44	25.04	74.00	54.00	36.56	28.96
7207.415	H	2.00	41.92	31.55	43.82	1.09	36.39	9.17	44.75	34.38	74.00	54.00	29.25	19.62
7207.415	V	2.00	40.68	27.67	43.82	1.09	36.39	9.17	43.51	30.50	74.00	54.00	30.49	23.50

V/H: Vertical / Horizontal polarization
AMP, AF, CL and ATT: pre-amplifier gain, antenna factor, cable loss and attenuator/filter loss if used
Actual = Reading - AMP + ATT + AF + CL
Margin = Limit - Actual

(Operated from DC 24 V, for X-axis)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)		AMP (dB)	ATT (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			PK	AV					PK	AV	PK	AV	PK	AV
4811.623	H	1.50	48.51	40.49	44.42	1.19	31.16	6.90	43.34	35.32	74.00	54.00	30.66	18.68
4811.623	V	1.00	47.25	38.58	44.42	1.19	31.16	6.90	42.08	33.41	74.00	54.00	31.92	20.59
7207.415	H	1.00	42.62	29.83	43.82	1.09	36.39	9.17	45.45	32.66	74.00	54.00	28.55	21.34
7207.415	V	2.00	40.25	26.66	43.82	1.09	36.39	9.17	43.08	29.49	74.00	54.00	30.92	24.51

(Operated from DC 24 V, for Y-axis)

Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)		AMP (dB)	ATT (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			PK	AV					PK	AV	PK	AV	PK	AV
4811.623	H	1.00	48.19	38.72	44.42	1.19	31.16	6.90	43.02	33.55	74.00	54.00	30.98	20.45
4811.623	V	1.00	47.48	39.79	44.42	1.19	31.16	6.90	42.31	34.62	74.00	54.00	31.69	19.38
7207.415	H	1.00	43.85	32.64	43.82	1.09	36.39	9.17	46.68	35.47	74.00	54.00	27.32	18.53
7207.415	V	1.00	44.44	33.05	43.82	1.09	36.39	9.17	47.27	35.88	74.00	54.00	26.73	18.12

(Operated from DC 24 V, for Z-axis)

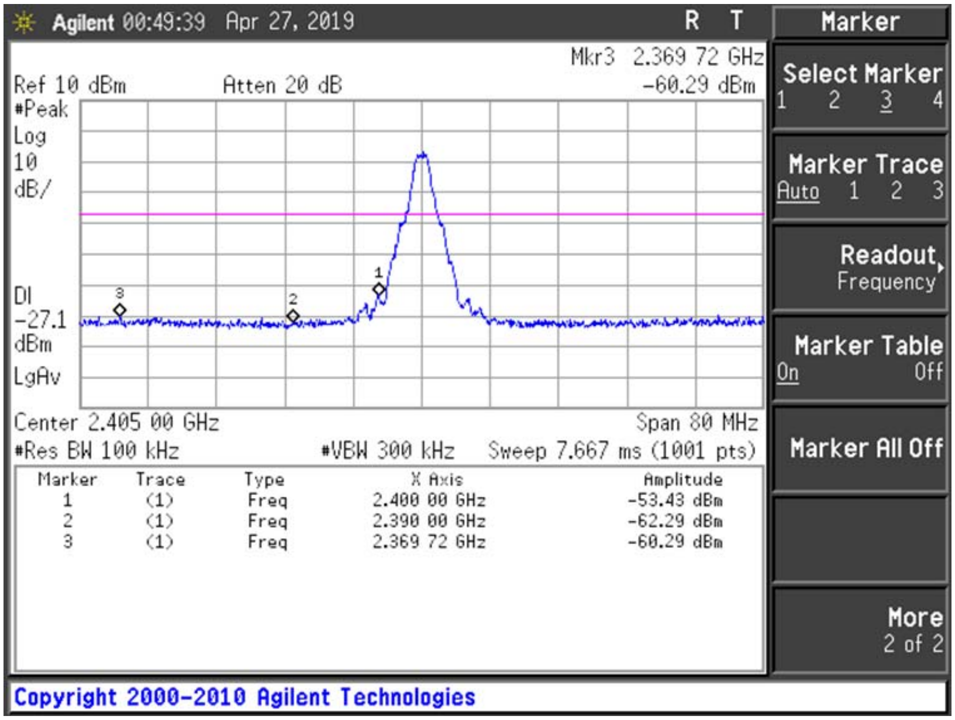
Frequency (MHz)	Pol. (V/H)	Height (m)	Reading (dBμV)		AMP (dB)	ATT (dB)	AF (dB/m)	CL (dB)	Actual (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			PK	AV					PK	AV	PK	AV	PK	AV
4811.623	H	1.00	48.62	41.68	44.42	1.19	31.16	6.90	43.45	36.51	74.00	54.00	30.55	17.49
4811.623	V	1.00	43.89	30.22	44.42	1.19	31.16	6.90	38.72	25.05	74.00	54.00	35.28	28.95
7207.415	H	2.00	41.99	31.50	43.82	1.09	36.39	9.17	44.82	34.33	74.00	54.00	29.18	19.67
7207.415	V	2.00	40.43	27.67	43.82	1.09	36.39	9.17	43.26	30.50	74.00	54.00	30.74	23.50

V/H: Vertical / Horizontal polarization
AMP, AF, CL and ATT: pre-amplifier gain, antenna factor, cable loss and attenuator/filter loss if used
Actual = Reading - AMP + ATT + AF + CL
Margin = Limit - Actual

Figure 3. Plot of the Band Edge (Conducted)

During the measurements, the insertion loss of the cable loss and the external attenuator (10 dB) was corrected in the spectrum analyzer

(Operated from DC 12 V)



(Operated from DC 24 V)

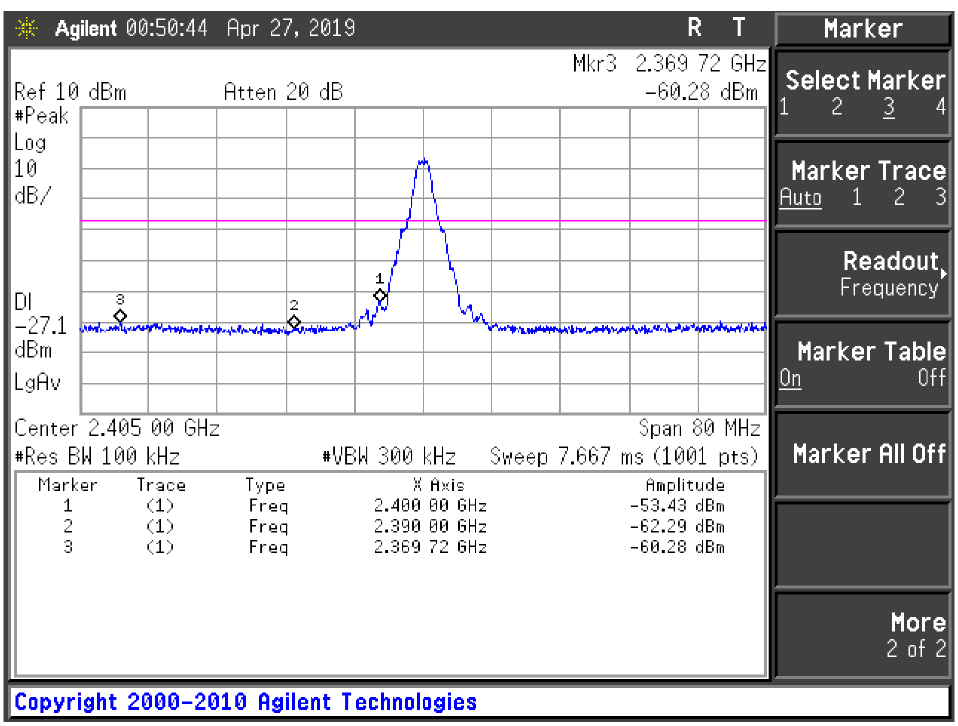
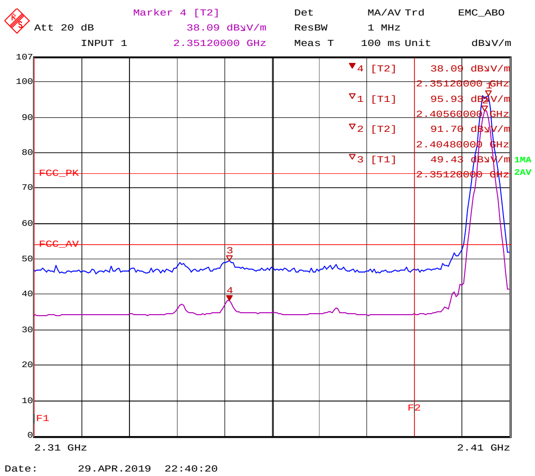
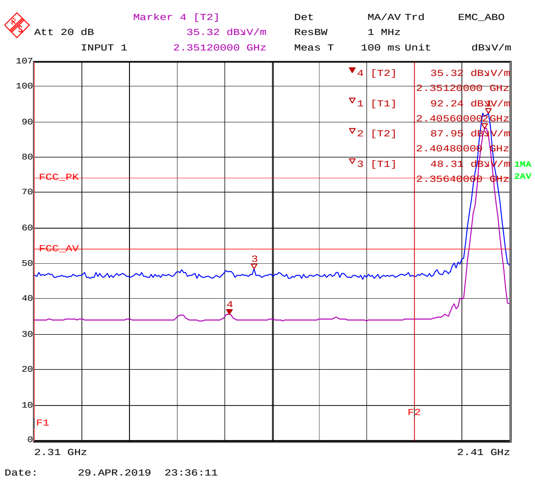


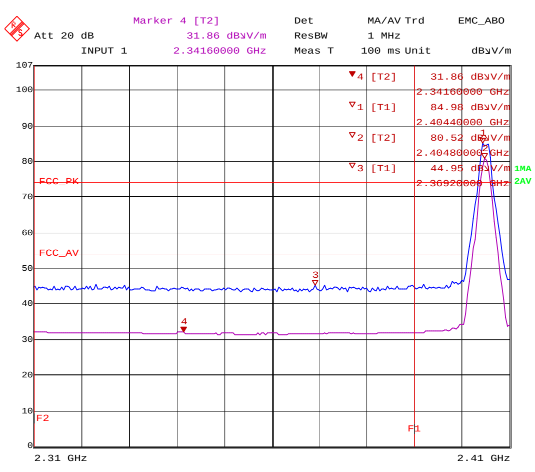
Figure 4. Plot of the Band Edge (Radiated)

(Operated from DC 12 V)

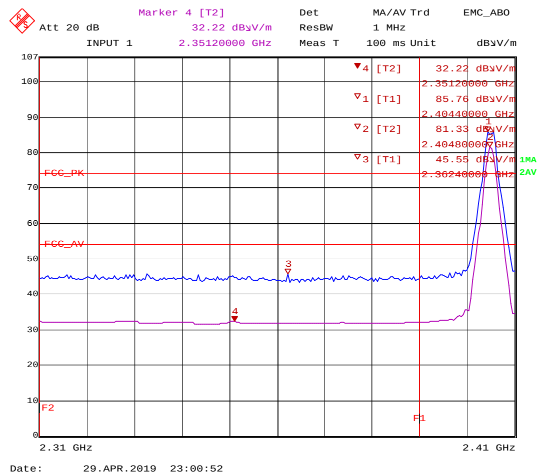
Horizontal (X, Y and Z-axis)

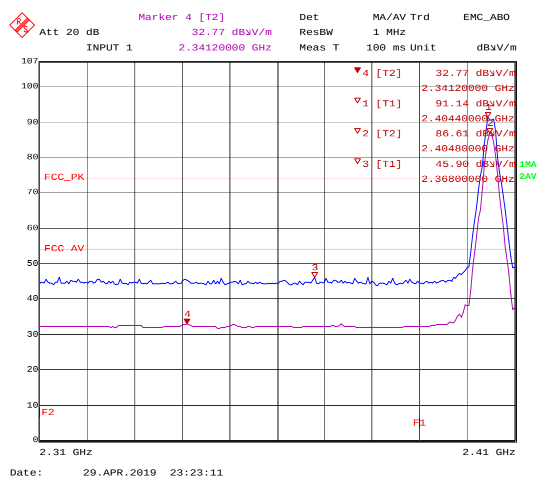


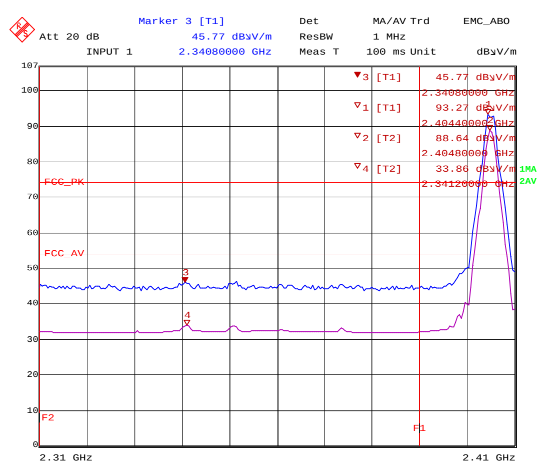




Vertical (X, Y and Z-axis)

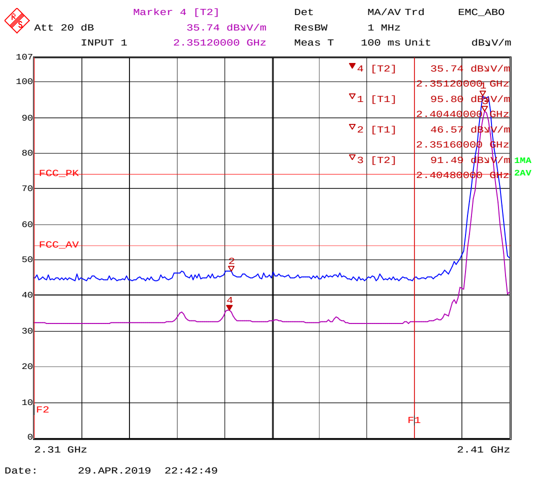


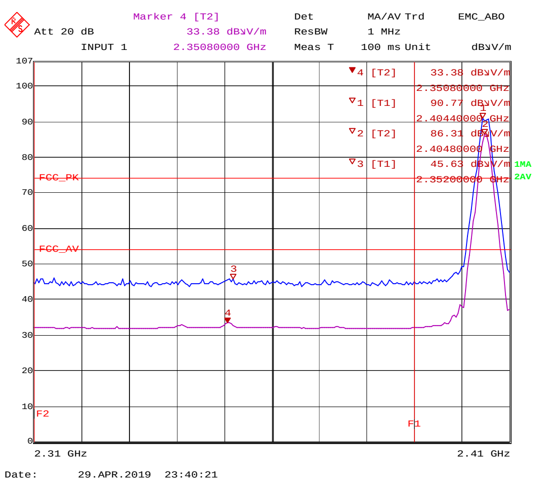


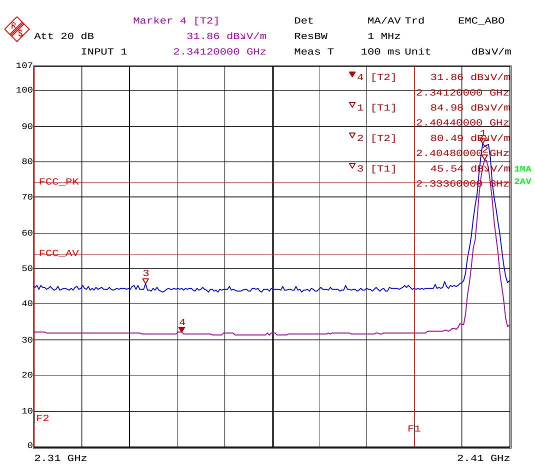


(Operated from DC 24 V)

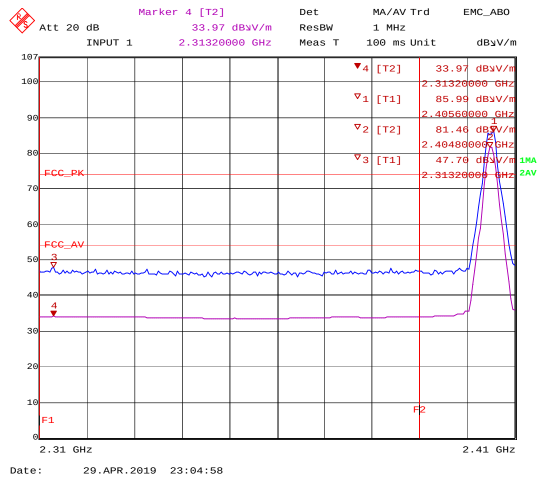
Horizontal (X, Y and Z-axis)

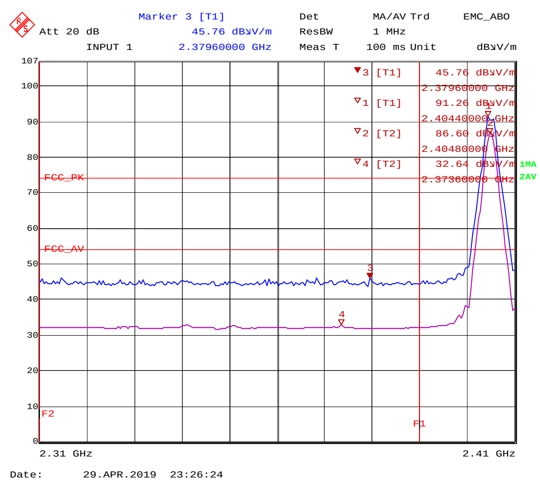






Vertical (X, Y and Z-axis)





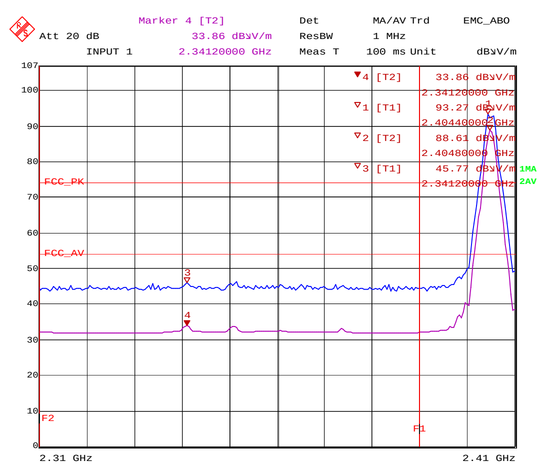
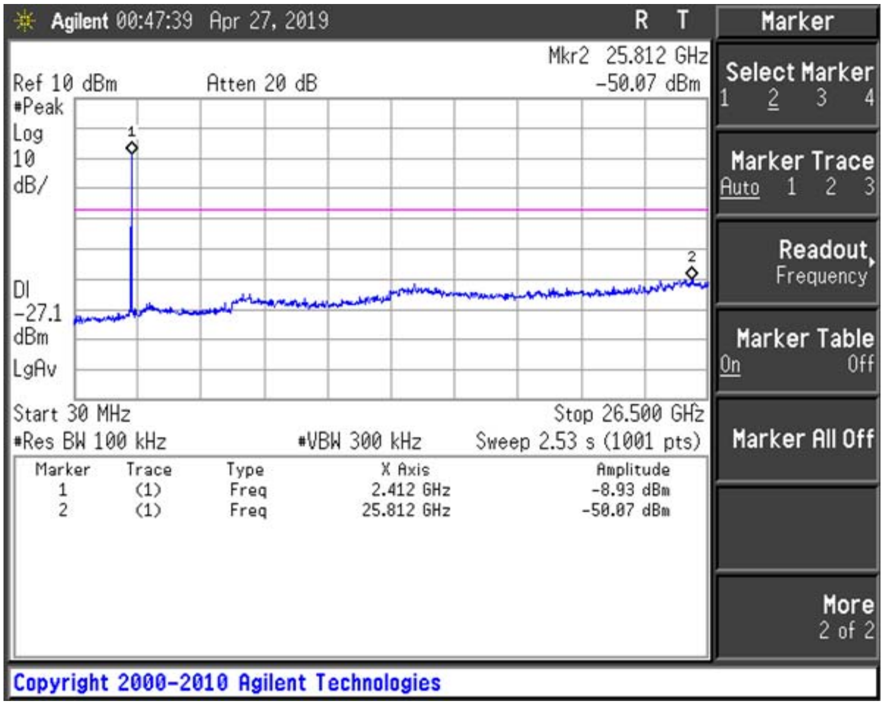


Figure 5. Spurious RF conducted emissions

During the measurements, the insertion loss of the cable loss and the external attenuator (10 dB) was corrected in the spectrum analyzer.

The DL line on the plot was used as the limit (20 dB below the highest level of the desired power in the 100 kHz bandwidth (100 kHz bandwidth PSD in Figure 7 on the page 33).

(Operated from DC 12 V)



(Operated from DC 24 V)

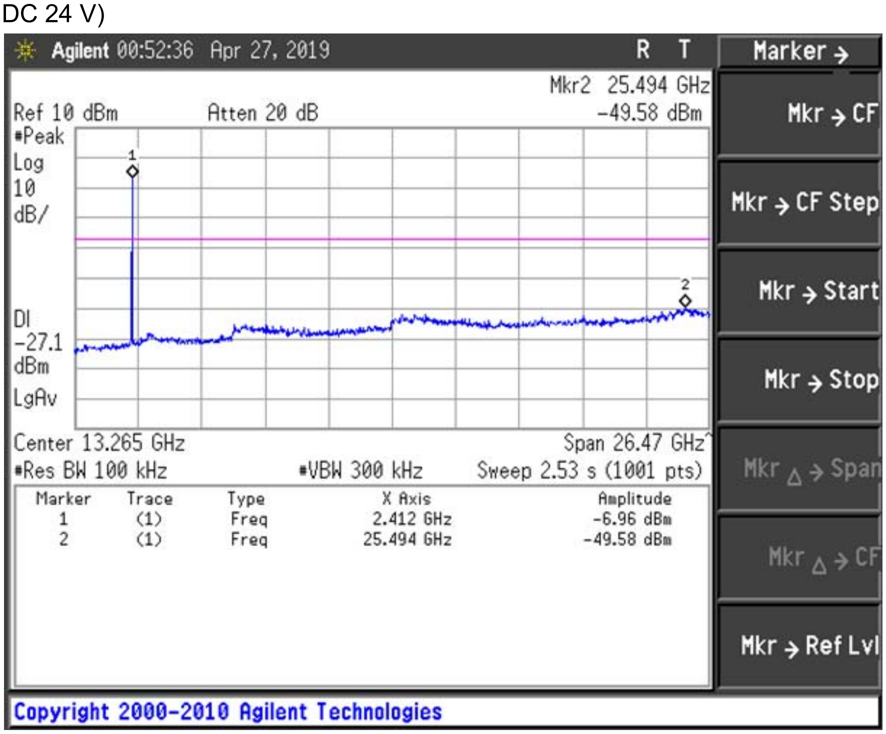
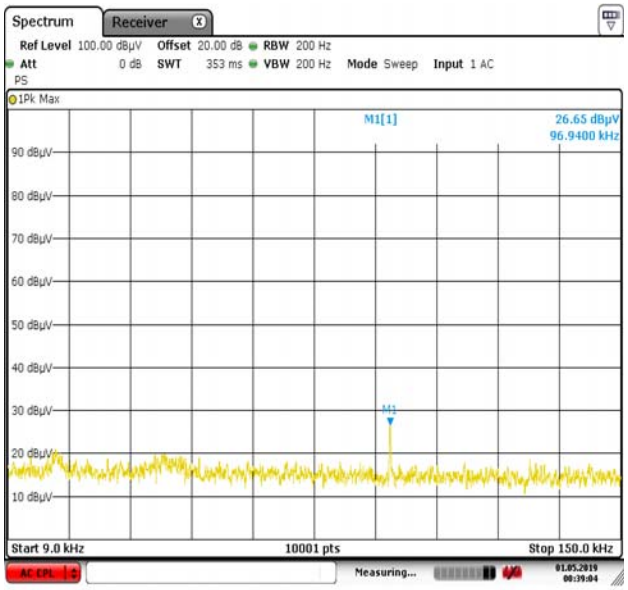


Figure 6. Emission plot for the preliminary radiated measurements

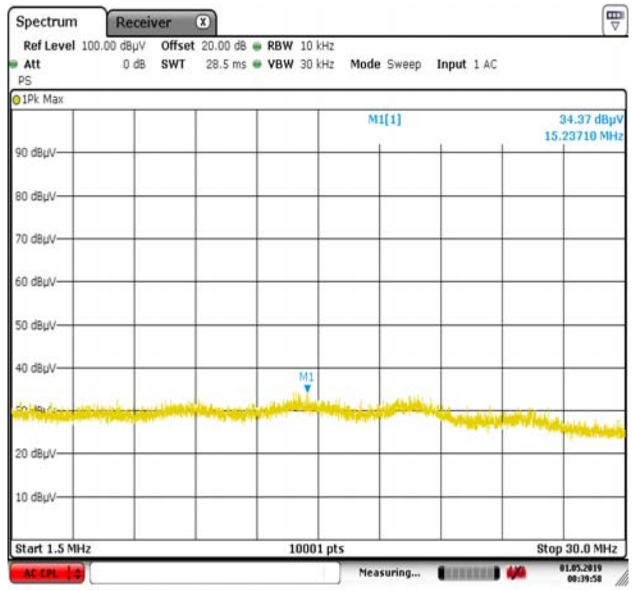
The worst-case plots were attached

(Operated from DC 12 V)

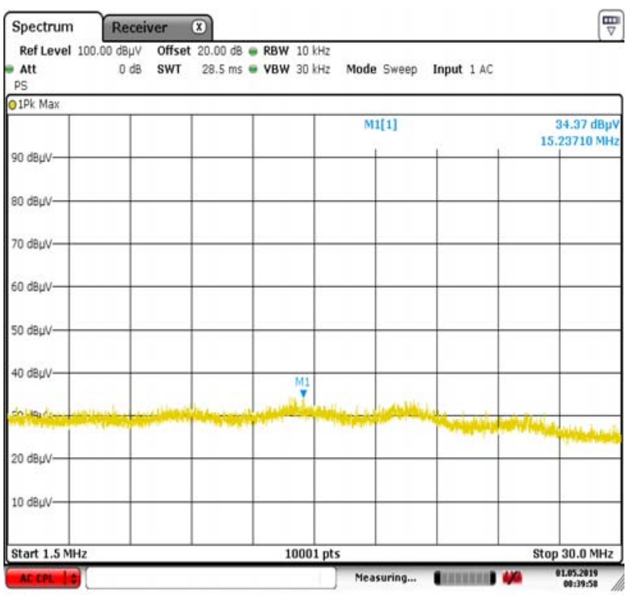
Frequency Range: 9 kHz ~ 150 kHz



Frequency Range: 150 kHz ~ 1.5 MHz



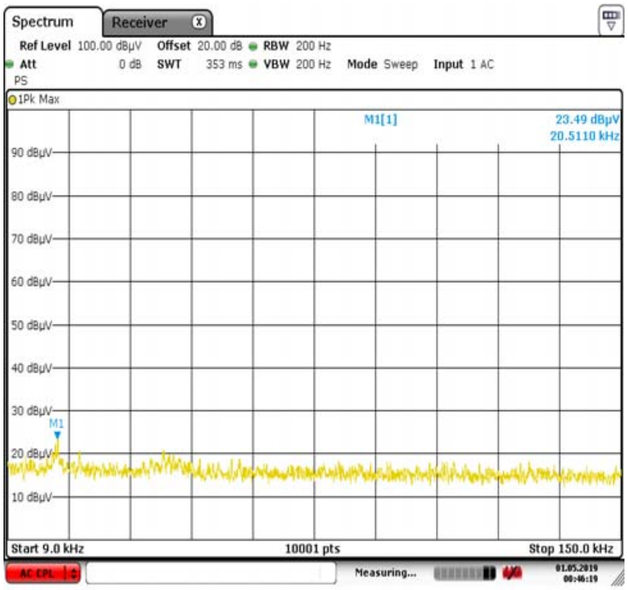
Frequency Range: 1.5 MHz ~ 30 MHz



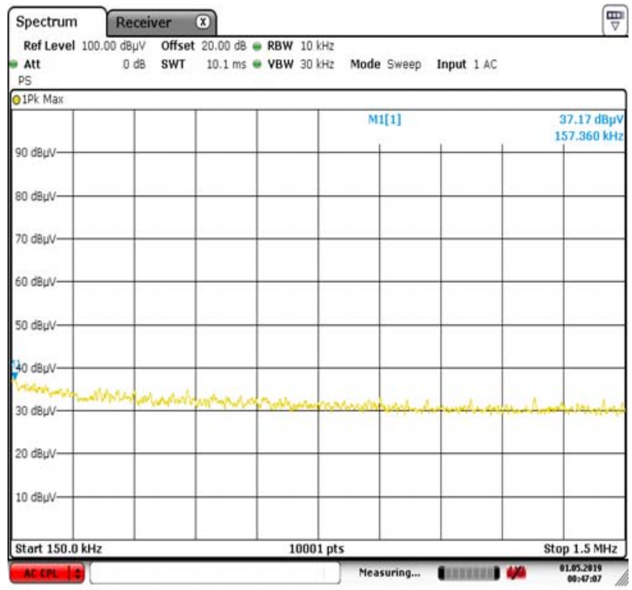
Remark: during the measurements, the correction factor (antenna factor and cable loss) was compensated as Offset 20 dB.
Therefore the plots represented the measured results of the field strength in spite of the unit dBµV.

(Operated from DC 24 V)

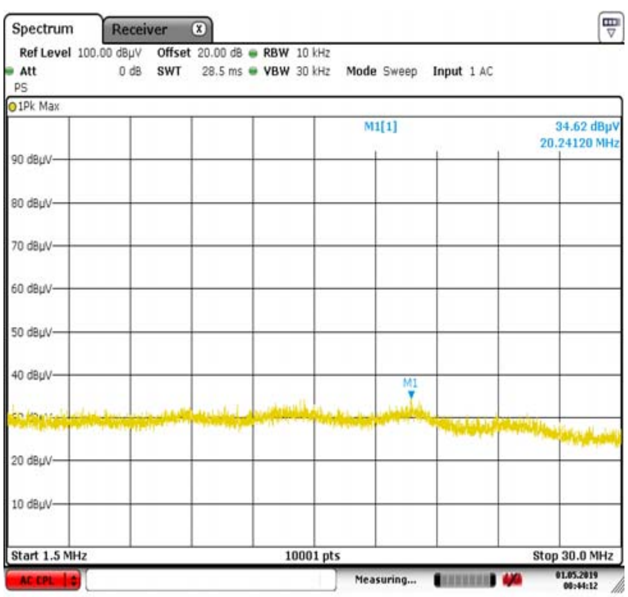
Frequency Range: 9 kHz ~ 150 kHz



Frequency Range: 150 kHz ~ 1.5 MHz



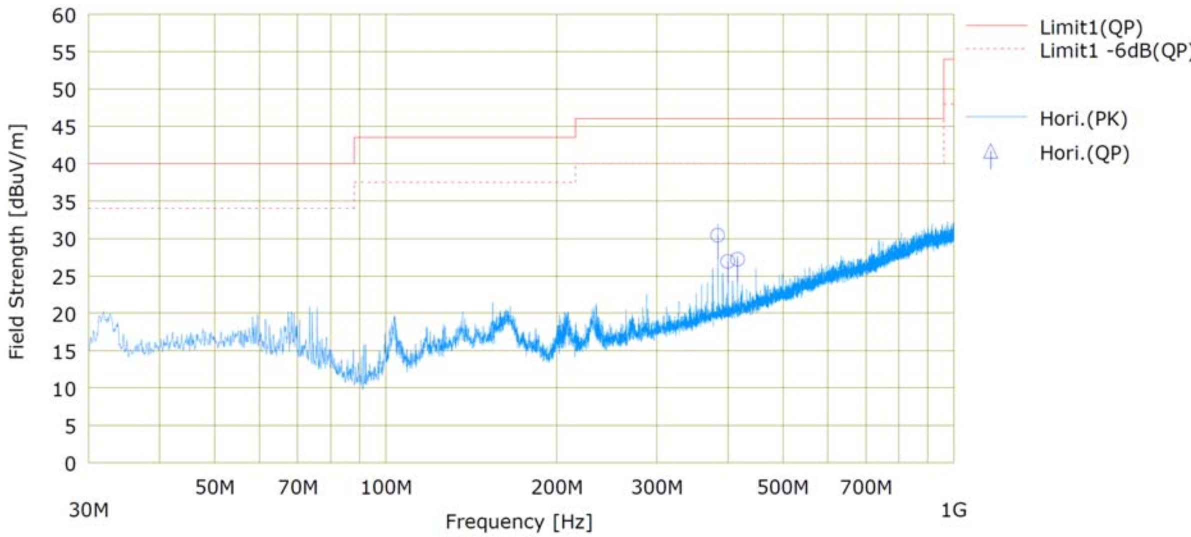
Frequency Range: 1.5 MHz ~ 30 MHz

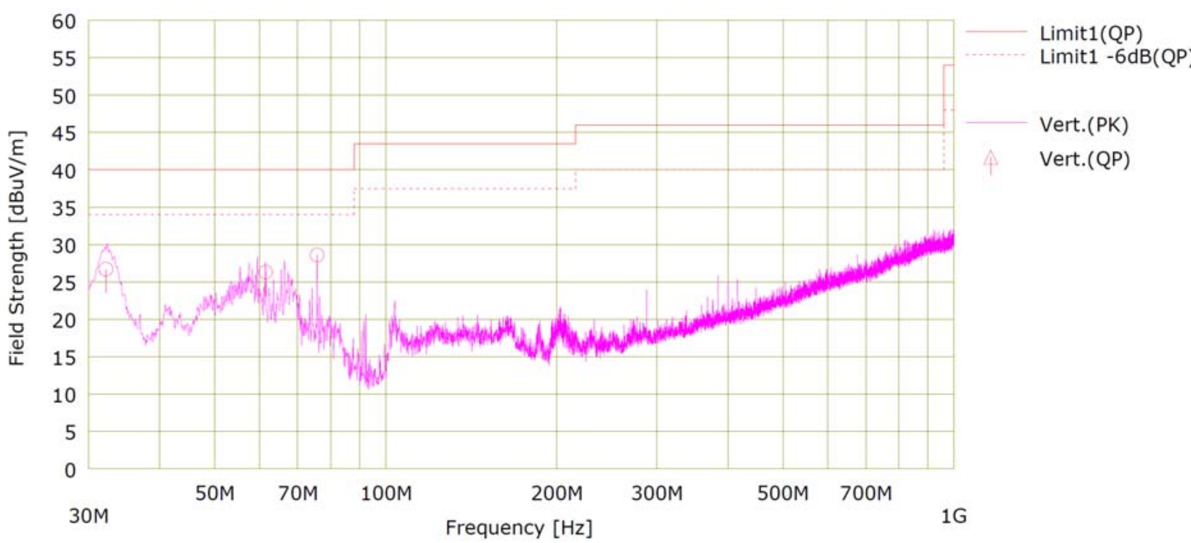


Remark: during the measurements, the correction factor (antenna factor and cable loss) was compensated as Offset 20 dB.
Therefore the plots represented the measured results of the field strength in spite of the unit dBµV.

Frequency Range: 30 MHz ~ 1 GHz

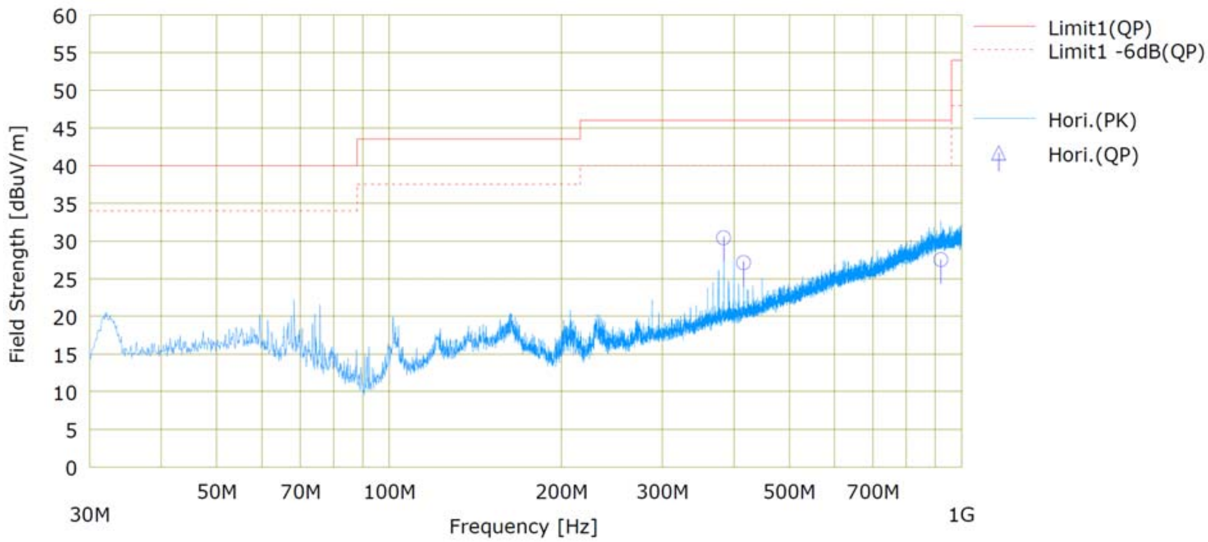
(Operated from DC 12 V)

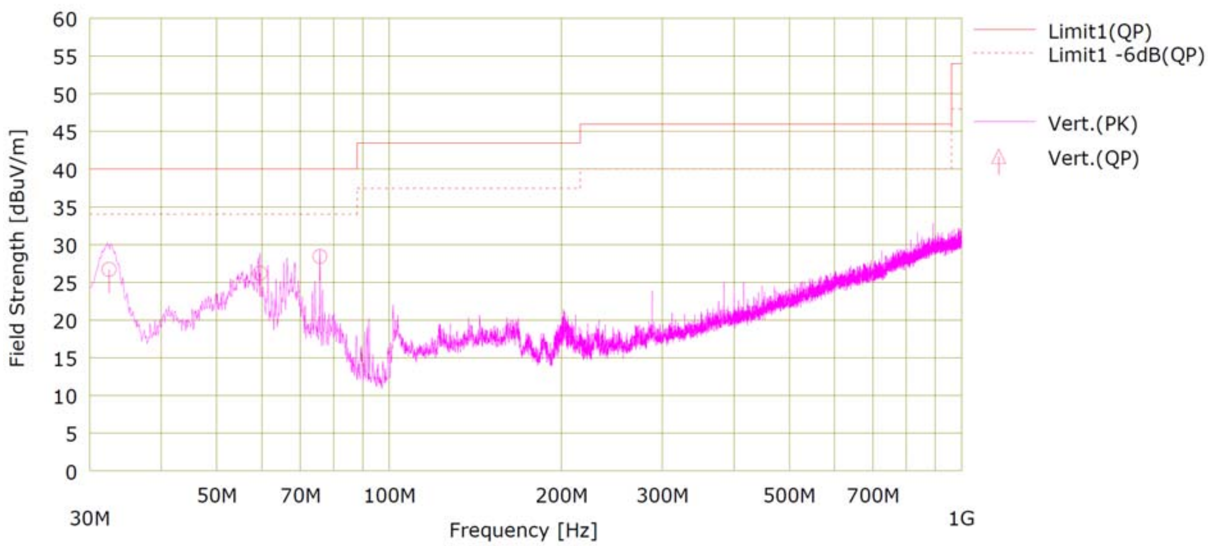




Frequency Range: 30 MHz ~ 1 GHz

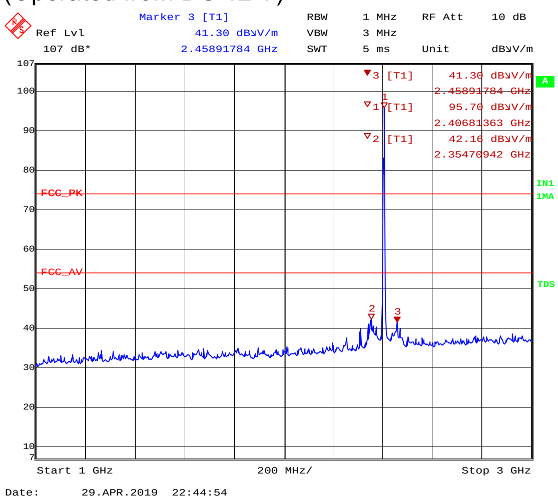
(Operated from DC 24 V)

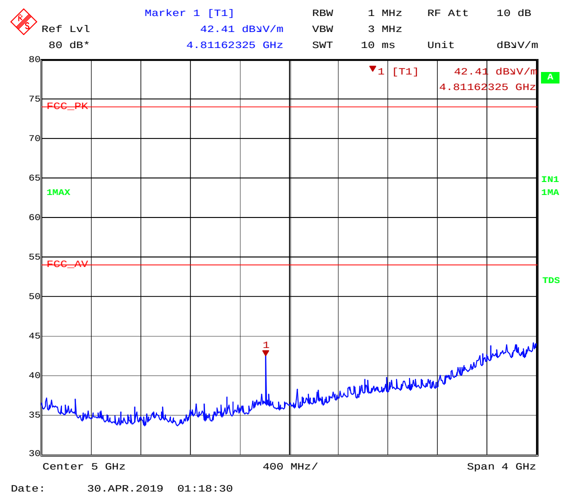


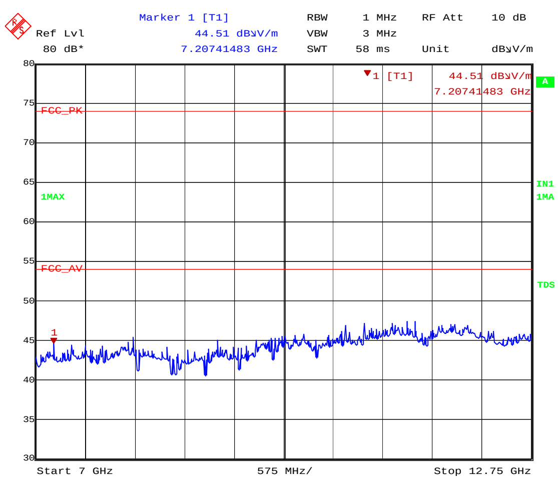


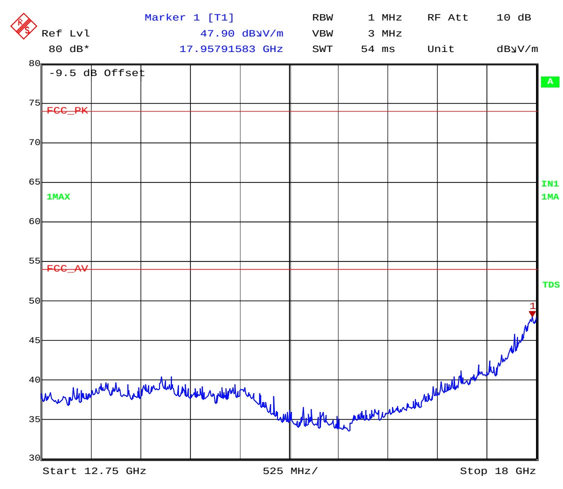
Frequency above 1 GHz

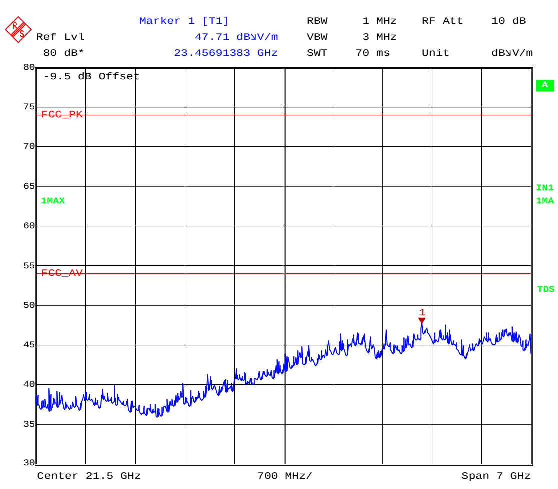
(Operated from DC 12 V)



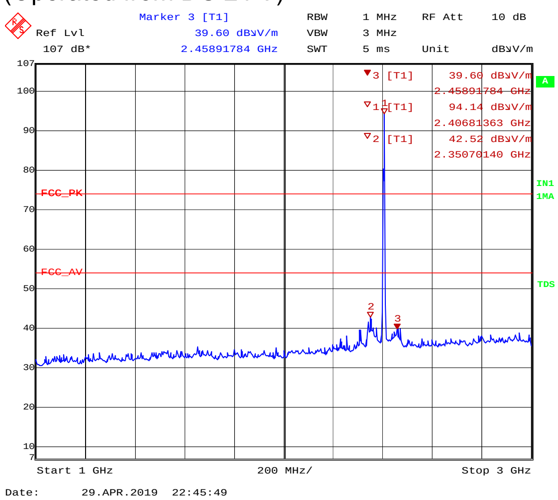


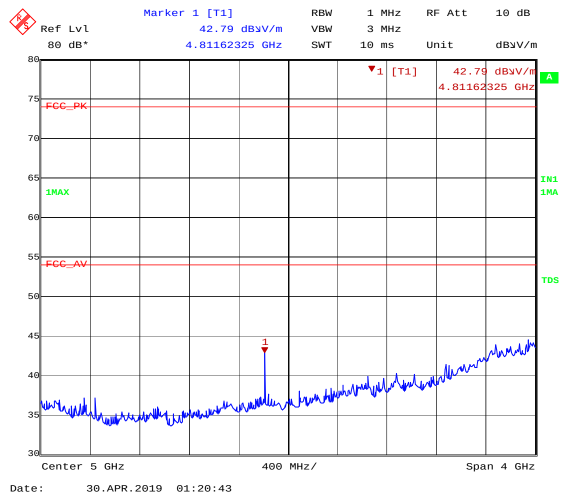


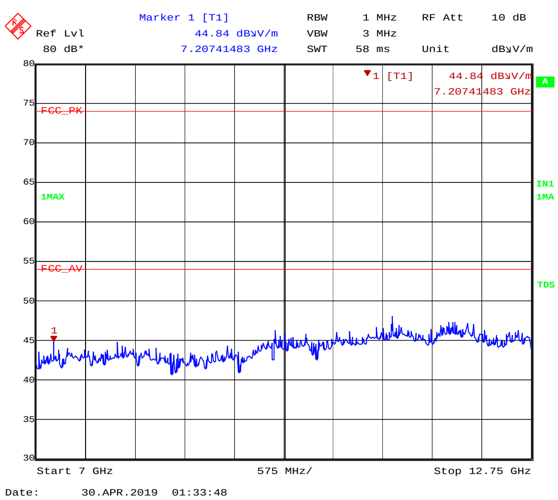


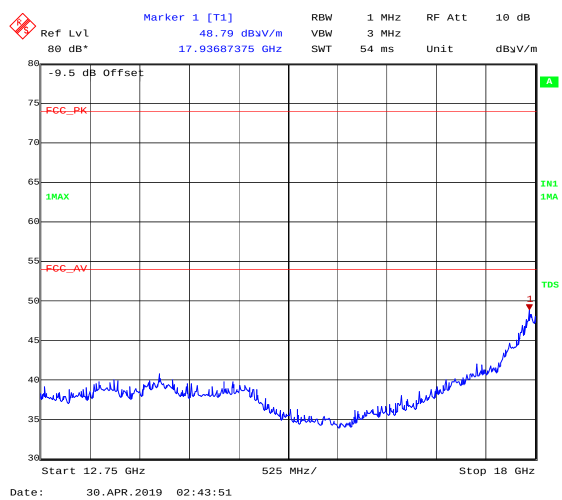


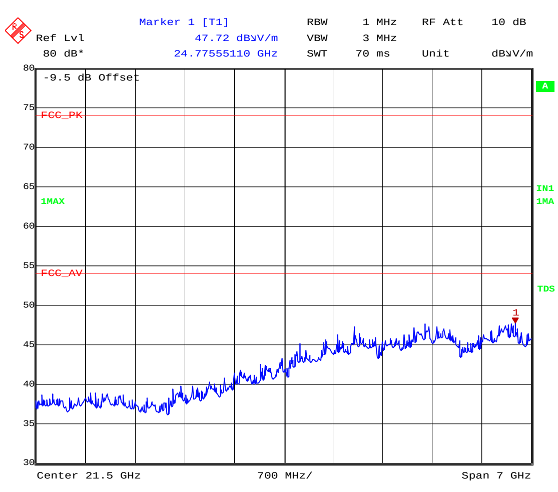
(Operated from DC 24 V)











5.5. Peak power spectral density

5.5.1 Regulation

According to §15.247(e), for digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

5.5.2 Test Procedure(peak PSD)

5.5.1 Regulation

According to §15.247(e), for digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

5.5.2 Test Procedure(peak PSD)

Set the spectrum analyzer as follows:

1. Set analyzer center frequency to DTS channel center frequency.
2. Set the span to 1.5 x DTS bandwidth.
3. Set the RBW to: 3 kHz ≤ RBW ≤ 100 kHz.
4. Set the VBW ≥ 3 x RBW.
5. Detector = peak.
6. Sweep time = auto couple.
7. Trace mode = max hold.
8. Allow trace to fully stabilize.
9. Use the peak marker function to determine the maximum amplitude level within the RBW.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

5.5.3 Test Results: PASS

Table 6: Measured values of the Peak Power Spectral Density

(Operated from DC 12 V)

Modulation	Operating frequency	PSD/3 kHz (dBm)	Limit (dBm)
OQPSK	2405 MHz	-18.97	8

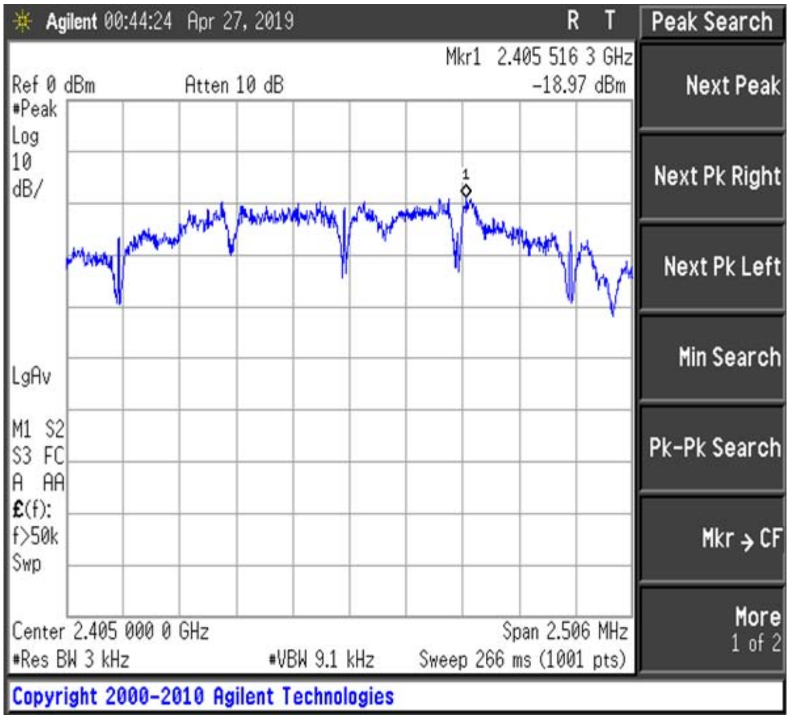
(Operated from DC 24 V)

Modulation	Operating frequency	PSD/3 kHz (dBm)	Limit (dBm)
OQPSK	2405 MHz	-18.10	8

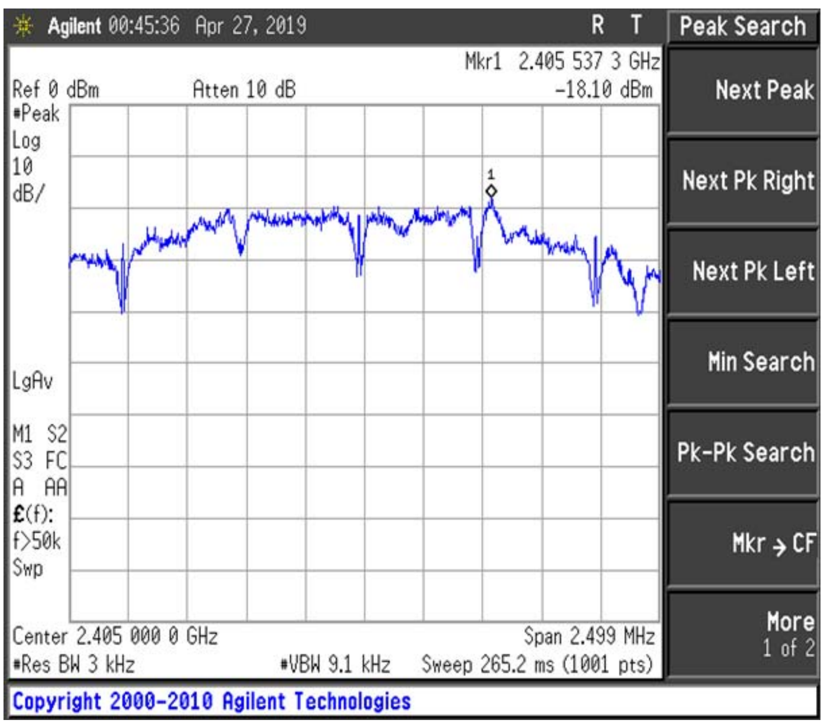
Figure 7. Plot of the Peak Power Spectral Density

During the measurements, the insertion loss of the cable loss and the external attenuator (10 dB) was corrected in the spectrum analyzer.

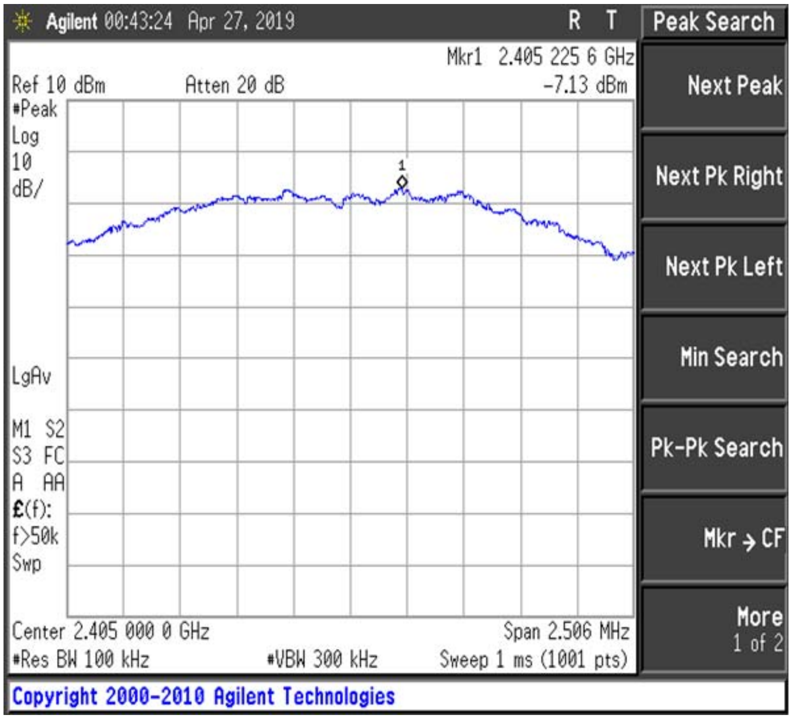
(Operated from DC 12 V; 3 kHz bandwidth)



(Operated from DC 24 V; 3 kHz bandwidth)



(Operated from DC 12 V; 100 kHz bandwidth)



(Operated from DC 24 V; 100 kHz bandwidth)