

RADIO TEST REPORT – 474474-3TRFWL

Type of assessment:

Final product testing

Applicant:

Favero Electronics Srl

Via R. Lombardi, 64 – 31030 Arcade (TV) – Italy

Product:

Sensor

Model:

F-PM2

FCC ID:

2ATKD-FPM2

Specifications:

- ◆ FCC 47 CFR Part 15 Subpart C, §15.247

Date of issue: October 3, 2022

P. Barbieri

Tested by



Signature

D. Guarnone

Reviewed by



Signature

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Limits of responsibility

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Section 1 Report summary

1.1 Test specifications

FCC 47 CFR Part 15, Subpart C, Clause 15.247	Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–585 MHz
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1.2 Test methods

558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019)	Guidance for compliance measurements on digital transmission system, frequency hopping spread spectrum system, and hybrid system devices operating under section 15.247 of the FCC rules.
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.3 Exclusions

None

1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard except as noted in section 1.3 above. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

See “Summary of test results” for full details.

1.5 Test report revision history

Table 1.5-1: Test report revision history

Revision #	Date of issue	Details of changes made to test report
474474-3TRFWL	October 3, 2022	Original report issued

Section 2 Engineering considerations

2.1 Modifications incorporated in the EUT for compliance

There were no modifications performed to the EUT during this assessment.

2.2 Technical judgment

None

2.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 3 Test conditions

3.1 Atmospheric conditions

Temperature	15 °C – 35 °C
Relative humidity	20 % – 75 %
Air pressure	86 kPa (860 mbar) – 106 kPa (1060 mbar)

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

The following instruments are used to monitor the environmental conditions:

Equipment	Manufacturer	Model no.	Asset no.	Cal date	Next cal.
Thermo-hygrometer data loggers	Testo	175-H2	20012380/305	2020-12	2022-12
Thermo-hygrometer data loggers	Testo	175-H2	38203337/703	2020-12	2022-12
Barometer	Castle	GPB 3300	072015	2022-04	2023-04

3.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages $\pm 5\%$, for which the equipment was designed.

Section 4 Measurement uncertainty

4.1 Uncertainty of measurement

The measurement uncertainty was calculated for each test and quantity listed in this test report, according to CISPR 16-4-2 and other specific test standard and is documented in Nemko Spa working manual WML1002.

The assessment of conformity for each test performed on the equipment is performed not taking into account the measurement uncertainty. The two following possible verdicts are stated in the report:

P (Pass) - The measured values of the equipment respect the specification limit at the points tested. The specific risk of false accept is up to 50% when the measured result is close to the limit.

F (Fail) - One or more measured values of the equipment do not respect the specification limit at the points tested. The specific risk of false reject is up to 50% when the measured result is close to the limit.

Hereafter Nemko's measurement uncertainties are reported:

EUT	Type	Test	Range	Measurement Uncertainty	Notes
Transmitter	Conducted	Frequency error	0.001 MHz ÷ 40 GHz	0.08 ppm	(1)
		Carrier power RF Output Power	0.009 MHz ÷ 30 MHz	1.1 dB	(1)
			30 MHz ÷ 18 GHz	1.5 dB	(1)
			18 MHz ÷ 40 GHz	3.0 dB	(1)
			40 MHz ÷ 140 GHz	5.0 dB	(1)
		Adjacent channel power	1 MHz ÷ 18 GHz	1.4 dB	(1)
		Conducted spurious emissions	0.009 MHz ÷ 18 GHz	3.0 dB	(1)
			18 GHz ÷ 40 GHz	4.2 dB	(1)
			40 GHz ÷ 220 GHz	6.0 dB	(1)
		Intermodulation attenuation	1 MHz ÷ 18 GHz	2.2 dB	(1)
		Attack time – frequency behaviour	1 MHz ÷ 18 GHz	2.0 ms	(1)
		Attack time – power behaviour	1 MHz ÷ 18 GHz	2.5 ms	(1)
		Release time – frequency behaviour	1 MHz ÷ 18 GHz	2.0 ms	(1)
		Release time – power behaviour	1 MHz ÷ 18 GHz	2.5 ms	(1)
		Transient behaviour of the transmitter– Transient frequency behaviour	1 MHz ÷ 18 GHz	0.2 kHz	(1)
		Transient behaviour of the transmitter – Power level slope	1 MHz ÷ 18 GHz	9%	(1)
		Frequency deviation - Maximum permissible frequency deviation	0.001 MHz ÷ 18 GHz	1.3%	(1)
		Frequency deviation - Response of the transmitter to modulation frequencies above 3 kHz	0.001 MHz ÷ 18 GHz	0.5 dB	(1)
		Dwell time	-	3%	(1)
		Hopping Frequency Separation	0.01 MHz ÷ 18 GHz	1%	(1)
	Occupied Channel Bandwidth	0.01 MHz ÷ 18 GHz	2%	(1)	
	Modulation Bandwidth	0.01 MHz ÷ 18 GHz	2%	(1)	
	Radiated	Radiated spurious emissions	0.009 MHz ÷ 26.5 GHz	6.0 dB	(1)
26.5 GHz ÷ 66 GHz			8.0 dB	(1)	
66 GHz ÷ 220 GHz			10 dB	(1)	
Effective radiated power transmitter		10 kHz ÷ 26.5 GHz	6.0 dB	(1)	
		26.5 GHz ÷ 66 GHz	8.0 dB	(1)	
		66 GHz ÷ 220 GHz	10 dB	(1)	

NOTES:

(1) The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95 %

Section 5 Information provided by the applicant

5.1 Disclaimer

This section contains information provided by the applicant and has been utilized to support the test plan. Inaccurate information provided by the applicant can affect the validity of the results contained within this test report. Nemko accepts no responsibility for the information contained within this section and the impact it may have on the test plan and resulting measurements.

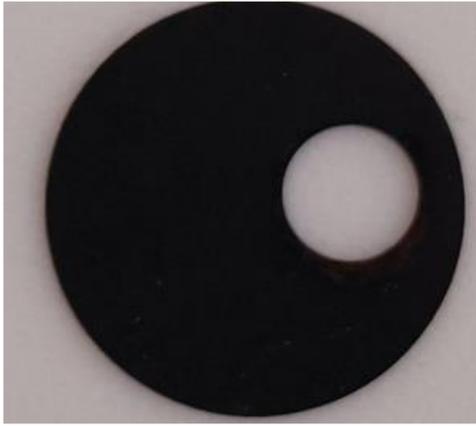
5.2 Applicant/Manufacture

Applicant name	Favero Electronics Srl
Applicant address	Via R. Lombardi, 64 – 31030 Arcade (TV) – Italy
Manufacture name	Same as applicant
Manufacture address	Same as applicant

5.3 EUT information

Product	Sensor
Model	F-PM2
Model variant(s)	--
Serial number	EUT with integrated antenna: 4744740002 (Number assigned by Nemko Spa) EUT with temporary antenna connector: 4744740003 (Number assigned by Nemko Spa)
Power supply requirements	3.7 V DC from internal Lithium battery 5 V DC from USB line (recharging)
Product description and theory of operation	The EUT is an electronic sensor that can be used to make a power meter for cycling. The sensor contains an electronic board with a Nordic Semiconductor nRF52840 transceiver integrated circuit, to which a custom antenna made with a circular flexible circuit is connected.

5.4 Radio technical information

Category of Wideband Data Transmission equipment	<input type="checkbox"/> Frequency Hopping Spread Spectrum (FHSS) equipment <input checked="" type="checkbox"/> Other types of Wideband Data Transmission equipment (e.g. DSSS, OFDM, etc.).
Frequency band	2400–2483.5 MHz
Frequency Min (MHz)	2402 MHz
Frequency Max (MHz)	2480 MHz
Channel numbers	39
RF power Max (dBm), Conducted	6.3
Field strength, dB μ V/m @ 3 m	--
Measured BW (kHz), 99% OBW	1063.8 kHz
Type of modulation	BLE (GFSK)
Emission classification	F1D, W7D
Transmitter spurious, dB μ V/m @ 3 m	48.5 dB μ V/m Average
Antenna information	Custom antenna (flexible PCB diskette with unknown gain) 

5.5 EUT setup details

5.5.1 Radio exercise details

Operating conditions	<p>The EUT has been tested in continuous transmission mode with the following software.</p>
Transmitter state	<p>The power level has been set to 5 according to applicant's request.</p> <p>Transmitter set into continuous mode.</p>

5.5.2 EUT setup configuration

Table 5.5-1: EUT sub assemblies

Description	Brand name	Model, Part number, Serial number, Revision level
--	--	--
The EUT is composed by a single unit		

Table 5.5-2: EUT interface ports

Description	Qty.
None	--
The EUT is supplied by internal battery with two recharging pins used only for recharge the battery	

Table 5.5-3: Support equipment

Description	Brand name	Model, Part number, Serial number, Revision level
Notebook	Dell	Latitude 7480

Table 5.5-4: Inter-connection cables

Cable description	From	To	Length (m)
Temporary antenna connector	EUT	Spectrum analyzer	0.15

The EUT has been modified with a temporary antenna connector. The following cable is not normally connected

EUT setup configuration, continued

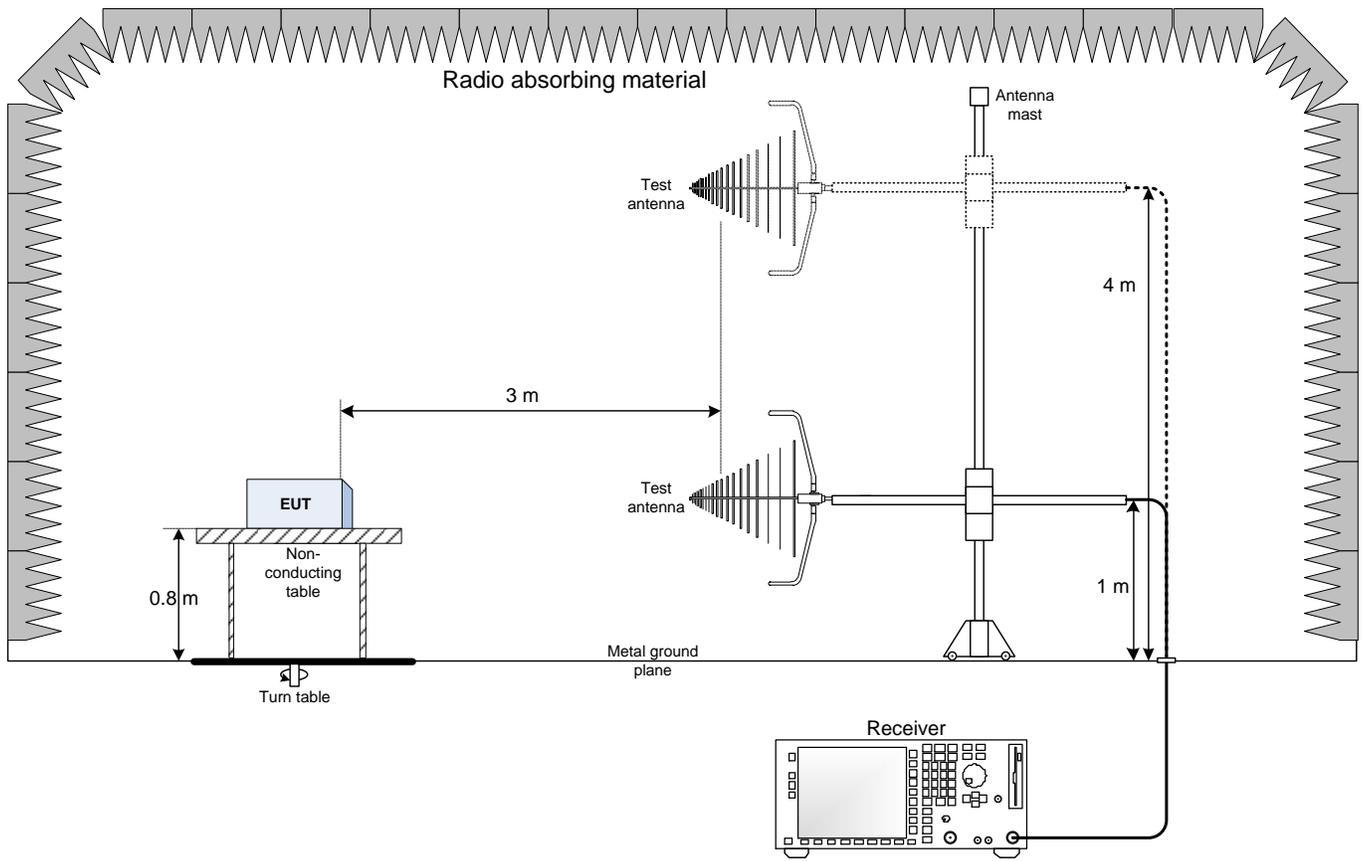


Figure 5.5-1: Radiated testing below 1 GHz block diagram

EUT setup configuration, continued

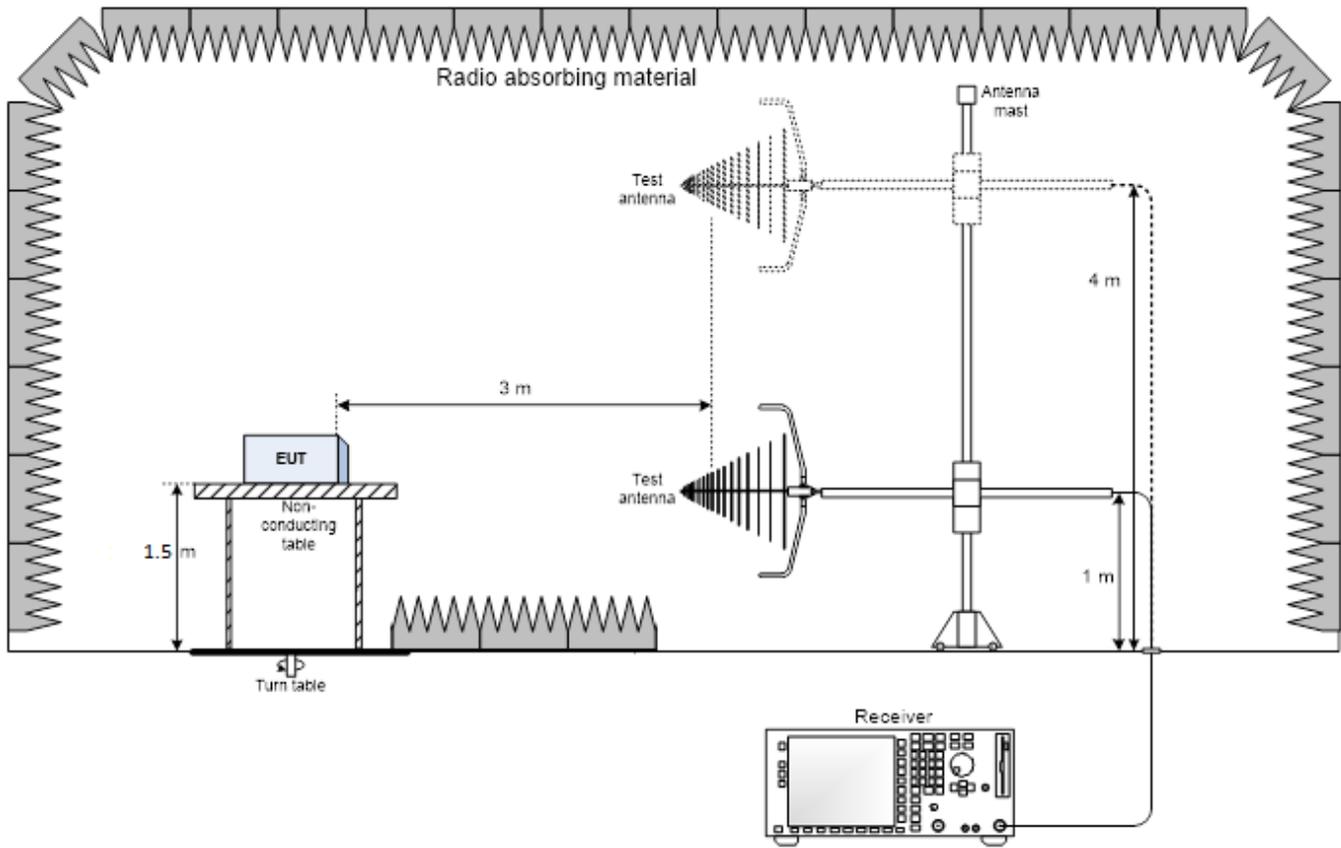


Figure 5.5-2: Radiated testing above 1 GHz block diagram

Section 6 Summary of test results

6.1 Testing location

Test location (s) Nemko Spa

6.2 Testing period

Test start date September 22, 2022 Test end date October 3, 2022

6.3 Sample information

Receipt date August 8, 2022 Nemko sample ID number(s) 474474

6.4 FCC Part 15 Subpart A and C, general requirements test results

Table 6.4-1: FCC general requirements results

Part	Test description	Verdict
§15.207(a)	Conducted limits	Not applicable
§15.31l	Variation of power source	Pass
§15.31(m)	Number of tested frequencies	Pass
§15.203	Antenna requirement	Pass

Notes: EUT is a battery operated device, the testing was performed using full charged battery.

6.5 FCC Part §15.247 test results for frequency hopping spread spectrum systems (FHSS)

Table 6.5-1: FCC FHSS requirements results

Part	Test description	Verdict
§15.247(a)(1)(i)	Requirements for operation in the 902–928 MHz band	Not applicable
§15.247(a)(1)(ii)	Requirements for operation in the 5725–5850 MHz band	Not applicable
§15.247(a)(1)(iii)	Requirements for operation in the 2400–2483.5 MHz band	Not applicable
§15.247(b)(1)	Maximum peak output power in the 2400–2483.5 MHz band and 5725–5850 MHz band	Not applicable
§15.247(b)(2)	Maximum peak output power in the 902–928 MHz band	Not applicable
§15.247(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247(2)	Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams	Not applicable
§15.247(d)	Spurious emissions	Not applicable
§15.247(f)	Time of occupancy for hybrid systems	Not applicable
§15.247(i)	Radiofrequency radiation exposure evaluation	Not applicable

Notes: --

6.6 FCC Part §15.247 test results for digital transmission systems (DTS)

Table 6.6-1: FCC DTS requirements results

Part	Test description	Verdict
§15.247(a)(2)	Minimum 6 dB bandwidth	Pass
§15.247(b)(3)	Maximum peak output power in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands	Pass
§15.247(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247(2)	Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams	Not applicable
§15.247(d)	Spurious emissions	Pass
§15.247	Power spectral density	Pass
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

Notes: --

Section 7 Test equipment

7.1 Test equipment list

Table 7.1-1: Equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Spectrum Analyzer	Rohde & Schwarz	FSW43	101767	2021-12	2022-12
EMI Receiver	Rohde & Schwarz	ESW44	101620	2022-08	2023-08
Antenna Trilog 25MHz - 8GHz	Schwarzbeck Mess-Elektronik	VULB9162	9162-025	2021-07	2024-07
Antenna 1 - 18 GHz	Schwarzbeck Mess-Elektronik	STLP9148	STLP 9148-152	2021-09	2024-09
Double Ridge Horn Antenna	RFSpin	DRH40	061106A40	2020-04	2023-04
Broadband Amplifier	Schwarzbeck Mess-Elektronik	BBV9718C	00121	2022-03	2023-03
Broadband Bench Top Amplifier	Sage	STB-1834034030-KFKF-L1	18490-01	2022-05	2023-05
Controller	Maturo	FCU3.0	10041	NCR	NCR
Tilt antenna mast	Maturo	TAM4.0-E	10042	NCR	NCR
Turntable	Maturo	TT4.0-ST	2.527	NCR	NCR
Semi-anechoic chamber	Nemko S.p.a.	10m semi-anechoic chamber	530	2021-09	2023-09

Notes: NCR - no calibration required, VOI - verify on use

Section 8 Testing data

8.1 Variation of power source

8.1.1 References, definitions and limits

FCC §15.31 (e):

For intentional radiators, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage. For battery operated equipment, the equipment tests shall be performed using a new battery.

8.1.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	September 22, 2022
Sample tested	4744740002		

8.1.3 Observations, settings and special notes

The testing was performed as per ANSI C63.10 Section 5.13.

- Where the device is intended to be powered from an external power adapter, the voltage variations shall be applied to the input of the adapter provided with the device at the time of sale. If the device is not marketed or sold with a specific adapter, then a typical power adapter shall be used.
- For devices, where operating at a supply voltage deviating $\pm 15\%$ from the nominal rated value may cause damages or loss of intended function, test to minimum and maximum allowable voltage per manufacturer's specification and document in the report.
- For devices with wide range of rated supply voltage, test at 15% below the lowest and 15% above the highest declared nominal rated supply voltage.
- For devices obtaining power from an input/output (I/O) port (USB, firewire, etc.), a test jig is necessary to apply voltage variation to the device from a support power supply, while maintaining the functionalities of the device.

For battery-operated equipment, the equipment tests shall be performed using a variable power supply.

8.1.4 Test data

EUT Power requirements:

	<input type="checkbox"/> AC	<input type="checkbox"/> DC	<input checked="" type="checkbox"/> Battery
If EUT is an AC or a DC powered, was the noticeable output power variation observed?	<input type="checkbox"/> YES	<input type="checkbox"/> NO	<input checked="" type="checkbox"/> N/A
If EUT is battery operated, was the testing performed using fresh batteries?	<input type="checkbox"/> YES	<input type="checkbox"/> NO	<input checked="" type="checkbox"/> N/A
If EUT is rechargeable battery operated, was the testing performed using fully charged batteries?	<input checked="" type="checkbox"/> YES	<input type="checkbox"/> NO	<input type="checkbox"/> N/A

8.2 Number of frequencies

8.2.1 References, definitions and limits

FCC §15.31:

- (m) Measurements on intentional radiators or receivers shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table.

Table 8.2-1: Frequency Range of Operation

Frequency range over which the device operates (in each band)	Number of test frequencies required	Location of measurement frequency inside the operating frequency range
1 MHz or less	1	Center (middle of the band)
1–10 MHz	2	1 near high end, 1 near low end
Greater than 10 MHz	3	1 near high end, 1 near center and 1 near low end

Notes: "near" means as close as possible to or at the centre / low end / high end of the frequency range over which the device operates.

8.2.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	September 22, 2022
Sample tested	4744740002		

8.2.3 Observations, settings and special notes

ANSI C63.10, Clause 5.6.2.1:

The number of channels tested can be reduced by measuring the center channel bandwidth first and then applying the following relaxations as appropriate:

- For each operating mode, if the measured channel bandwidth on the middle channel is at least 150% of the minimum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.
- For multiple-input multiple-output (MIMO) systems, if the measured channel bandwidth on testing the middle channel exceeds the minimum permitted bandwidth by more than 50% on one transmit chain, then it is not necessary to repeat testing on the other chains.
- If the measured channel bandwidth on the middle channel is less than 50% of the maximum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.

ANSI C63.10, Clause 5.6.2.2:

For devices with multiple operating modes, measurements on the middle channel can be used to determine the worst-case mode(s). The worst-case modes are as follows:

- Band edge requirements—Measurements on the mode with the widest bandwidth can be used to cover the same channel (center frequency) on modes with narrower bandwidth that have the same or lower output power for each modulation family (e.g., OFDM and direct sequence spread spectrum).
- Spurious emissions—Measure the mode with the highest output power and the mode with the highest output power spectral density for each modulation family (e.g., OFDM and direct sequence spread spectrum).
- In-band PSD—Measurements on the mode with the narrowest bandwidth can be used to cover all modes within the same modulation family of an equal or lower output power provided the result is less than 50% of the limit.

8.2.4 Test data

Table 8.2-2: *Test channels selection*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
2400	2483.5	83.5	2402	2442	2480

8.3 Antenna requirement

8.3.1 References, definitions and limits

FCC §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. This requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

FCC §15.247:

- (b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:
- (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.

8.3.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	September 22, 2022
Sample tested	4744740002		

8.3.3 Observations, settings and special notes

None

8.3.4 Test data

- Must the EUT be professionally installed? YES NO
- Does the EUT have detachable antenna(s)? YES NO
- If detachable, is the antenna connector(s) non-standard? YES NO N/A

Table 8.3-1: Antenna information

Antenna type	Manufacturer	Model number	Average gain	Connector type
Flexible PCB diskette	Custom antenna	Custom antenna	Unknown gain	--

8.4 Minimum 6 dB bandwidth for DTS systems

8.4.1 References, definitions and limits

FCC §15.247:

- (a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:
- (2) Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

8.4.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	October 3, 2022
Sample tested	4744740003		

8.4.3 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.2 with reference to ANSI C63.10 subclause 11.8.
Spectrum analyser settings:

Resolution bandwidth	6 dB BW: 100 kHz; 99% OBW: 1–5% of OBW
Video bandwidth	$\geq 3 \times$ RBW
Frequency span	3 MHz
Detector mode	Peak
Trace mode	Max Hold

8.4.4 Test equipment used

Equipment	Manufacturer	Model no.	Asset no.
Spectrum Analyzer	Rohde & Schwarz	FSW43	101767

8.4.5 Test data

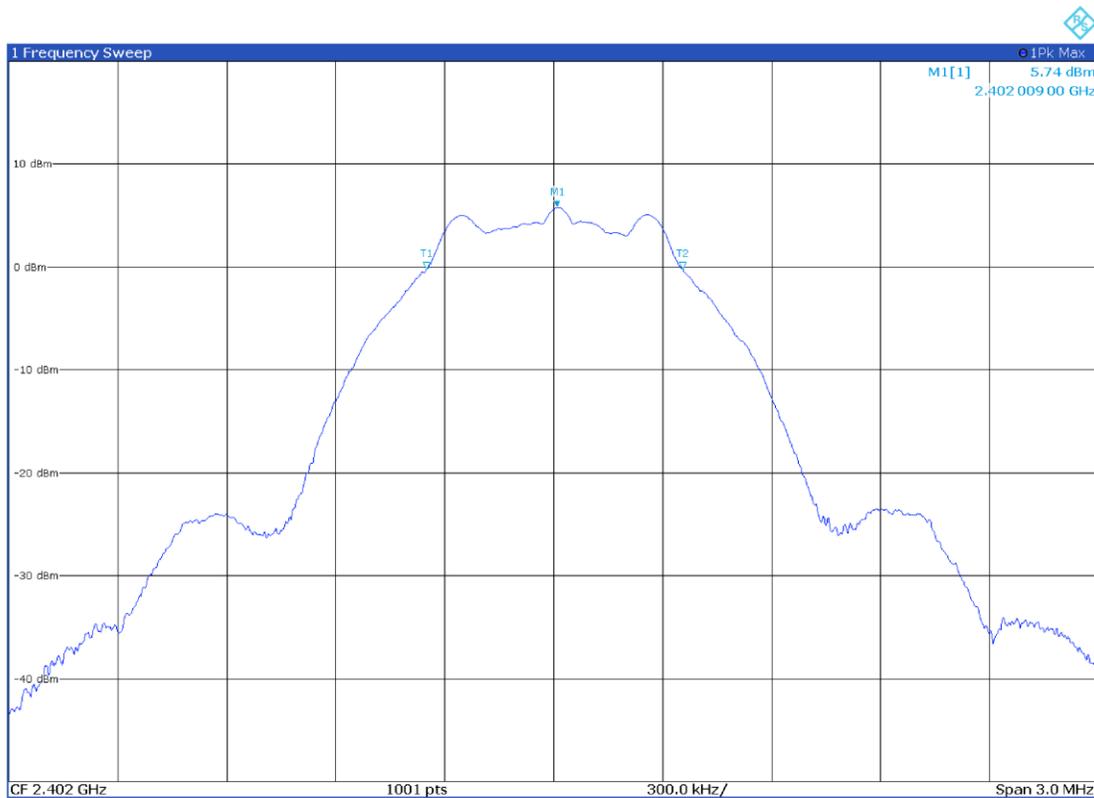
Table 8.4-1: 99% occupied bandwidth results

Modulation	Frequency, MHz	99% occupied bandwidth, kHz
GFSK	2402	1059.2
GFSK	2442	1061.7
GFSK	2480	1063.8

Notes: There is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

Table 8.4-2: 6 dB bandwidth results

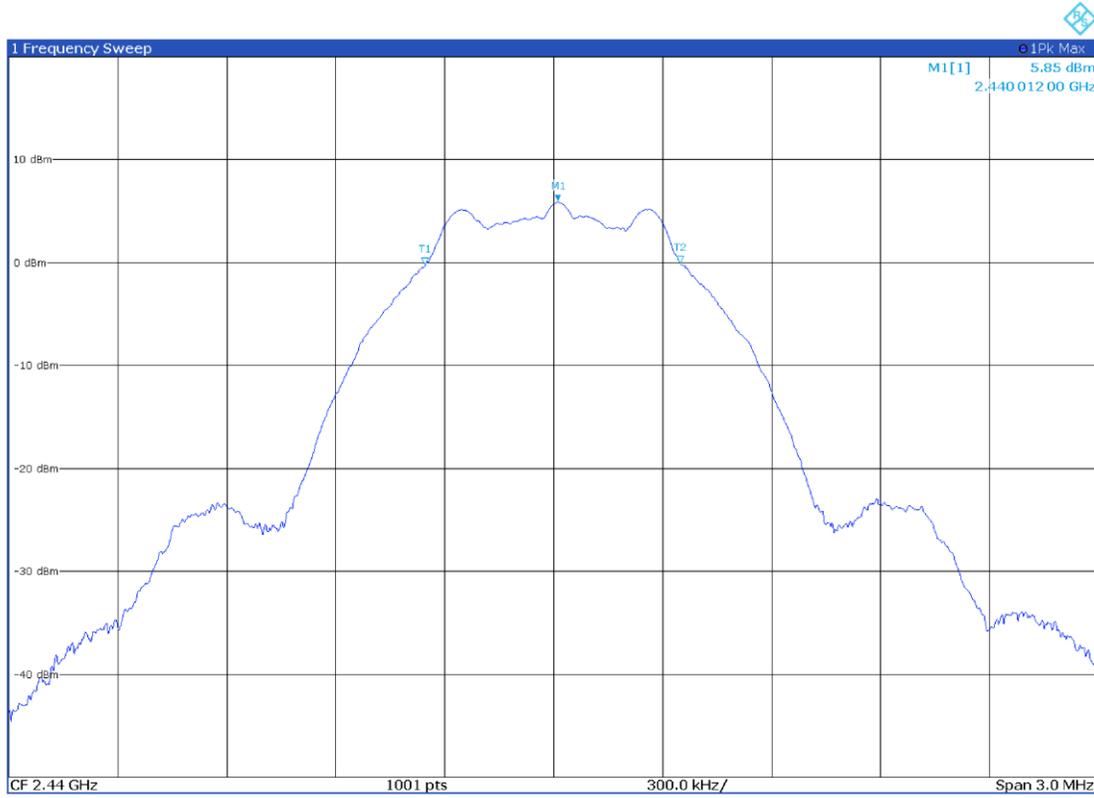
Modulation	Frequency, MHz	6 dB bandwidth, MHz	Minimum limit, MHz	Margin, MHz
GFSK	2402	0.704	0.500	-0.204
	2442	0.701	0.500	-0.201
	2480	0.704	0.500	-0.204



Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	2.402 009 GHz	5.74 dBm	ndB	6.0 dB
T1		1	2.401 649 4 GHz	-0.23 dBm	ndB down BW	704.30 kHz
T2		1	2.402 353 6 GHz	-0.25 dBm	Q Factor	3410.5

Figure 8.4-1: 6 dB bandwidth, low channel

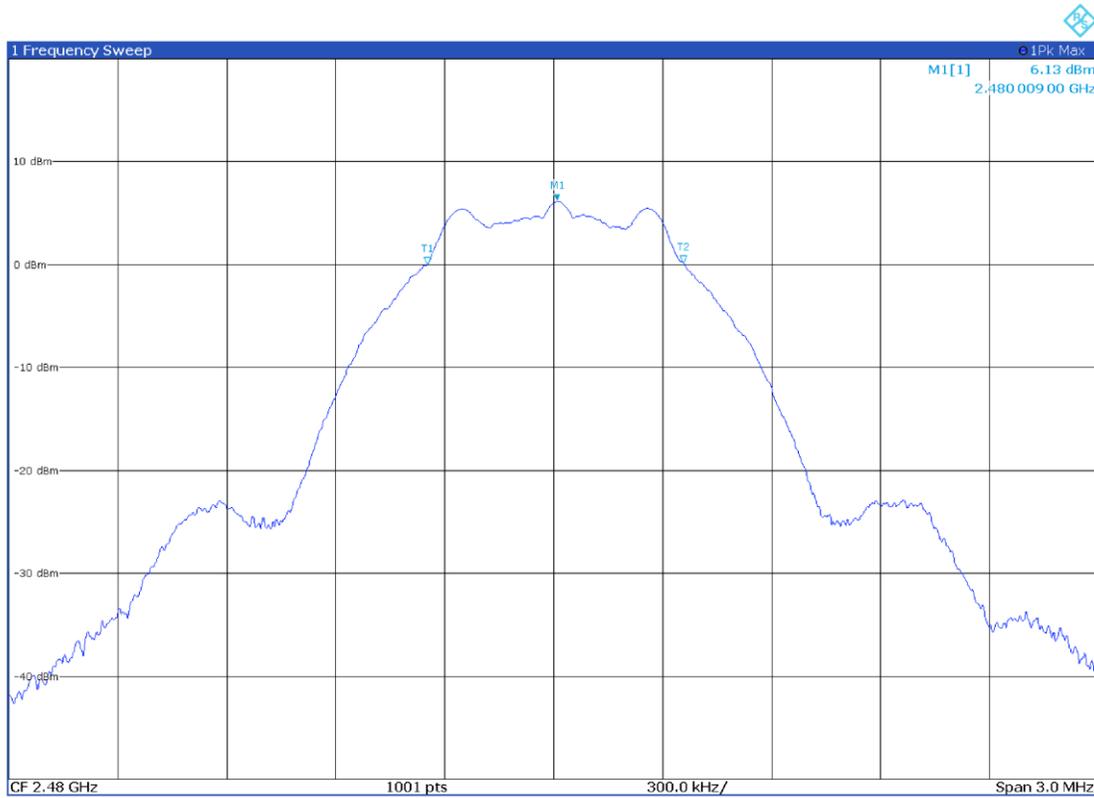
Test data, continued



2 Marker Table						
Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1	1		2.440 012 GHz	5.85 dBm	ndB	6.0 dB
T1	1		2.439 646 4 GHz	-0.24 dBm	ndB down BW	701.30 kHz
T2	1		2.440 347 7 GHz	-0.12 dBm	Q Factor	3 479.3

Figure 8.4-2: 6 dB bandwidth, mid channel

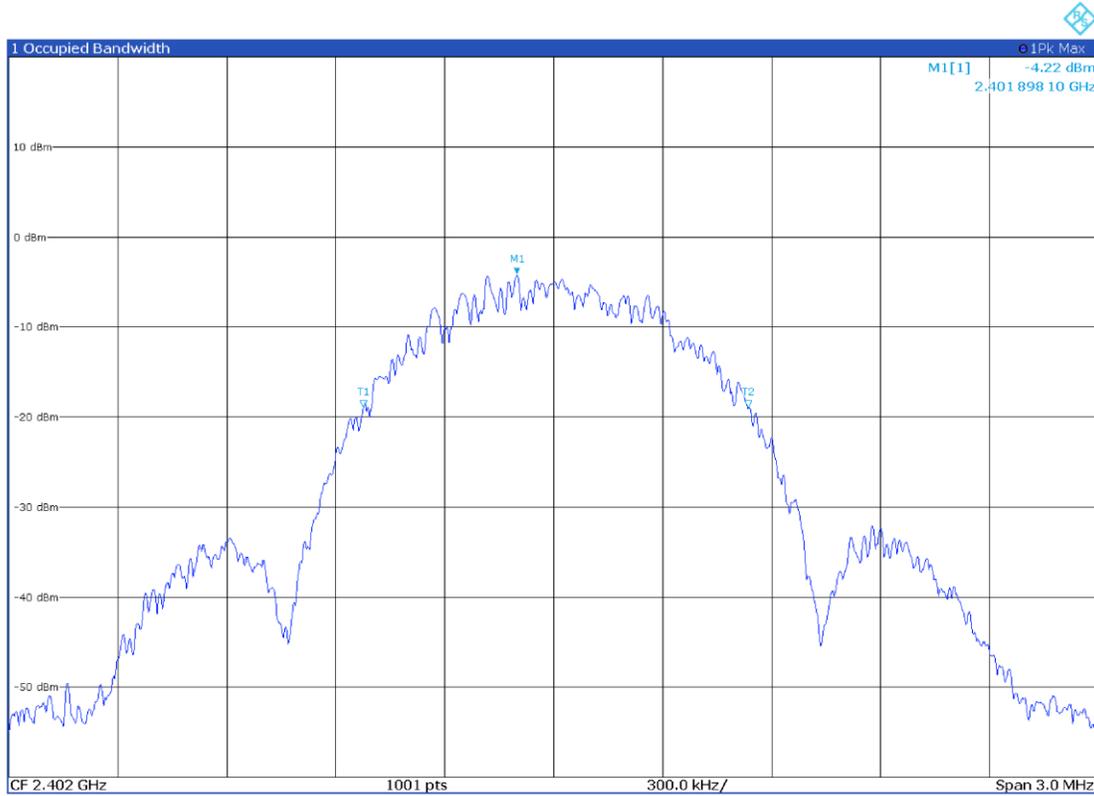
Test data, continued



2 Marker Table						
Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1	1		2.480 009 GHz	6.13 dBm	ndB	6.0 dB
T1	1		2.479 652 3 GHz	0.02 dBm	ndB down BW	704.30 kHz
T2	1		2.480 356 6 GHz	0.14 dBm	Q Factor	3 521.3

Figure 8.4-3: 6 dB bandwidth, high channel

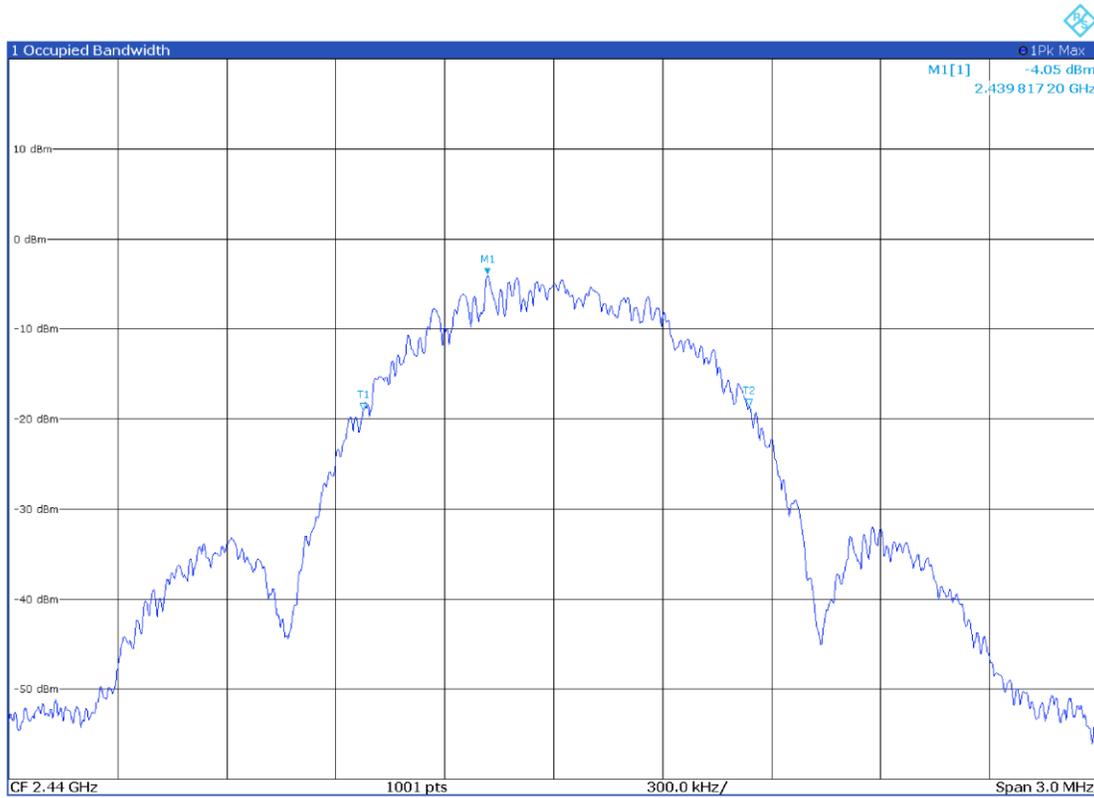
Test data, continued



2 Marker Table						
Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	2.401 898 1 GHz	-4.22 dBm	Occ Bw	1.059 203 834 MHz
T1		1	2.401 475 79 GHz	-19.03 dBm	Occ Bw Centroid	2.402 005 392 GHz
T2		1	2.402 534 99 GHz	-18.98 dBm	Occ Bw Freq Offset	5.391 723 653 kHz

Figure 8.4-4: 99% occupied bandwidth, low channel

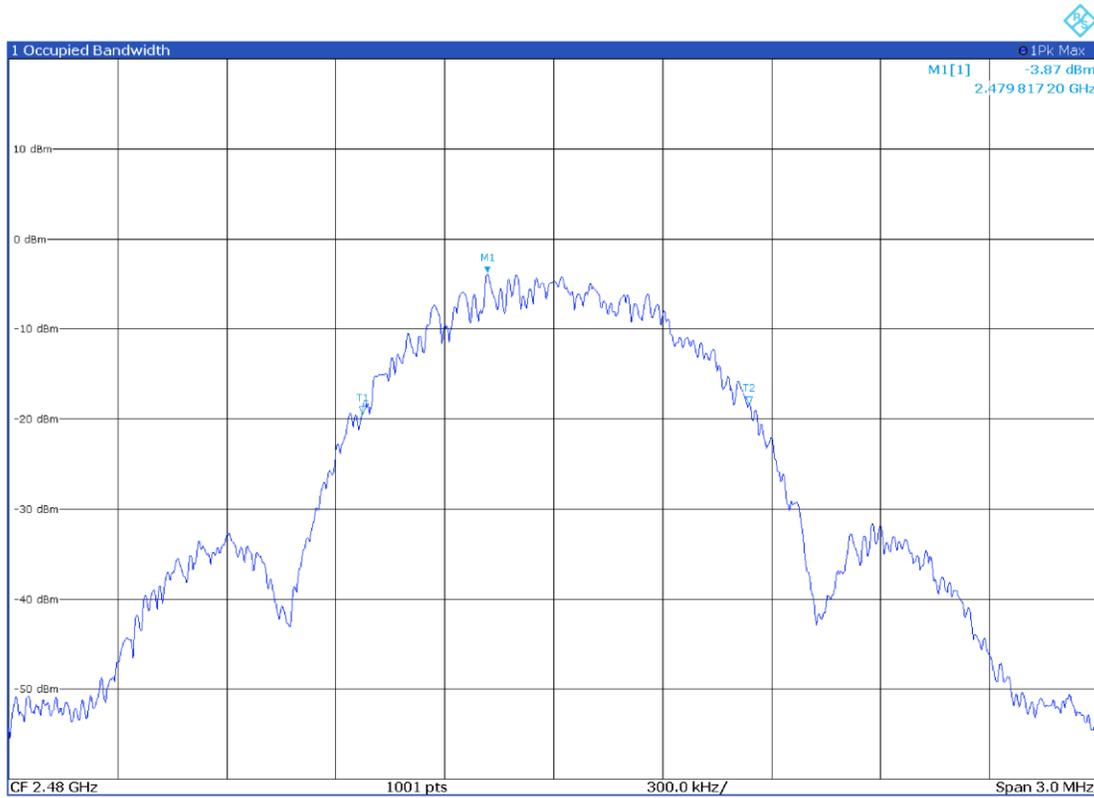
Test data, continued



2 Marker Table						
Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1	1		2.4398172 GHz	-4.05 dBm	Occ Bw	1.061682273 MHz
T1	1		2.43947494 GHz	-19.06 dBm	Occ Bw Centroid	2.440005778 GHz
T2	1		2.44053662 GHz	-18.67 dBm	Occ Bw Freq Offset	5.778083775 kHz

Figure 8.4-5: 99% occupied bandwidth, mid channel

Test data, continued



2 Marker Table						
Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1	1		2.479 817 2 GHz	-3.87 dBm	Occ Bw	1.063 759 434 MHz
T1	1		2.479 473 28 GHz	-19.43 dBm	Occ Bw Centroid	2.480 005 157 GHz
T2	1		2.480 537 04 GHz	-18.35 dBm	Occ Bw Freq Offset	5.157 141 048 kHz

Figure 8.4-6: 99% occupied bandwidth, high channel

8.5 Transmitter output power and e.i.r.p. requirements for DTS in 2.4 GHz

8.5.1 References, definitions and limits

FCC §15.247:

- (b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:
- (3) For systems using digital modulation in the 2400–2483.5 MHz band: 1 W (30 dBm). 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.
- (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.
- (c) Operation with directional antenna gains greater than 6 dBi.
 - (1) Fixed point-to-point operation:
 - (i) Systems operating in the 2400–2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum conducted output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.
 - (iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.
 - (2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:
 - (i) Different information must be transmitted to each receiver.
 - (ii) If the transmitter employs an antenna system that emits multiple directional beams but does not do emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:
 - (A) The directional gain shall be calculated as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.
 - (B) A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.
 - (iii) If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.
 - (iv) Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.

8.5.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	October 3, 2022
Sample tested	4744740002 for radiated measurement and 4744740003 for conducted measurement		

8.5.3 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.3 with reference to ANSI C63.10 subclause 11.9.1 (peak power) using method RBW≥DTS bandwidth (Maximum peak conducted output power).

Spectrum analyser settings:

Resolution bandwidth	≥DTS bandwidth
Video bandwidth	≥3 × RBW
Frequency span	10 MHz
Detector mode	Peak
Trace mode	Max-hold

8.5.4 Test equipment used

Equipment	Manufacturer	Model no.	Asset no.
Spectrum Analyzer	Rohde & Schwarz	FSW43	101767
Antenna 1 - 18 GHz	Schwarzbeck Mess-Elektronik	STLP9148	STLP 9148-152
Controller	Maturo	FCU3.0	10041
Tilt antenna mast	Maturo	TAM4.0-E	10042
Turntable	Maturo	TT4.0-5T	2.527
Semi-anechoic chamber	Nemko S.p.a.	10m semi-anechoic chamber	530

8.5.5 Test data

Table 8.5-1: Output power and EIRP results (radiated and conducted measurement)

Frequency, MHz	Field strength, dBμV/m	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB	Antenna gain, dBi	Output power, dBm	Output power limit, dBm	Output power margin, dB
2402	93.1	-2.1	36	-38.1	-8.00	5.9	30	-24.1
2442	94.1	-1.1	36	-37.1	-7.38	6.3	30	-23.7
2480	96.0	0.8	36	-35.2	-5.50	6.3	30	-23.7

Note: EIRP [dBm] = Field Strength [dBμV/m] – 95.23 [dB]; Antenna gain [dBi] = EIRP [dBm] – Output power [dBm]

Test data, continued

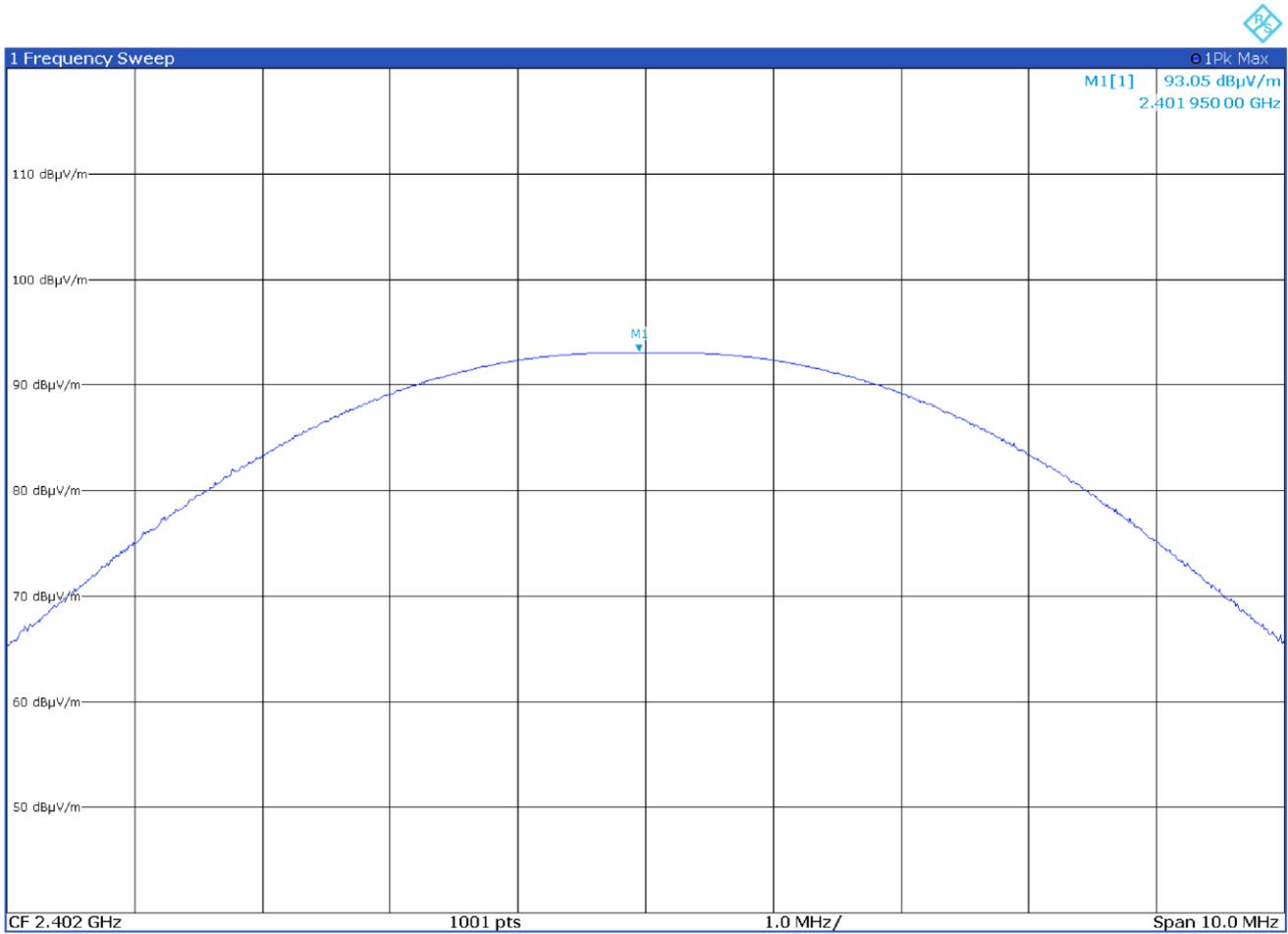


Figure 8.5-1: Field strength on low channel

Test data, continued

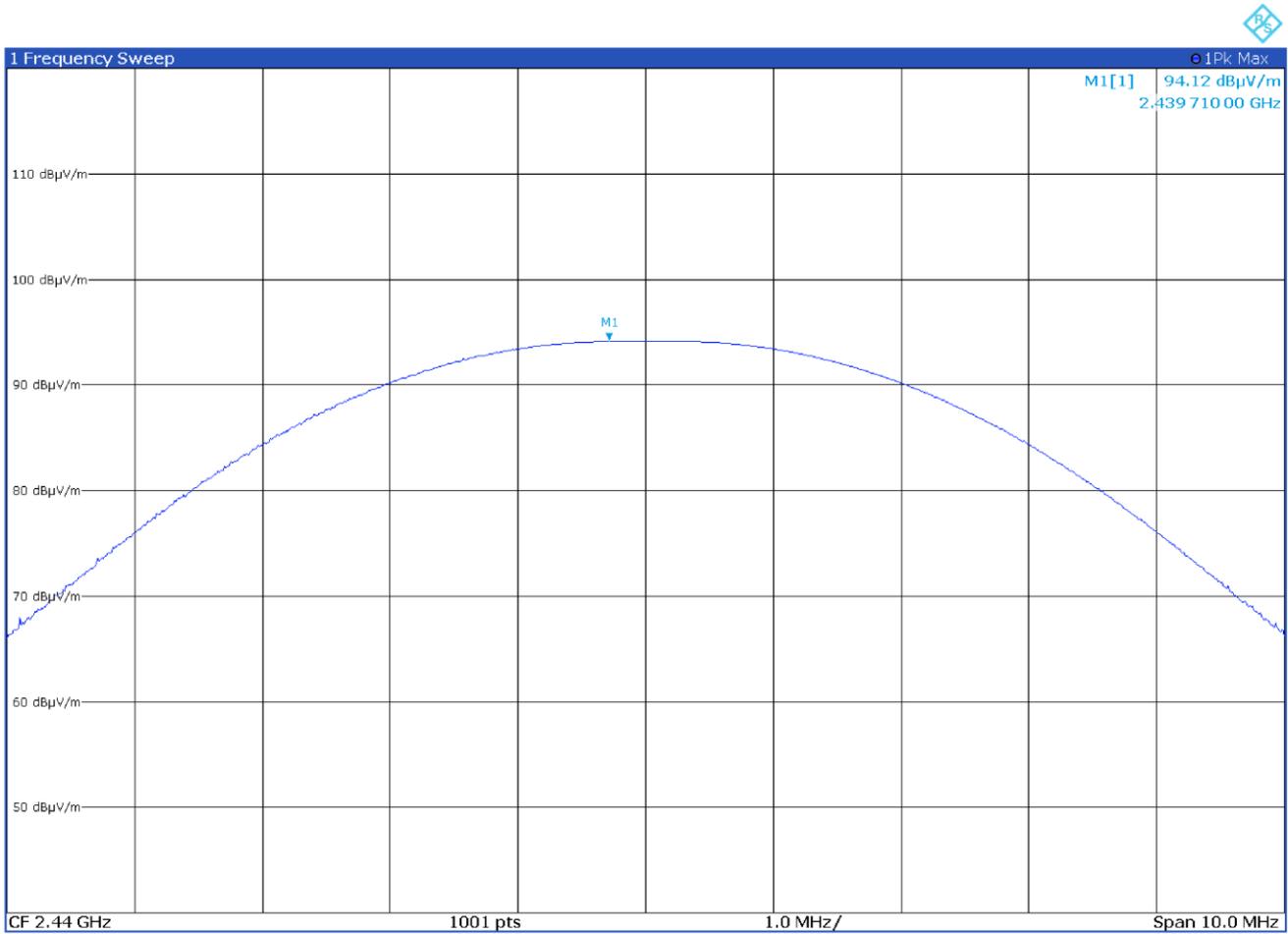


Figure 8.5-2: Field strength on mid channel

Test data, continued

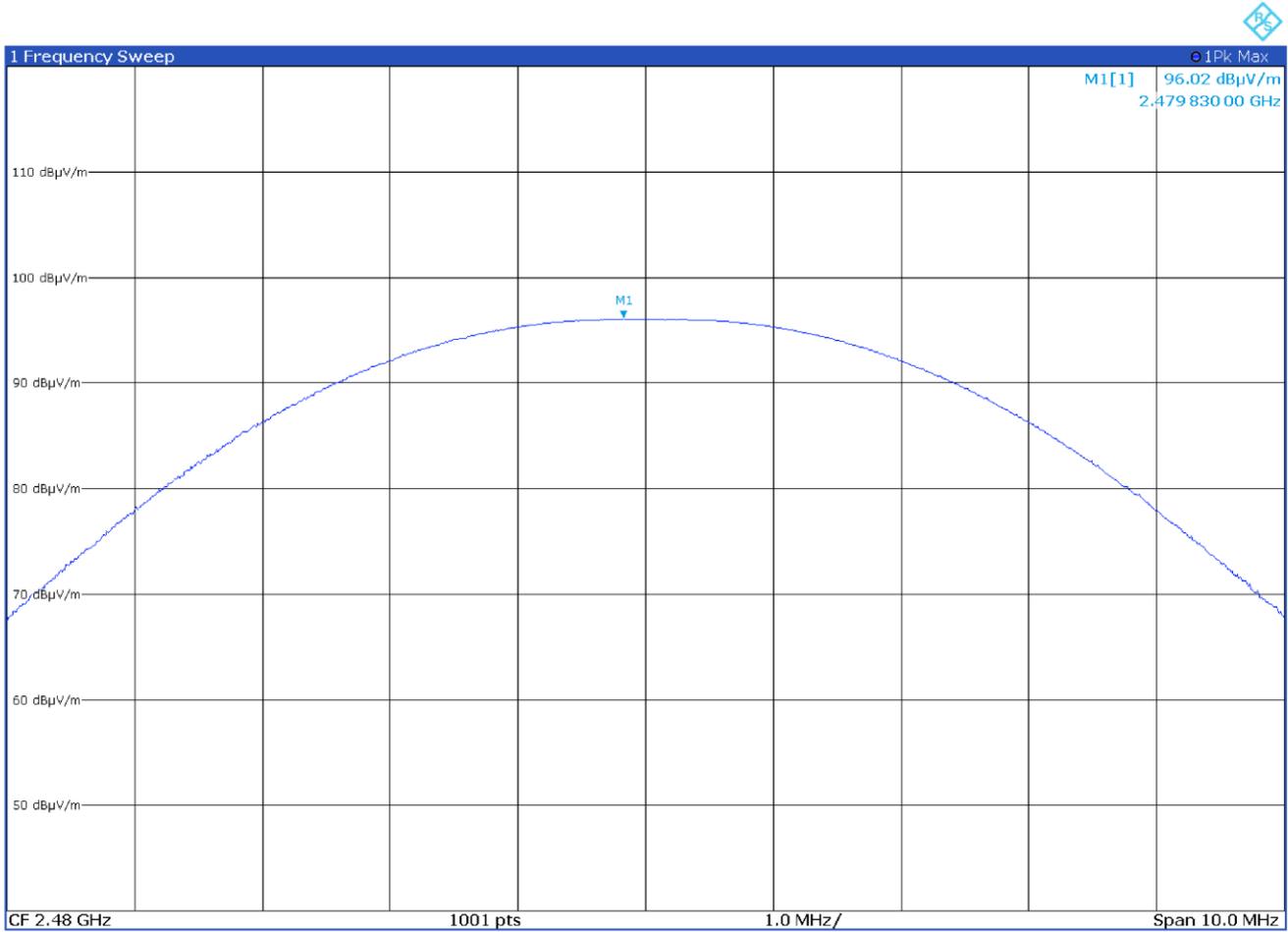


Figure 8.5-3: Field strength on high channel

Test data, continued

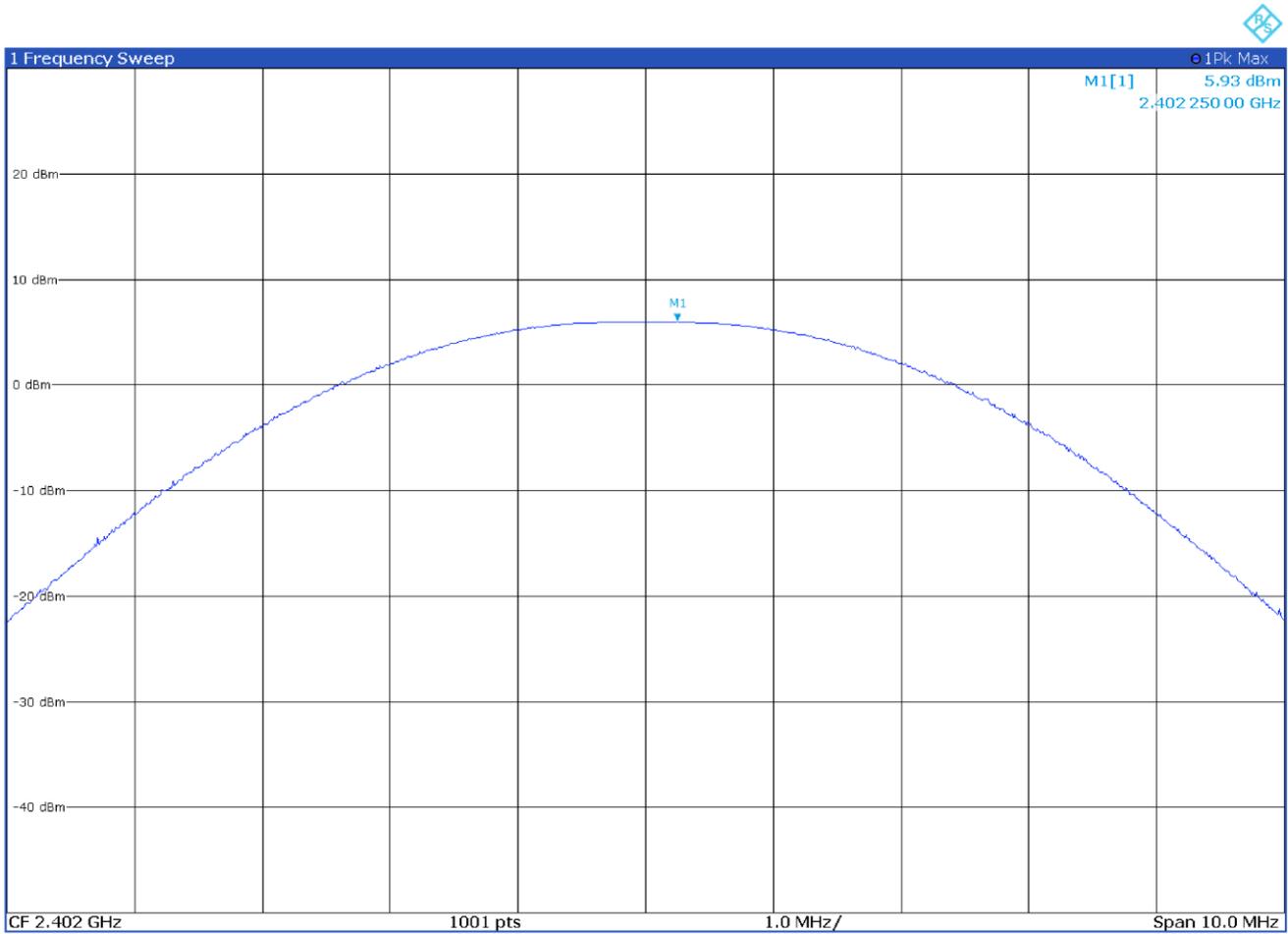


Figure 8.5-4: Output power on low channel

Test data, continued

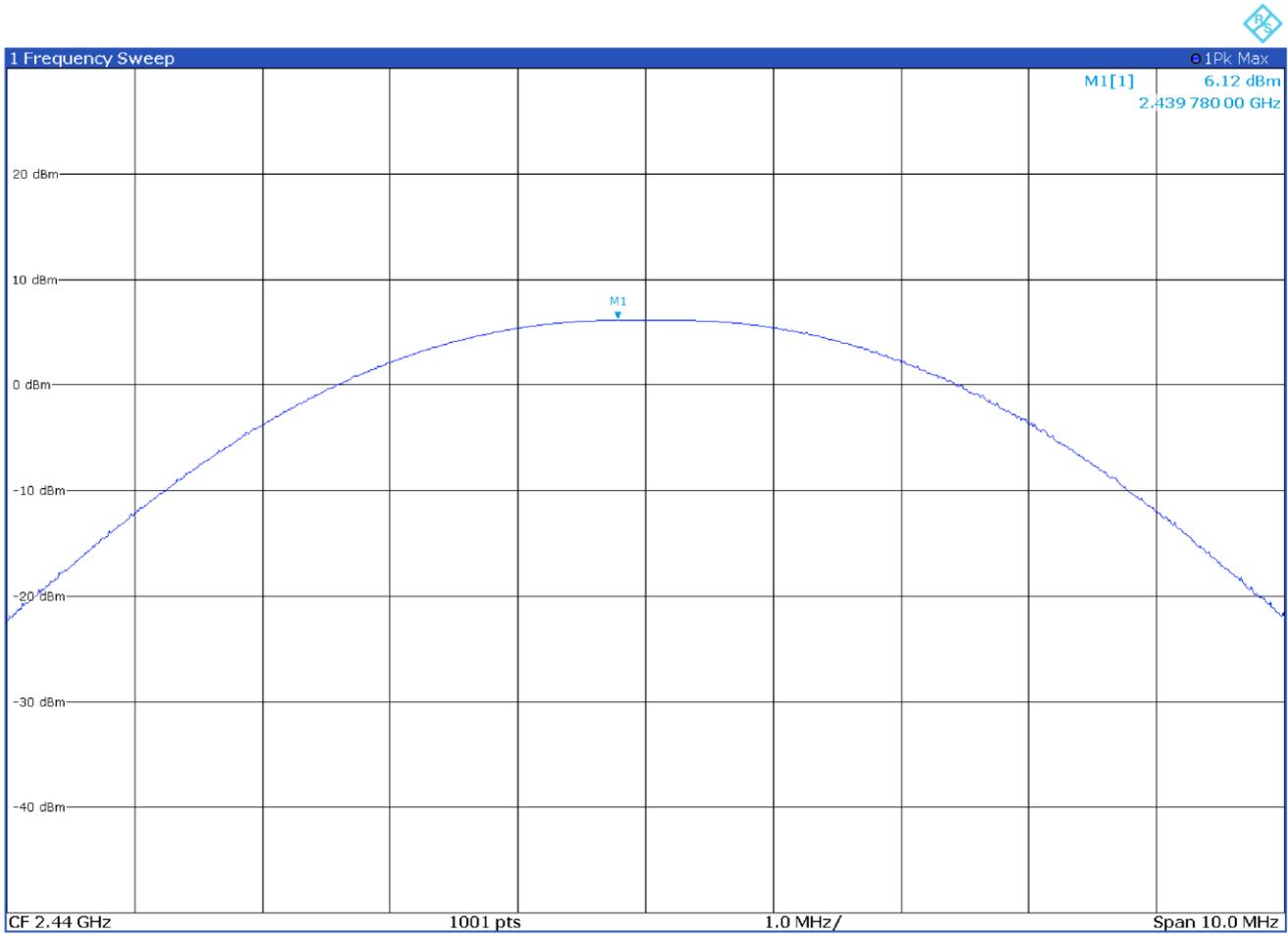


Figure 8.5-5: Output power on mid channel

Test data, continued

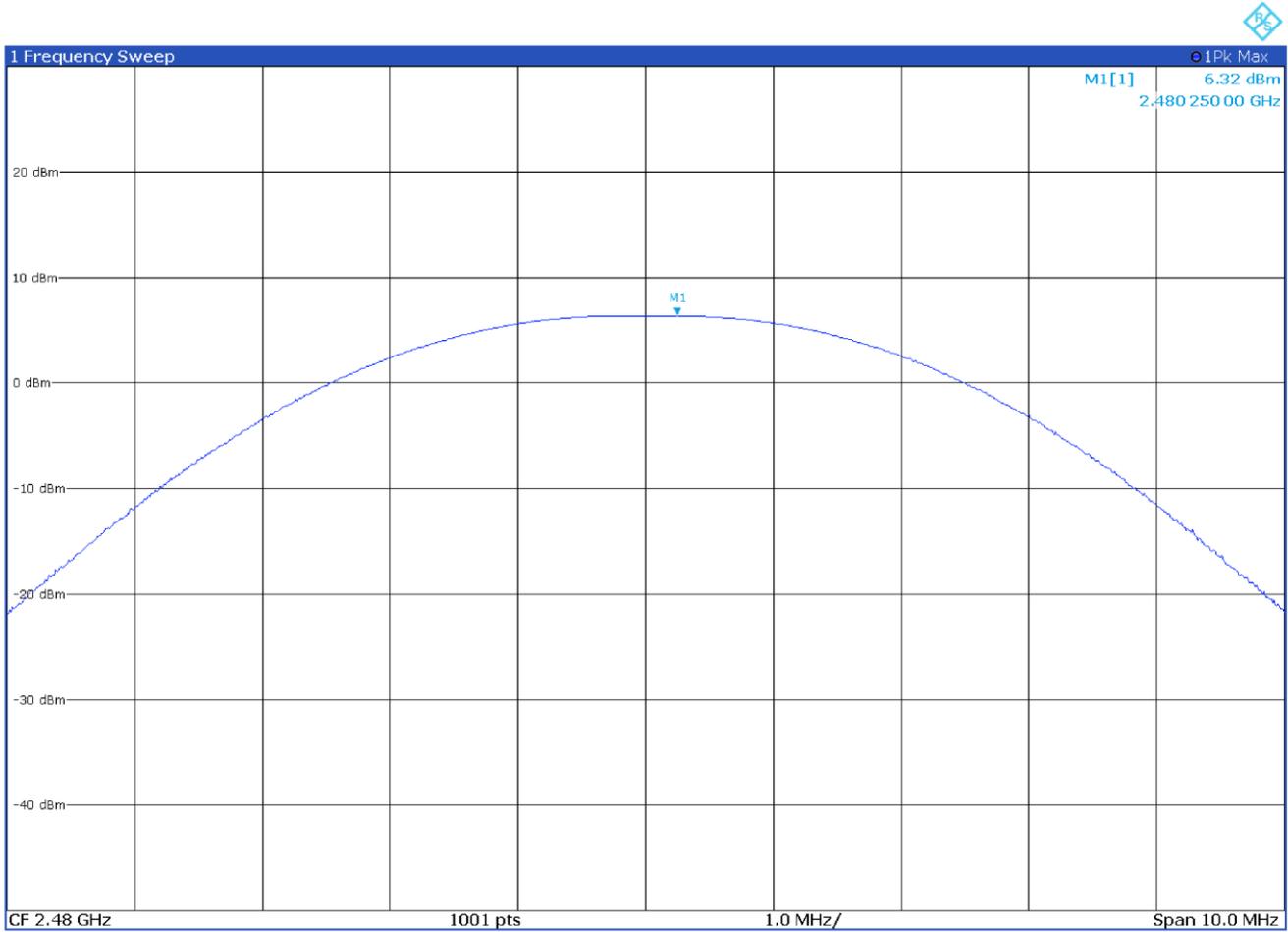


Figure 8.5-6: Output power on high channel

8.6 Spurious (out-of-band) unwanted emissions

8.6.1 References, definitions and limits

FCC §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)).

Table 8.6-1: FCC §15.209 – Radiated emission limits

Frequency, MHz	Field strength of emissions		Measurement distance, m
	µV/m	dBµV/m	
0.009–0.490	2400/F	67.6 – 20 × log ₁₀ (F)	300
0.490–1.705	24000/F	87.6 – 20 × log ₁₀ (F)	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

Notes: In the emission table above, the tighter limit applies at the band edges.
 For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test.

Table 8.6-2: FCC restricted frequency bands

MHz	MHz	MHz	GHz
0.090–0.110	16.42–16.423	399.9–410	4.5–5.15
0.495–0.505	16.69475–16.69525	608–614	5.35–5.46
2.1735–2.1905	16.80425–16.80475	960–1240	7.25–7.75
4.125–4.128	25.5–25.67	1300–1427	8.025–8.5
4.17725–4.17775	37.5–38.25	1435–1626.5	9.0–9.2
4.20725–4.20775	73–74.6	1645.5–1646.5	9.3–9.5
6.215–6.218	74.8–75.2	1660–1710	10.6–12.7
6.26775–6.26825	108–121.94	1718.8–1722.2	13.25–13.4
6.31175–6.31225	123–138	2200–2300	14.47–14.5
8.291–8.294	149.9–150.05	2310–2390	15.35–16.2
8.362–8.366	156.52475–156.52525	2483.5–2500	17.7–21.4
8.37625–8.38675	156.7–156.9	2690–2900	22.01–23.12
8.41425–8.41475	162.0125–167.17	3260–3267	23.6–24.0
12.29–12.293	167.72–173.2	3332–3339	31.2–31.8
12.51975–12.52025	240–285	3345.8–3358	36.43–36.5
12.57675–12.57725	322–335.4	3600–4400	Above 38.6
13.36–13.41			

8.6.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	September 22, 2022

8.6.3 Observations, settings and special notes

- As part of the current assessment, the test range of 9 kHz to 10th harmonic has been fully considered and compared to the actual frequencies utilized within the EUT. Since the EUT contains a transmitter in the GHz range, the EUT has been deemed compliant without formal testing in the 9 kHz to 30 MHz test range, therefore formal test results (tabular data and/or plots) are not provided within this test report.
- EUT was set to transmit with 100 % duty cycle.
- Radiated measurements were performed at a distance of 3 m.
- DTS emissions in non-restricted frequency bands test was performed as per KDB 558074, section 8.5 with reference to ANSI C63.10 subclause 11.11.
- Since fundamental power was tested using the maximum peak conducted output power procedure to demonstrate compliance, the spurious emissions limit is -20 dBc/100 kHz.
- DTS emissions in restricted frequency bands test was performed as per KDB 558074, section 8.6 with reference to ANSI C63.10 subclause 11.12.
- DTS band-edge emission measurements test was performed as per KDB 558074, section 8.7 with reference to ANSI C63.10 subclause 11.13.

Spectrum analyser settings for radiated measurements within restricted bands below 1 GHz:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser settings for peak radiated measurements within restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser settings for average radiated measurements within restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	RMS
Trace mode:	Power average
Averaging sweeps number:	100

8.6.4 Test equipment used

Equipment	Manufacturer	Model no.	Asset no.
EMI Receiver	Rohde & Schwarz	ESW44	101620
Antenna Trilog 25MHz - 8GHz	Schwarzbeck Mess-Elektronik	VULB9162	9162-025
Antenna 1 - 18 GHz	Schwarzbeck Mess-Elektronik	STLP9148	STLP 9148-152
Double Ridge Horn Antenna	RFSpin	DRH40	061106A40
Broadband Amplifier	Schwarzbeck Mess-Elektronik	BBV9718C	00121
Broadband Bench Top Amplifier	Sage	STB-1834034030-KFKF-L1	18490-01
Controller	Maturo	FCU3.0	10041
Tilt antenna mast	Maturo	TAM4.0-E	10042
Turntable	Maturo	TT4.0-5T	2.527
Semi-anechoic chamber	Nemko S.p.a.	10m semi-anechoic chamber	530

8.6.5 Test data

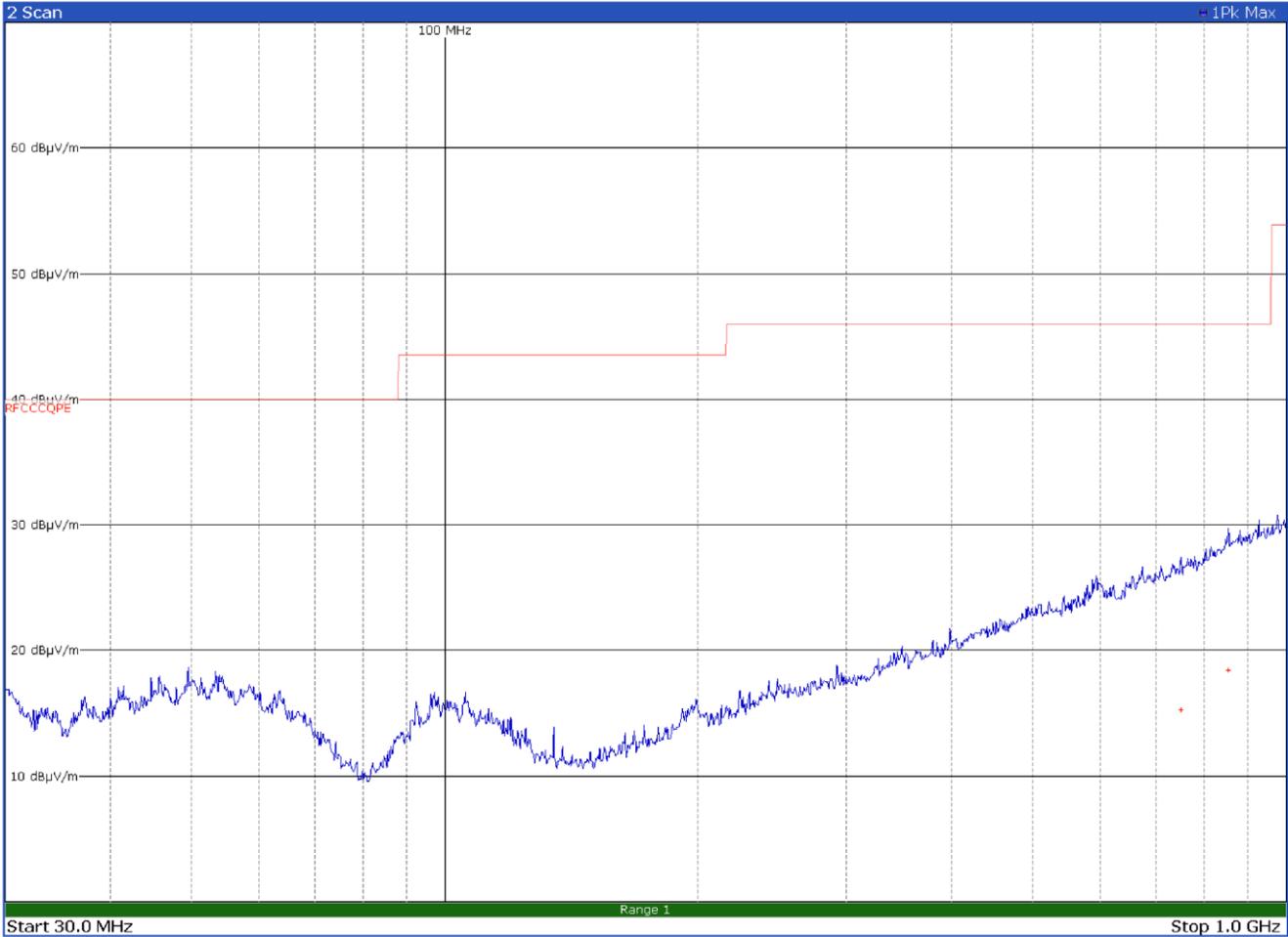


Figure 8.6-1: Radiated spurious emissions on low channel with antenna in horizontal polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
749.2200	15.3	46.0	-30.7	QP
853.8900	18.5	46.0	-27.5	QP

Test data, continued

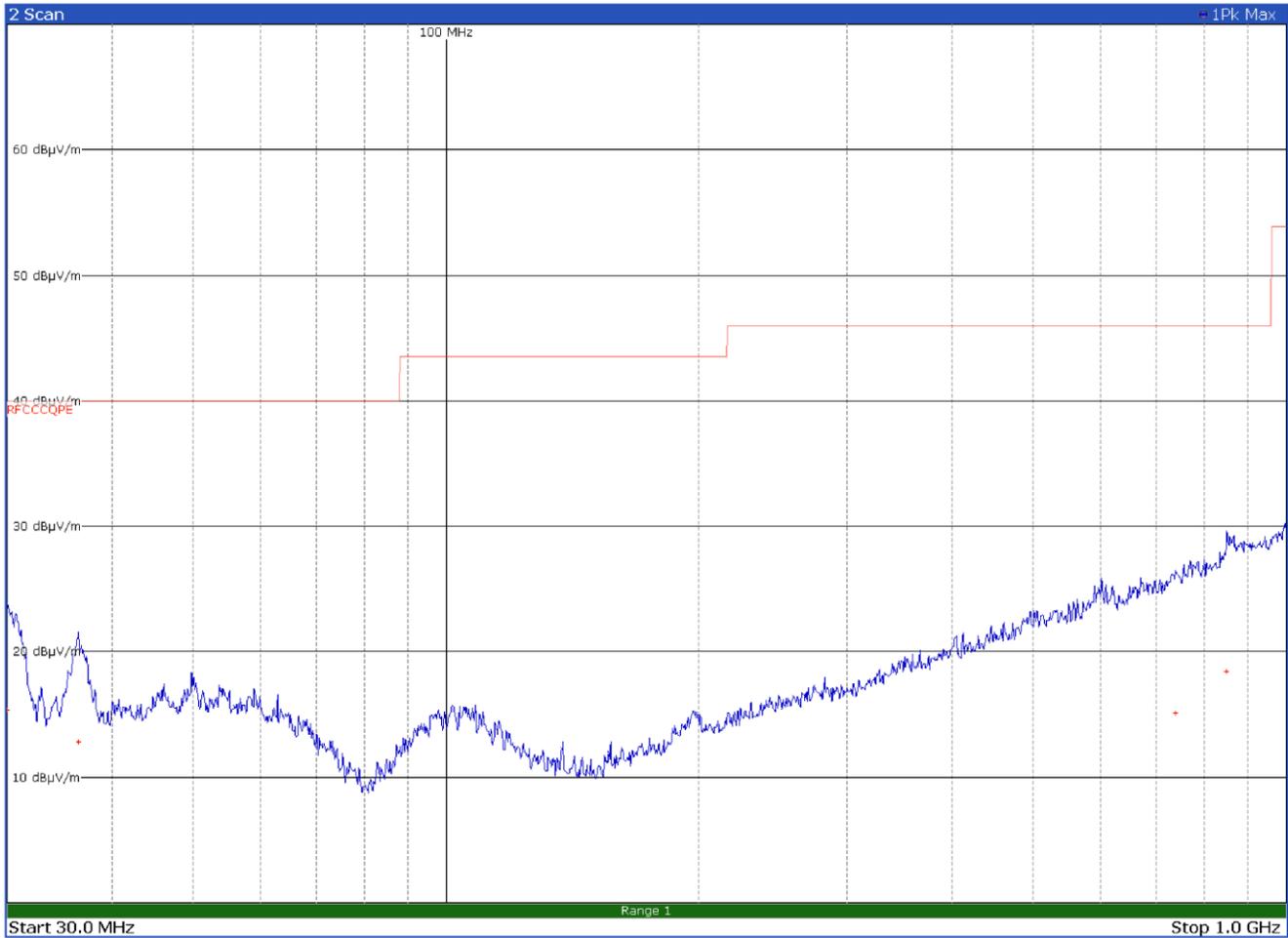


Figure 8.6-2: Radiated spurious emissions on low channel with antenna in vertical polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
30.0000	15.4	40.0	-24.6	QP
36.4800	12.9	40.0	-27.1	QP
738.0600	15.2	46.0	-30.8	QP
849.6900	18.5	46.0	-27.5	QP

Test data, continued

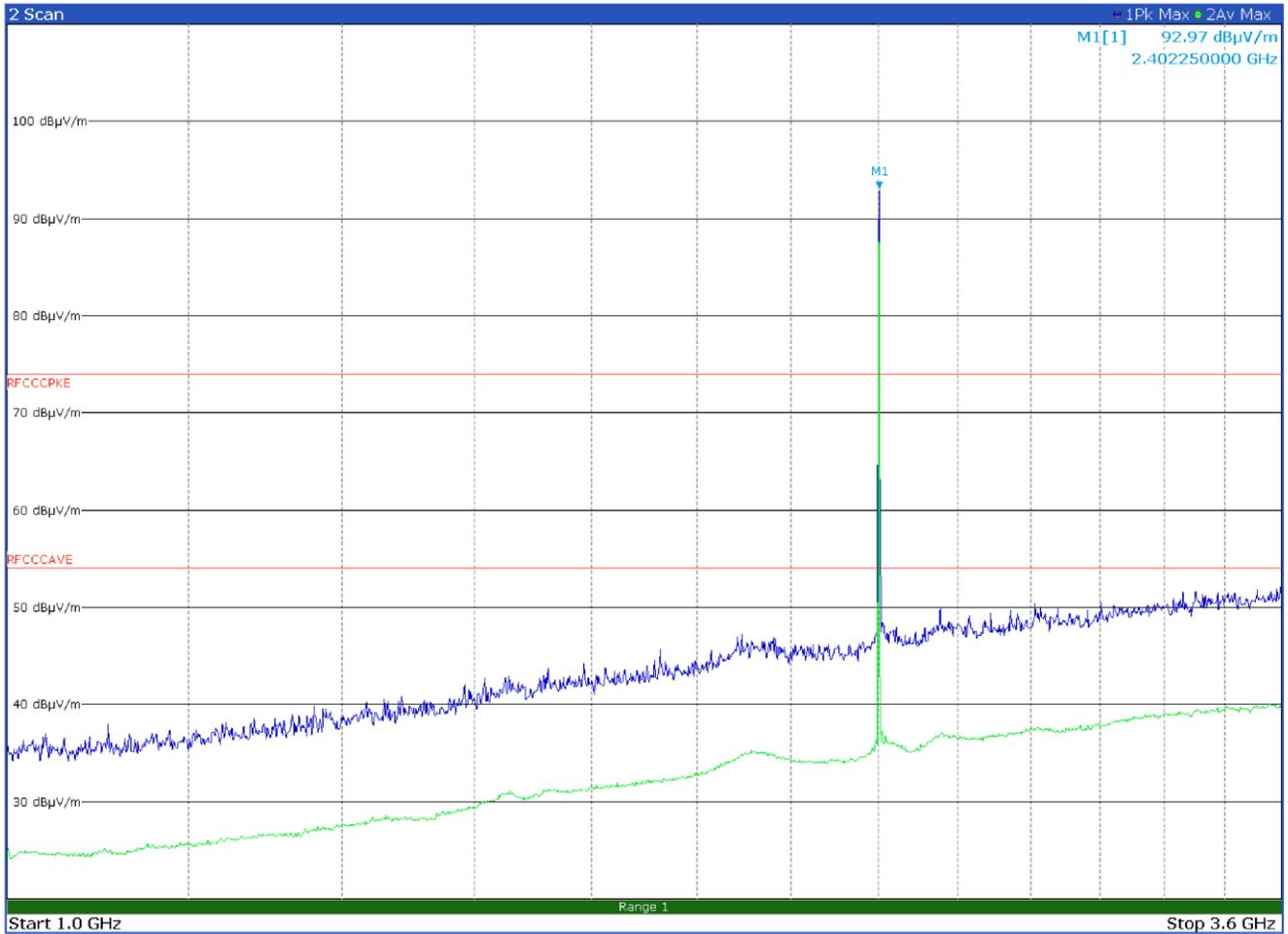


Figure 8.6-3: Radiated spurious emissions on low channel with antenna in horizontal polarization

No spurious detected in this range- Limit exceeded by the carrier

Test data, continued

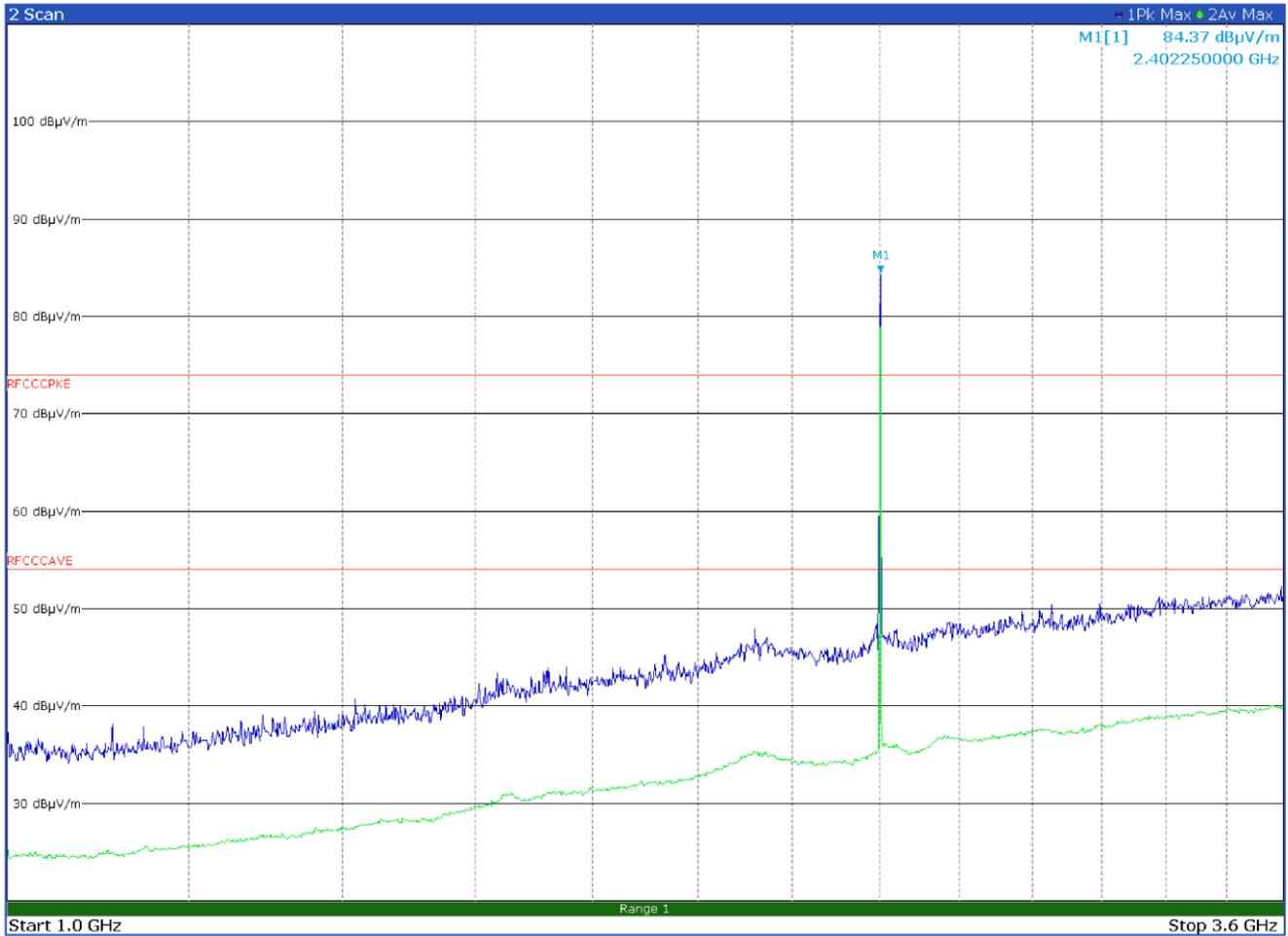


Figure 8.6-4: Radiated spurious emissions on low channel with antenna in vertical polarization

No spurious detected in this range- Limit exceeded by the carrier

Test data, continued

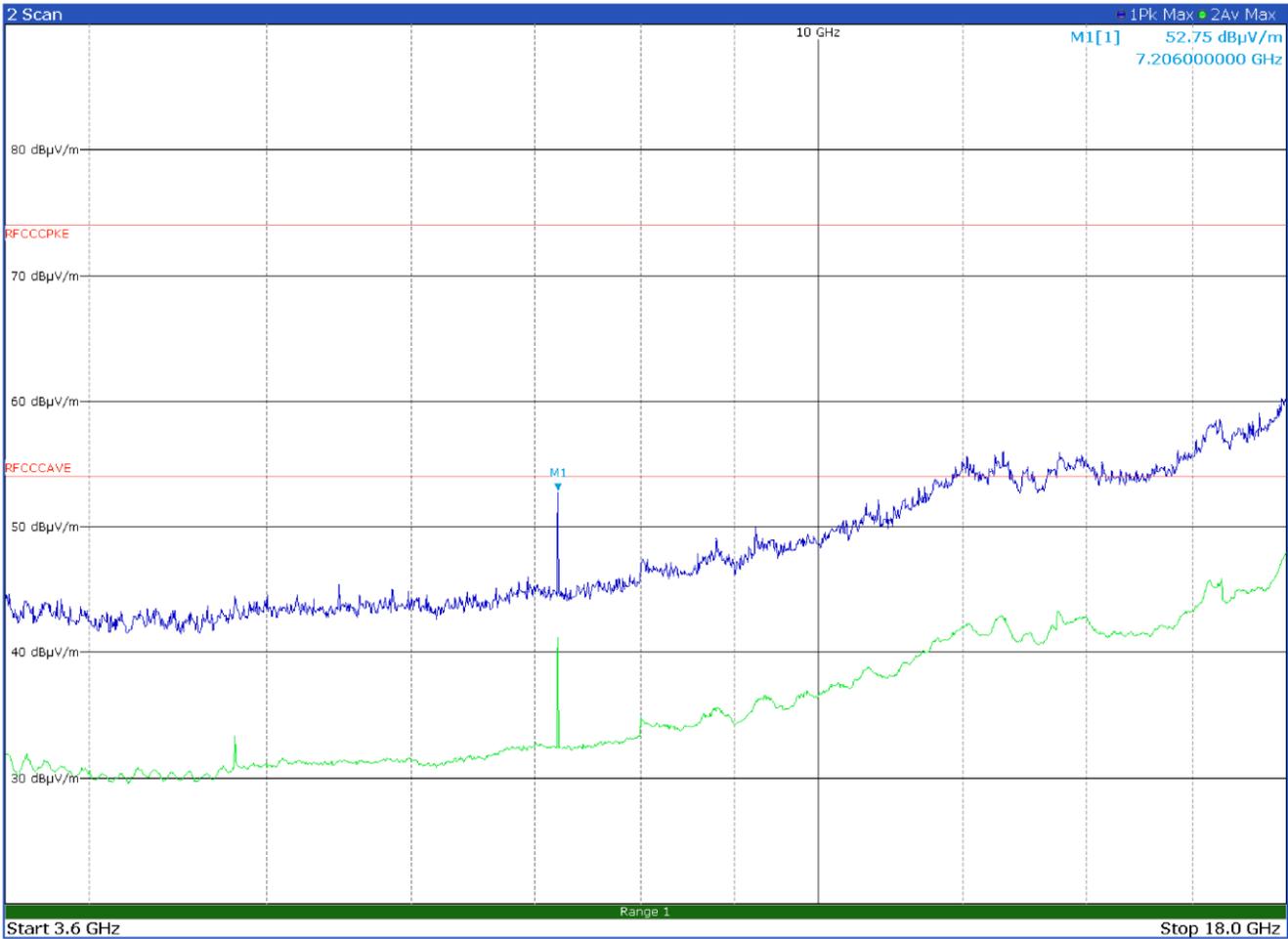


Figure 8.6-5: Radiated spurious emissions on low channel with antenna in horizontal polarization

Frequency (GHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
7.2060	52.8	74	-21.2	Pk
7.2060	48.5	54	-5.5	Av

Test data, continued

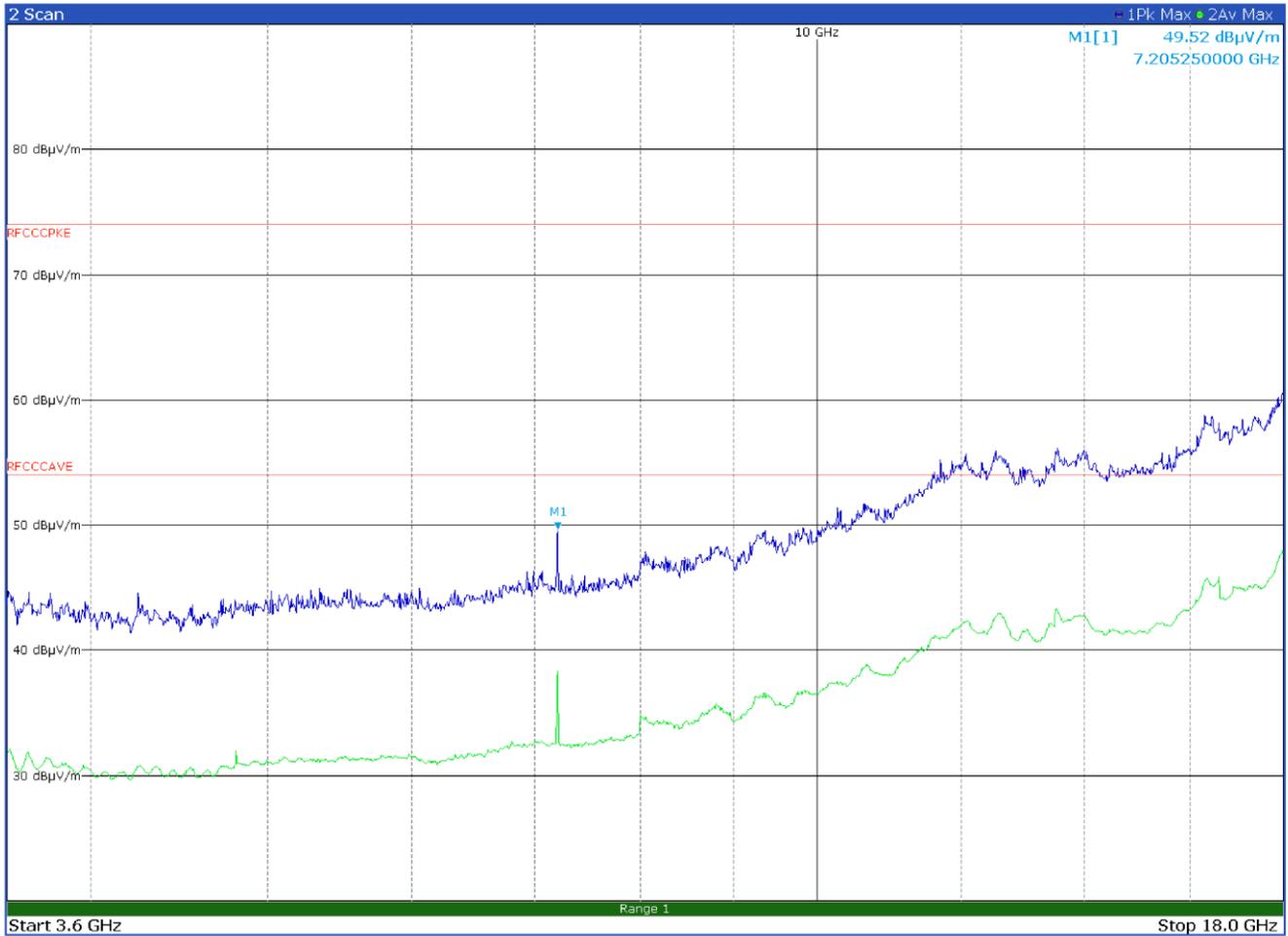


Figure 8.6-6: Radiated spurious emissions on low channel with antenna in vertical polarization

Frequency (GHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
7.2052	49.5	74	-24.5	Pk
7.2052	45.2	54	-8.8	Av

Test data, continued

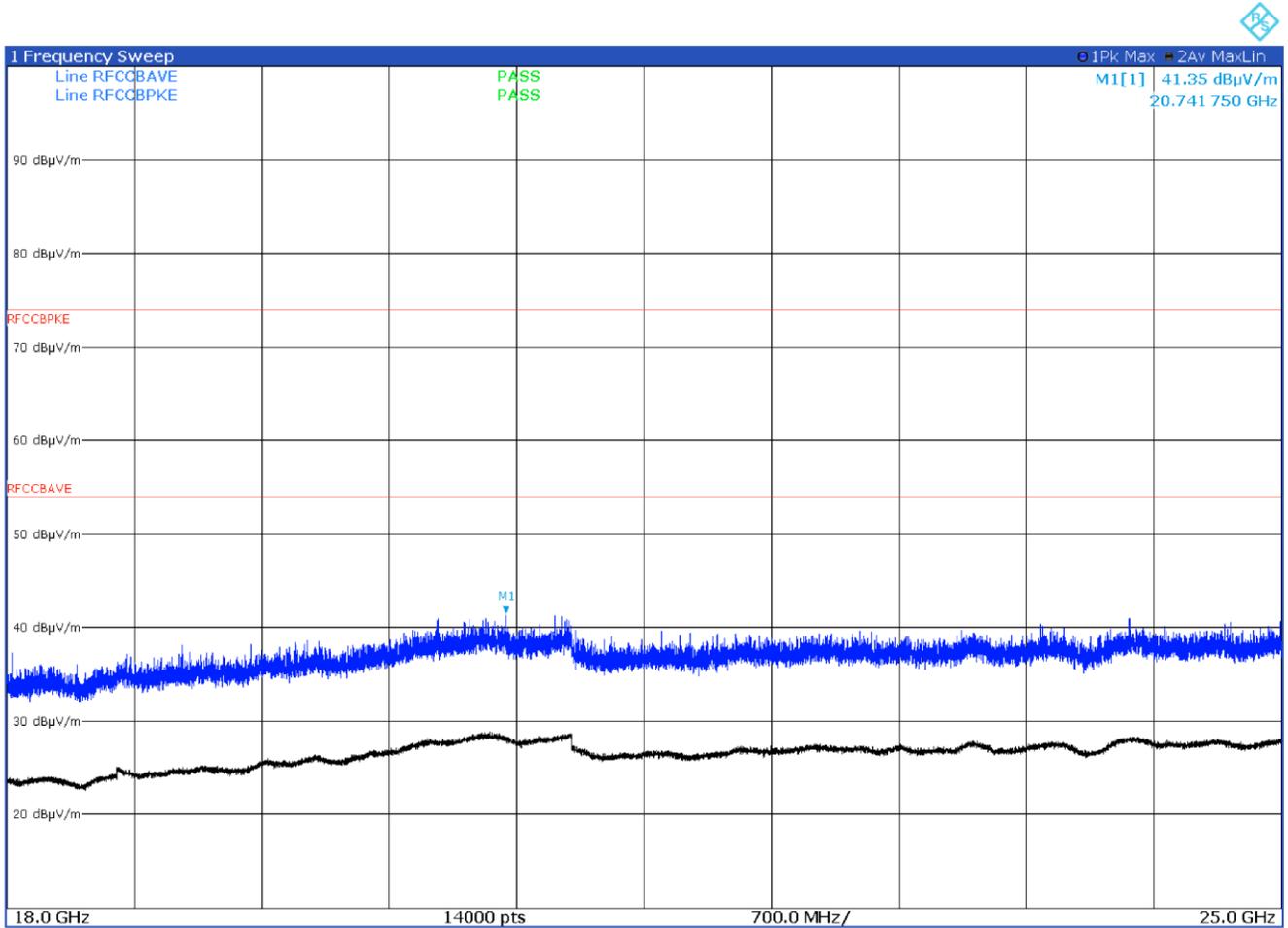


Figure 8.6-7: Radiated spurious emissions on low channel with antenna in horizontal polarization

No spurious detected in this range

Test data, continued

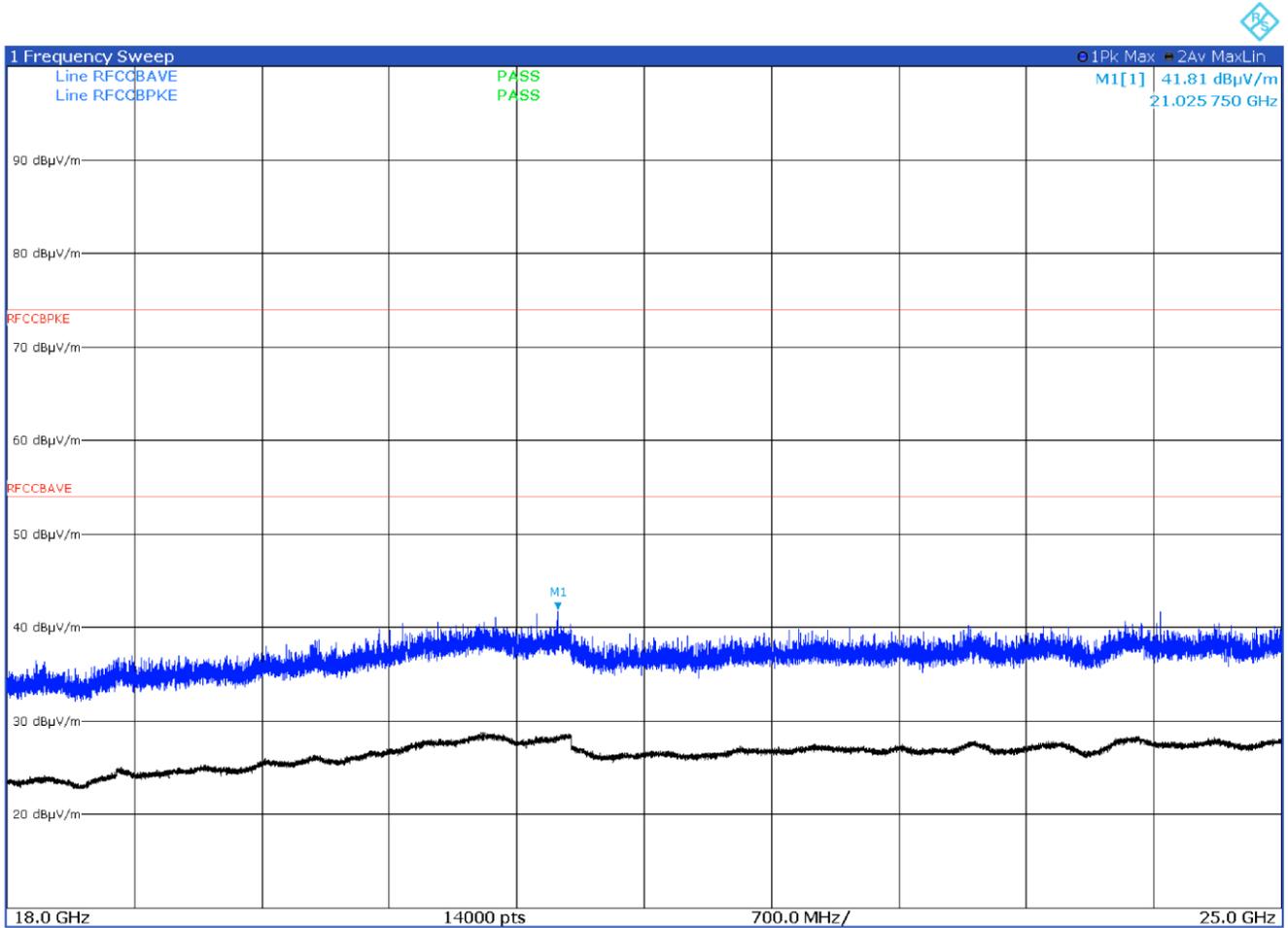
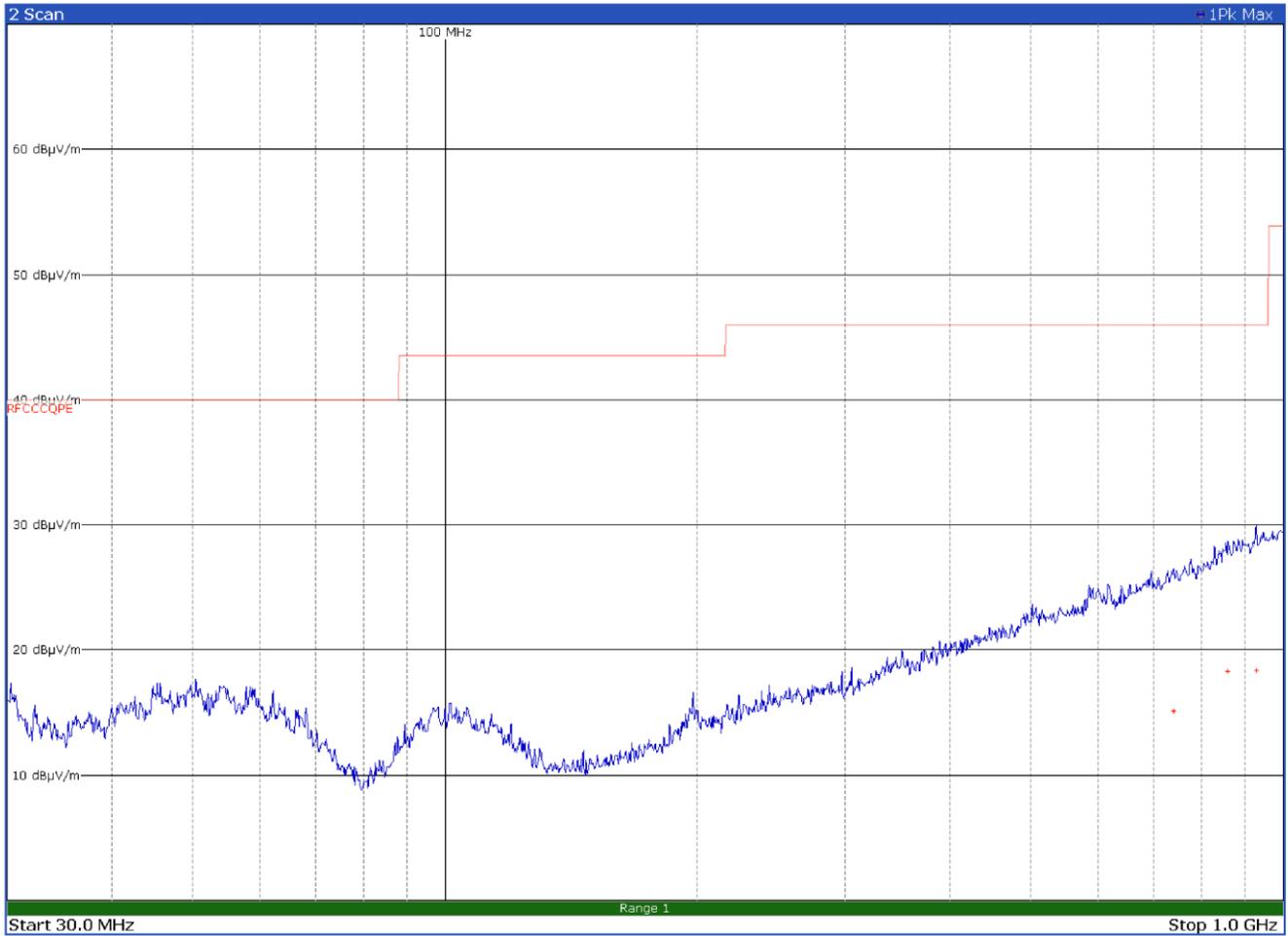


Figure 8.6-8: Radiated spurious emissions on low channel with antenna in vertical polarization

No spurious detected in this range

Test data, continued



Page 1/1

Figure 8.6-9: Radiated spurious emissions on mid channel with antenna in horizontal polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
739.2300	15.8	46.7	-30.9	QP
859.0800	18.7	46.3	-27.6	QP
928.0200	18.1	45.6	-27.5	QP

Test data, continued

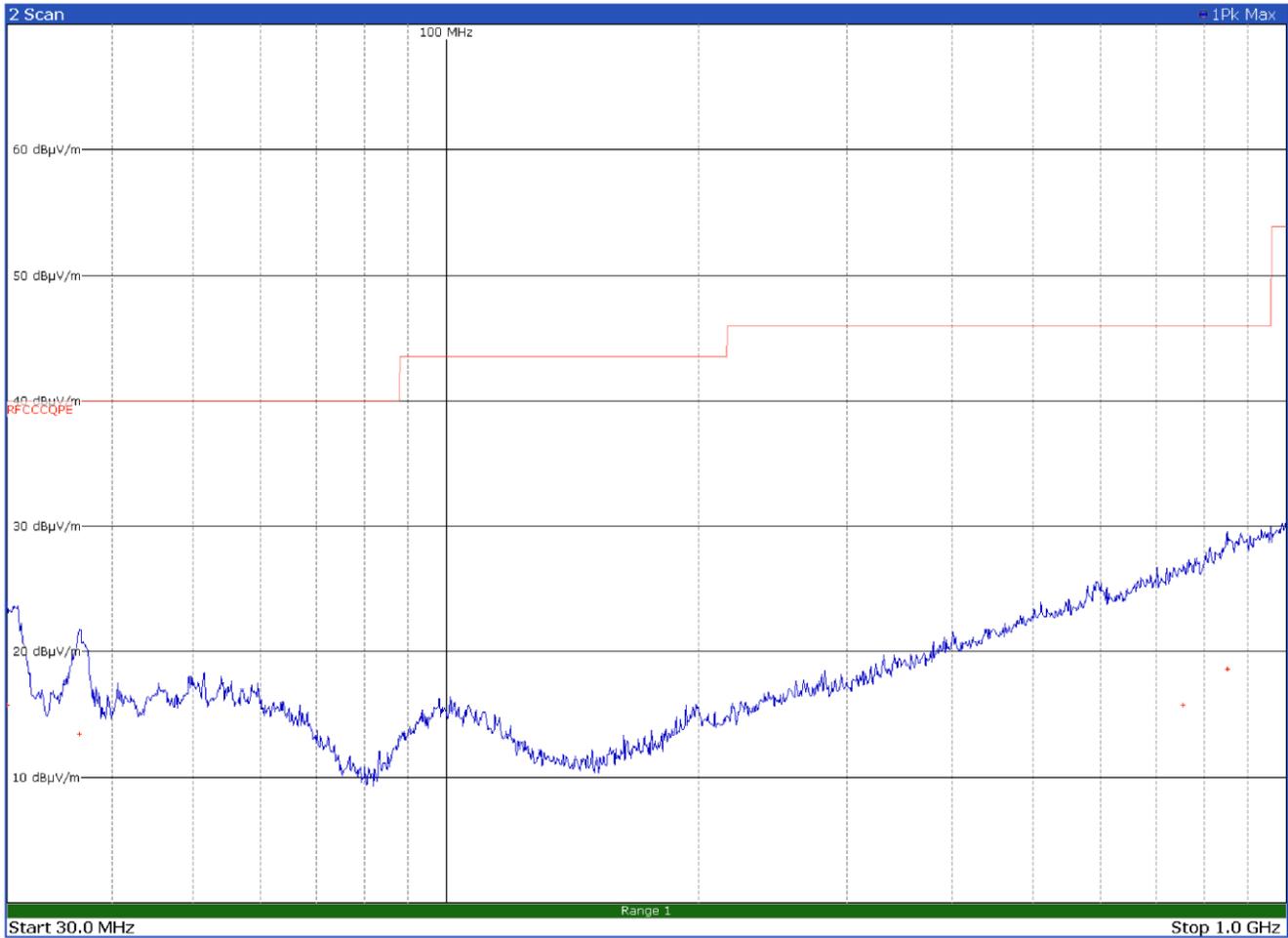


Figure 8.6-10: Radiated spurious emissions on mid channel with antenna in vertical polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
30.0000	15.3	39.6	-24.3	QP
36.5700	13.6	40.3	-26.7	QP
754.2900	15.1	45.5	-30.4	QP
850.4400	18.3	45.9	-27.6	QP

Test data, continued

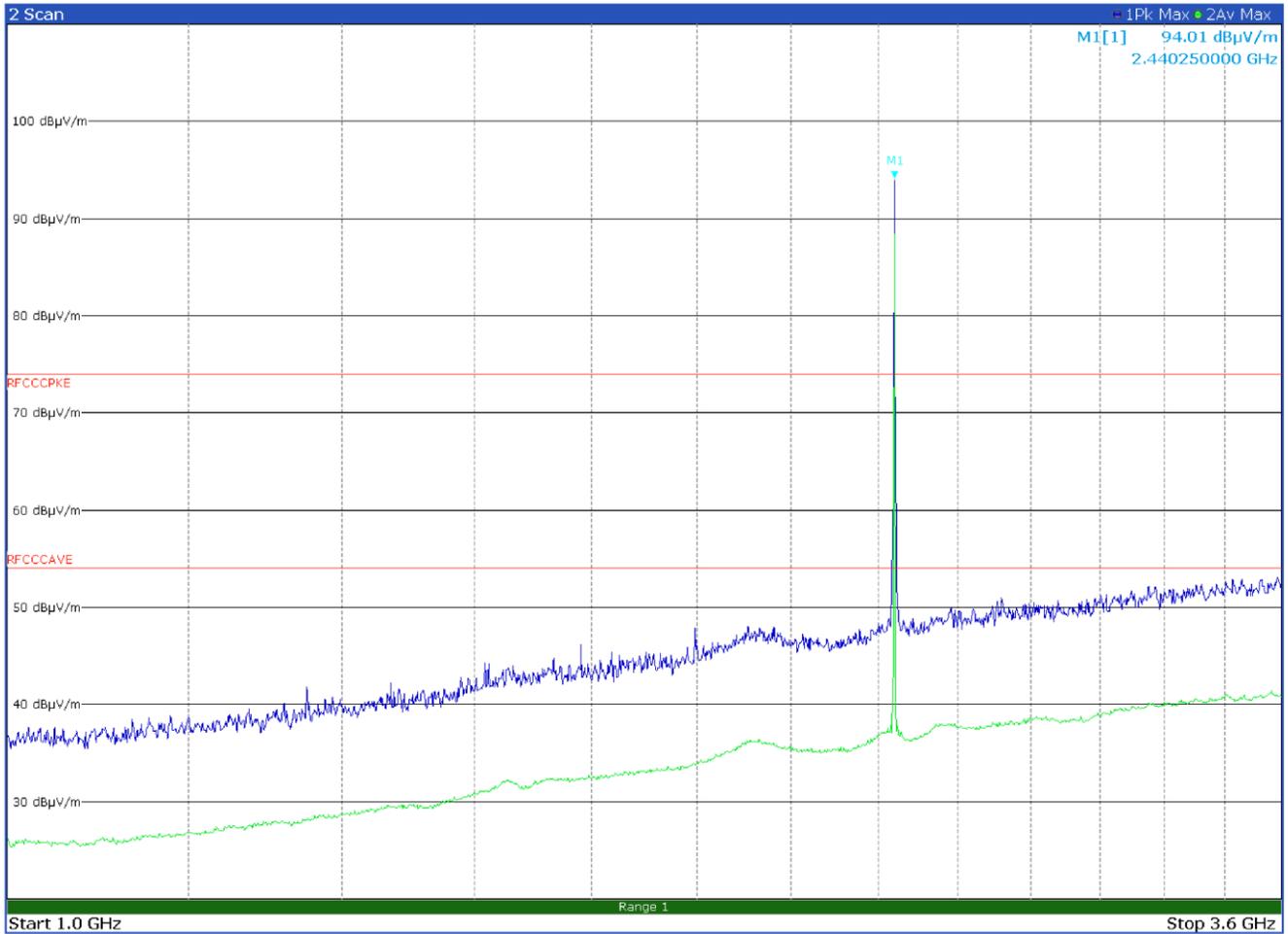


Figure 8.6-11: Radiated spurious emissions on mid channel with antenna in horizontal polarization

No spurious detected in this range- Limit exceeded by the carrier

Test data, continued

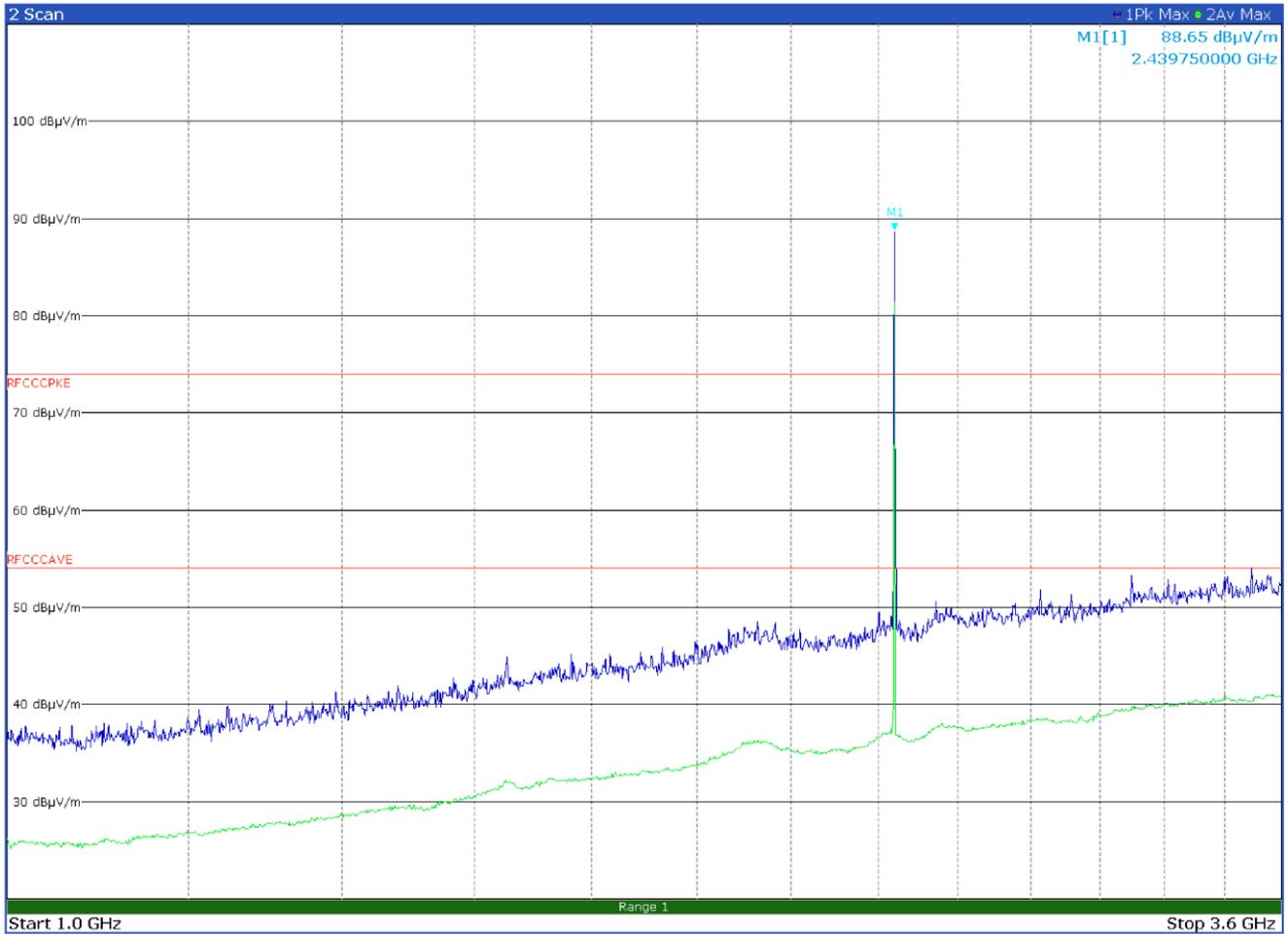


Figure 8.6-12: Radiated spurious emissions on mid channel with antenna in vertical polarization

No spurious detected in this range- Limit exceeded by the carrier

Test data, continued

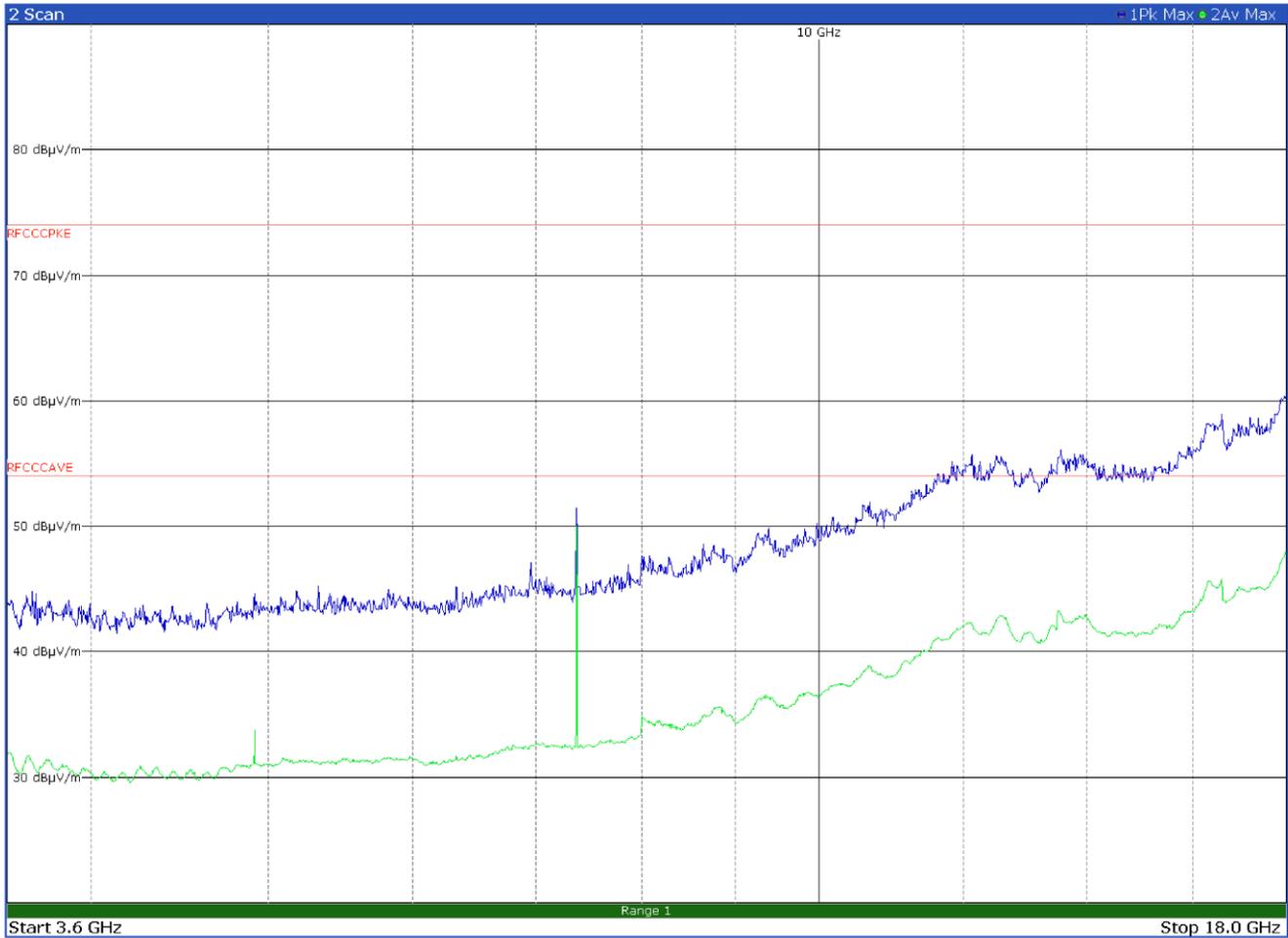


Figure 8.6-13: Radiated spurious emissions on mid channel with antenna in horizontal polarization

Frequency (GHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
7.3207	51.7	74	-22.3	Pk
7.3207	46.1	54	-7.9	Av

Test data, continued

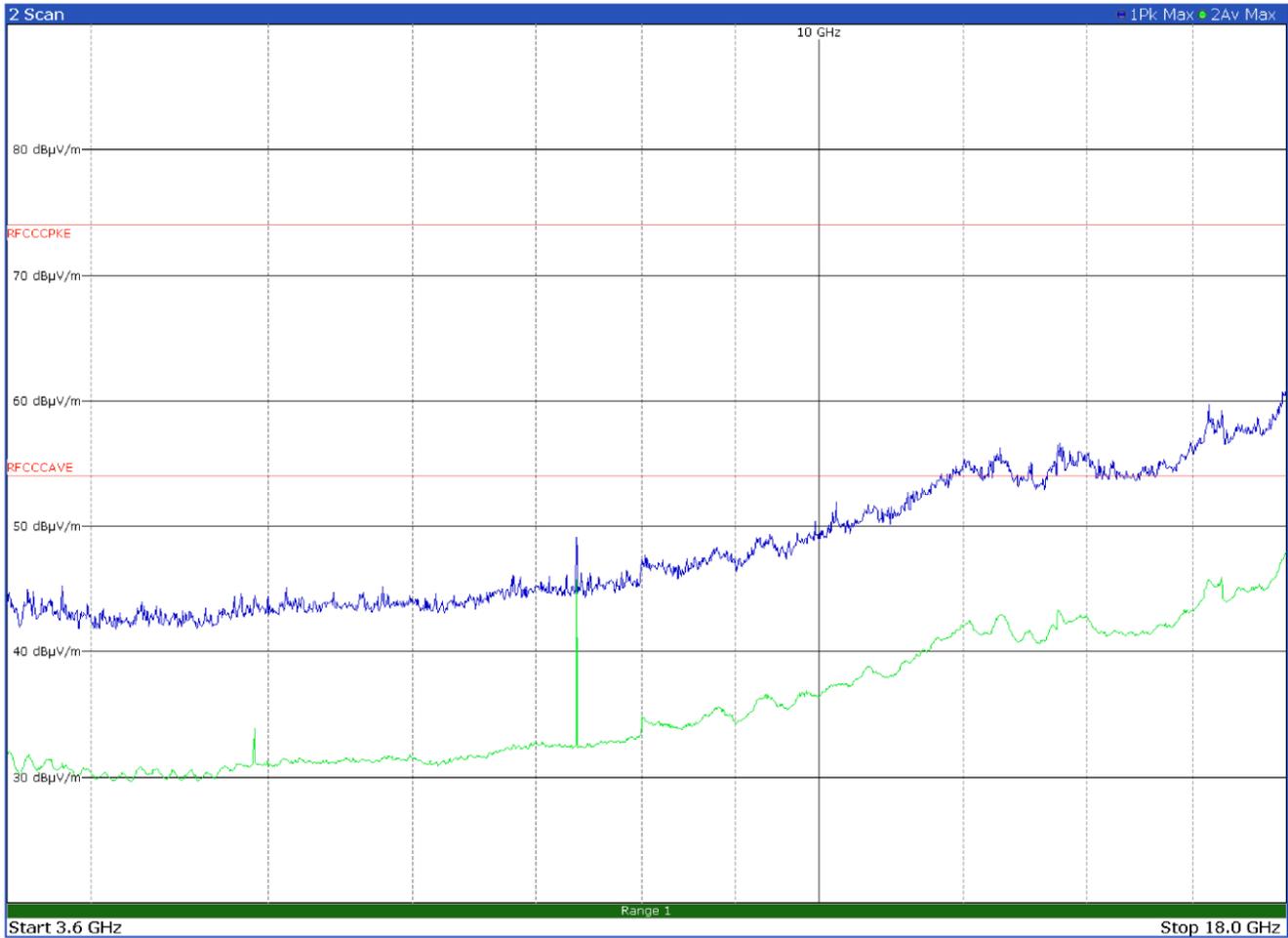


Figure 8.6-14: Radiated spurious emissions on mid channel with antenna in vertical polarization

Frequency (GHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
7.3207	49.3	74	-24.7	Pk
7.3207	45.2	54	-8.8	Av

Test data, continued

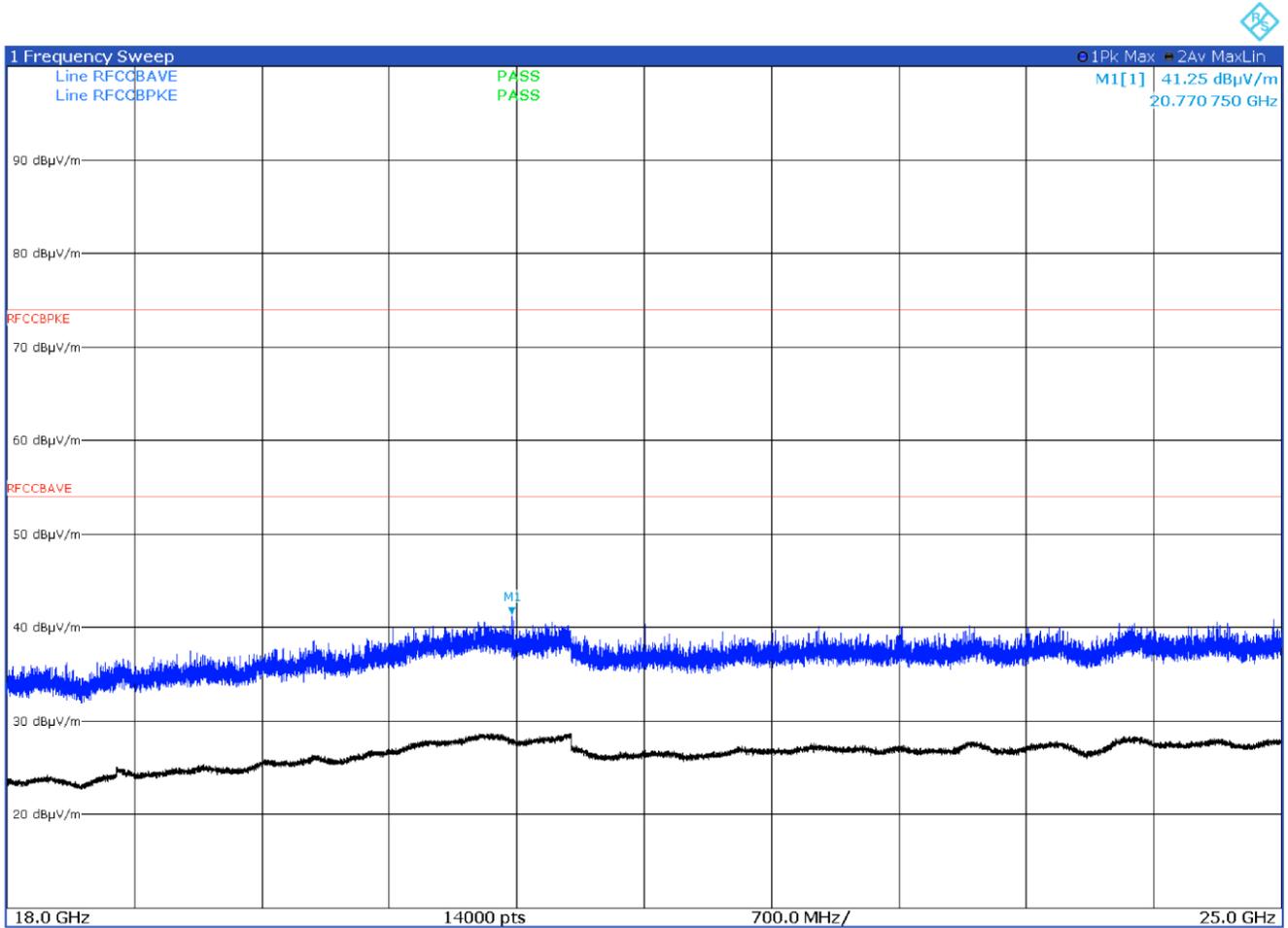


Figure 8.6-15: Radiated spurious emissions on mid channel with antenna in horizontal polarization

No spurious detected in this range

Test data, continued

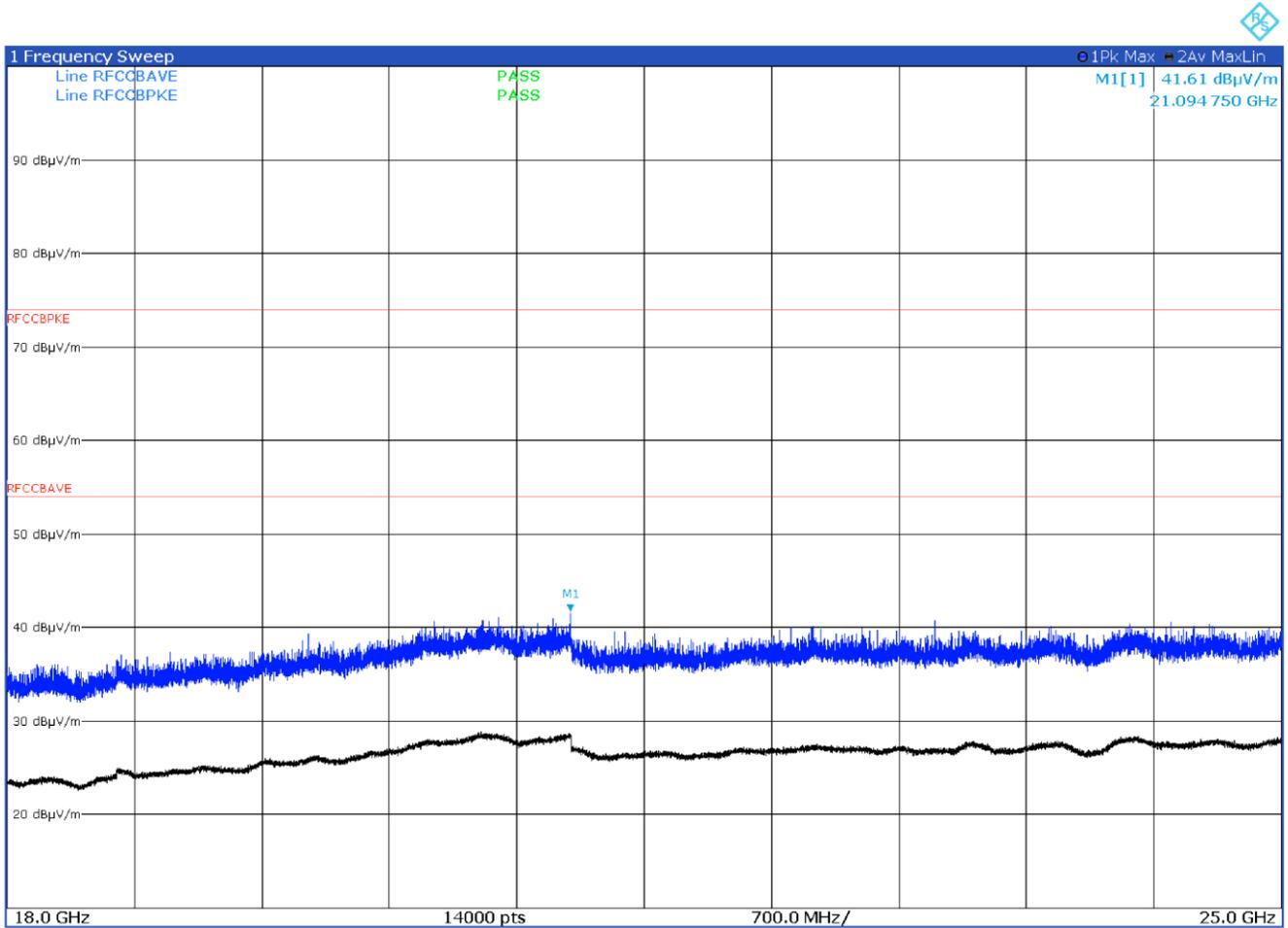


Figure 8.6-16: Radiated spurious emissions on mid channel with antenna in vertical polarization

No spurious detected in this range

Test data, continued

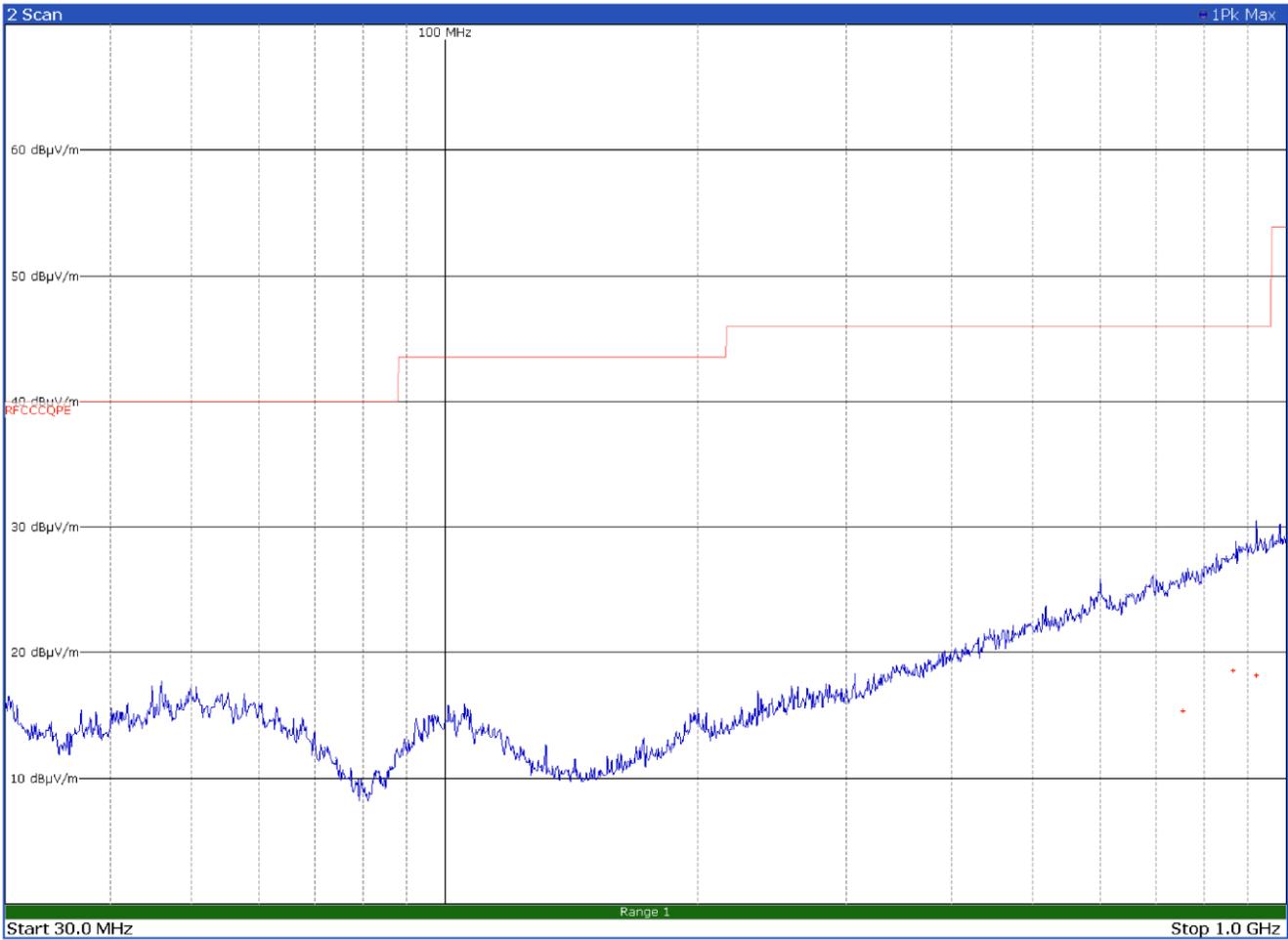


Figure 8.6-17: Radiated spurious emissions on high channel with antenna in horizontal polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
753.7200	15.4	46.0	-30.6	QP
864.8700	18.6	46.0	-27.4	QP
921.9300	18.2	46.0	-27.8	QP

Test data, continued

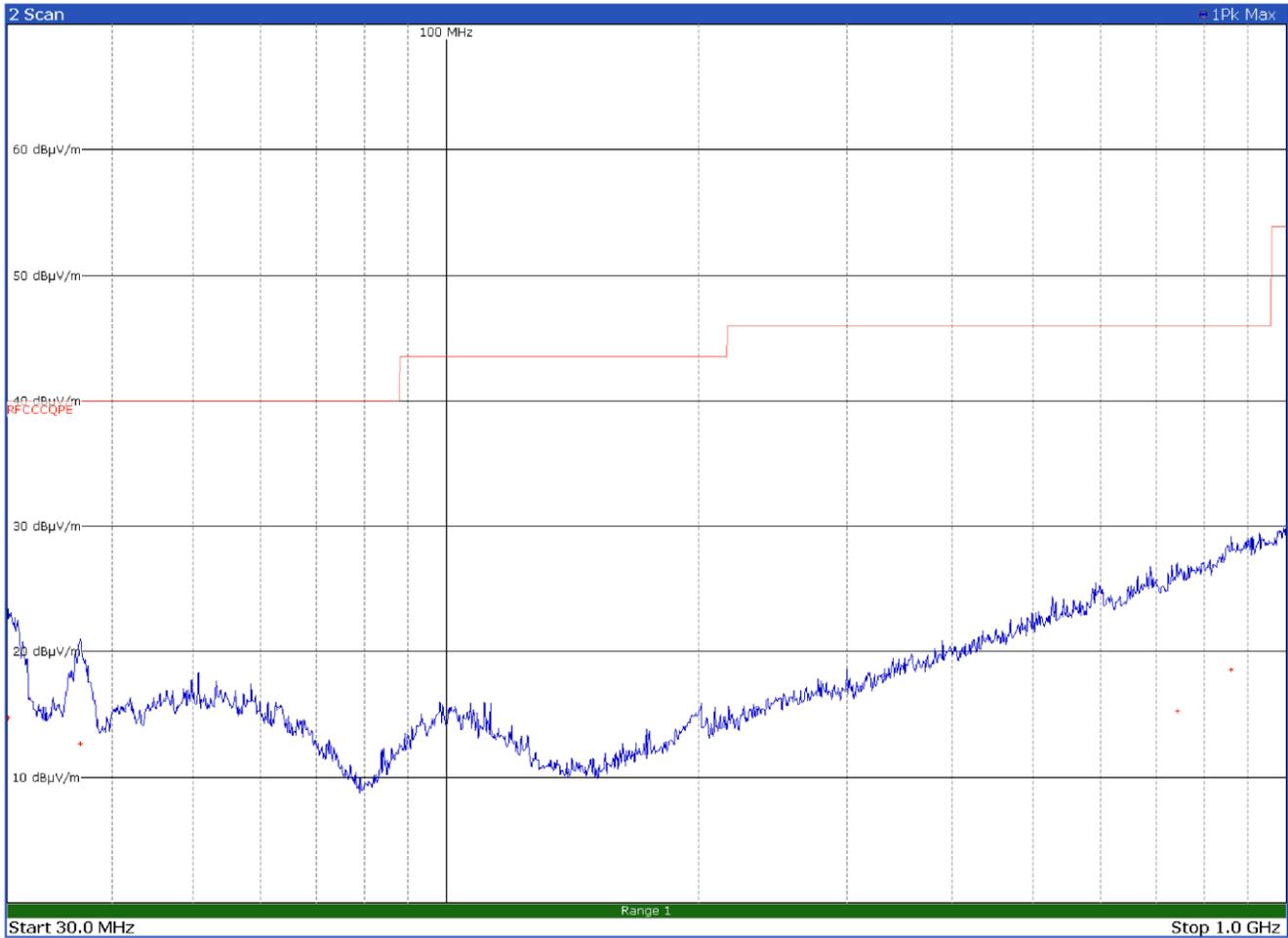


Figure 8.6-18: Radiated spurious emissions on high channel with antenna in vertical polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
30.0900	14.8	40.0	-25.2	QP
36.6900	12.7	40.0	-27.3	QP
741.3300	15.3	46.0	-30.7	QP
860.7000	18.6	46.0	-27.4	QP

Test data, continued

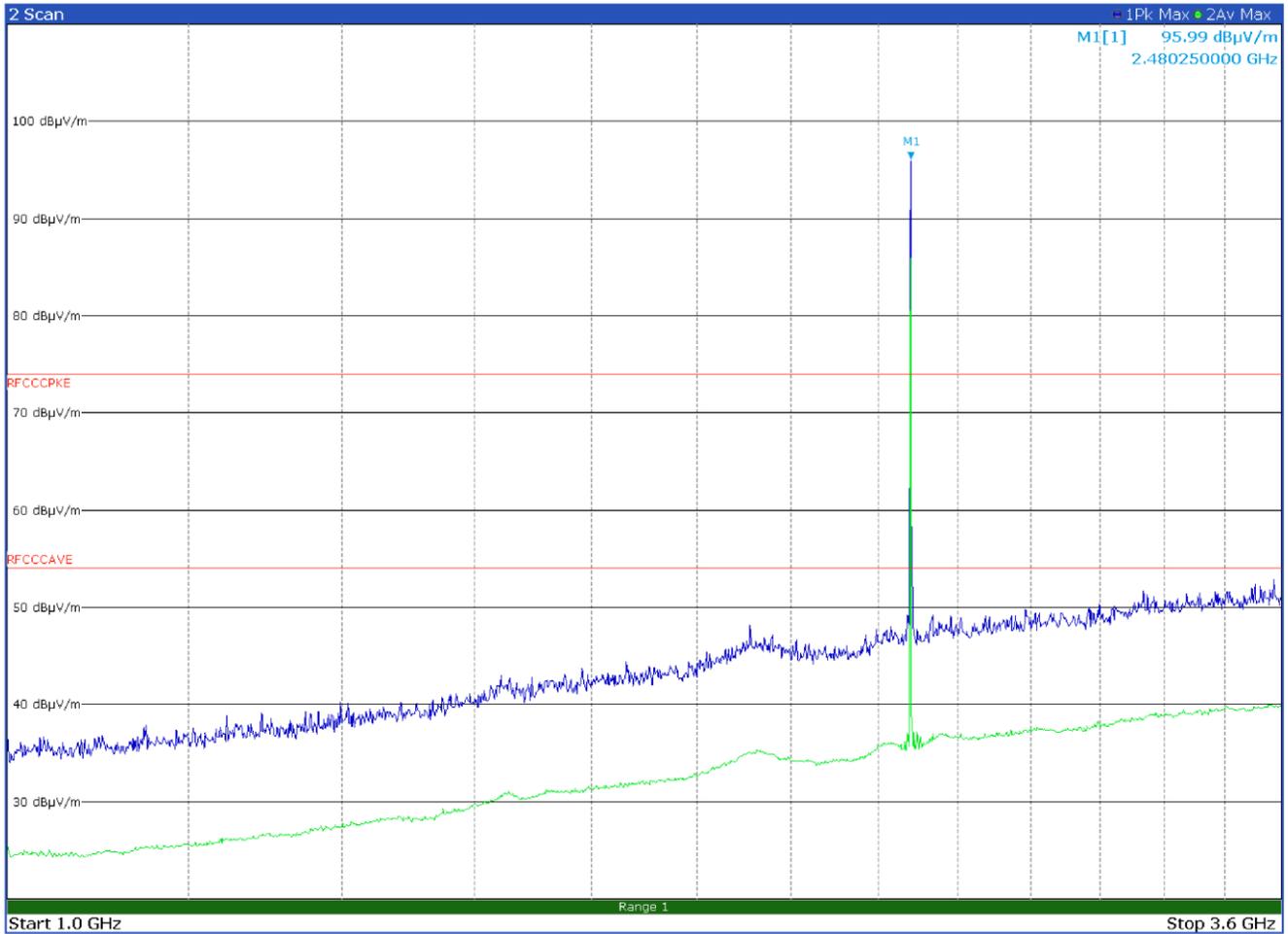


Figure 8.6-19: Radiated spurious emissions on high channel with antenna in horizontal polarization

No spurious detected in this range- Limit exceeded by the carrier

Test data, continued

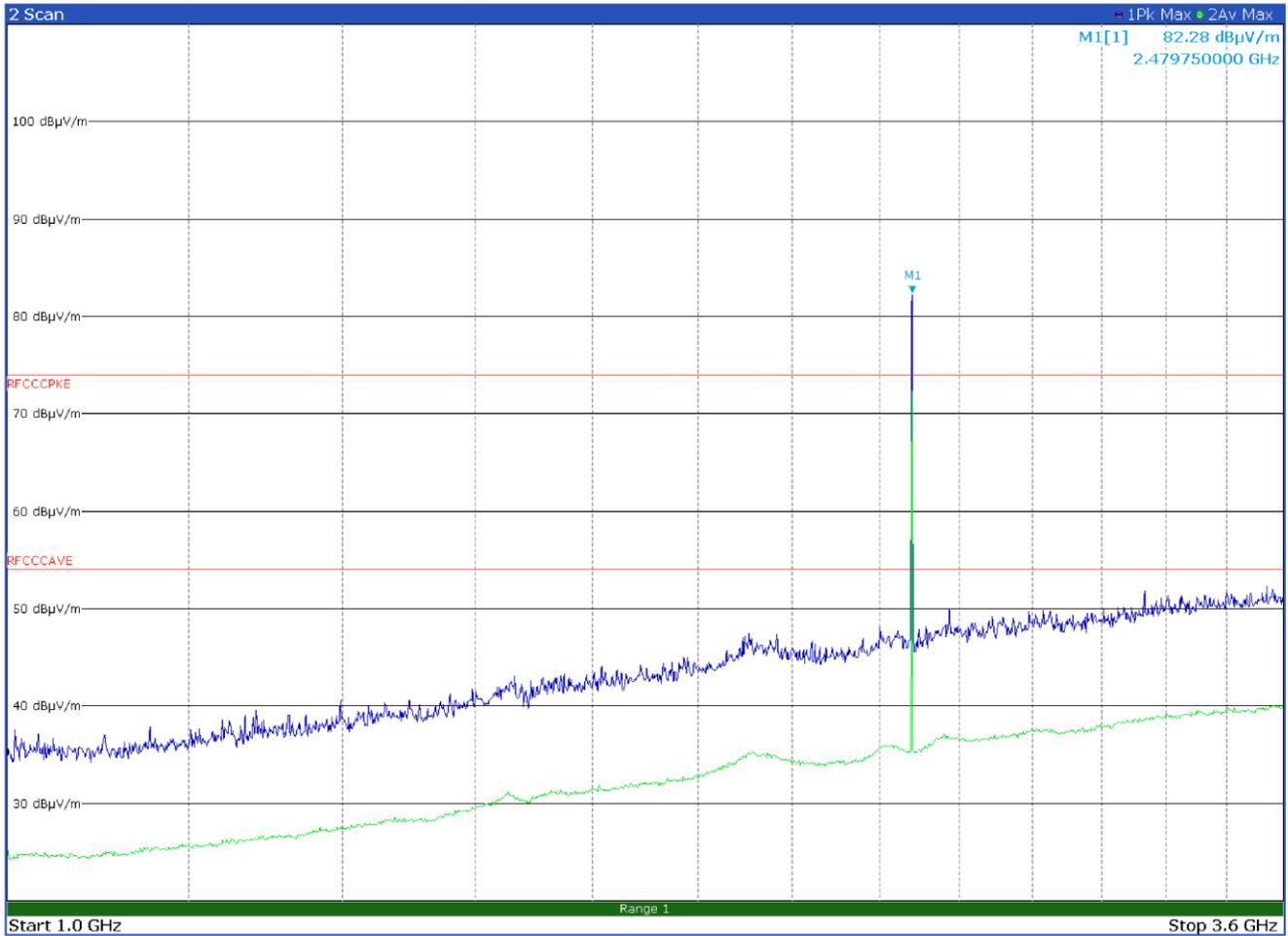


Figure 8.6-20: Radiated spurious emissions on high channel with antenna in vertical polarization

No spurious detected in this range- Limit exceeded by the carrier

Test data, continued

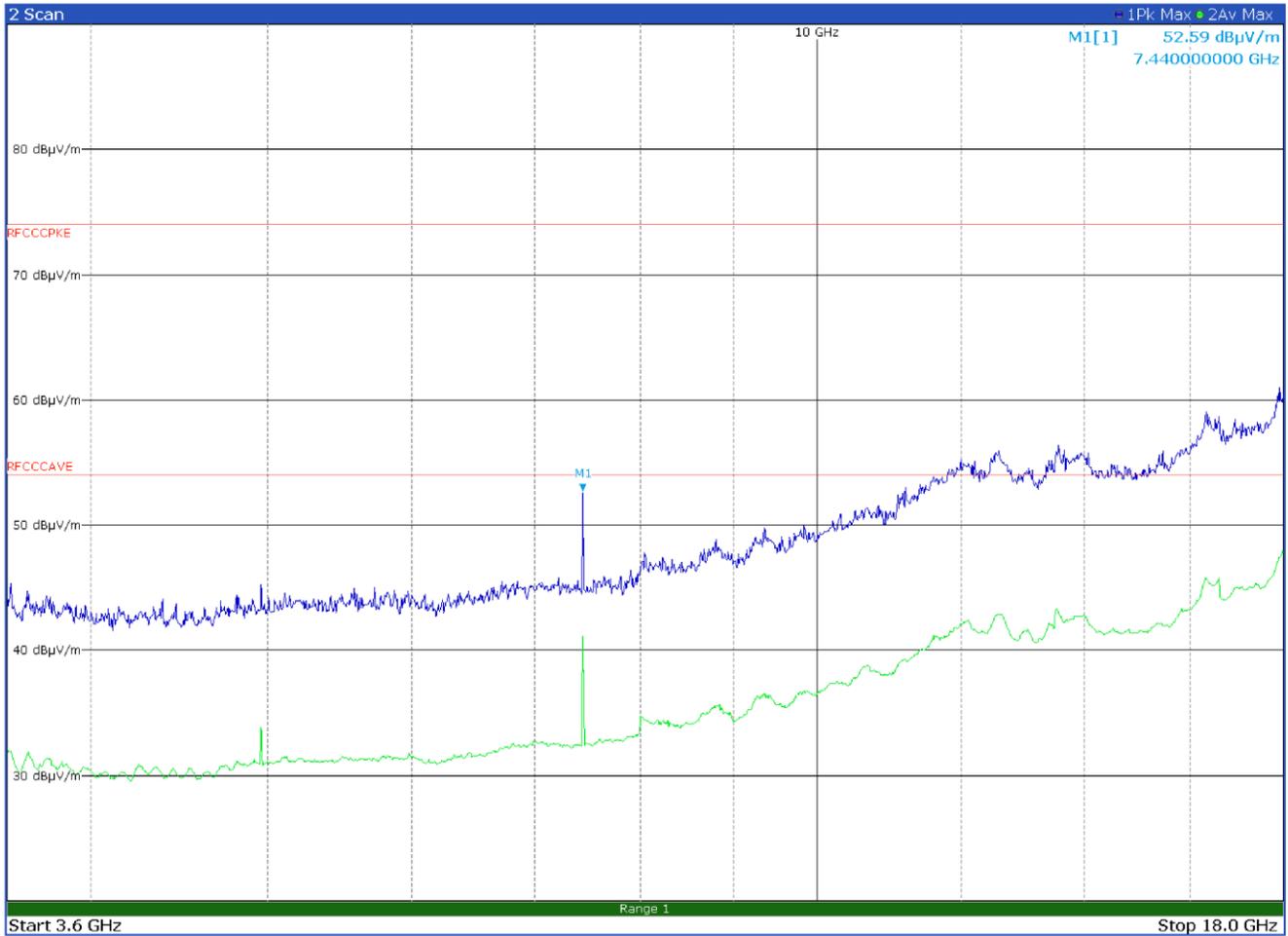


Figure 8.6-21: Radiated spurious emissions on high channel with antenna in horizontal polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
7.4400	52.6	74	-21.4	Pk
7.4400	48.1	54	-5.9	Av

Test data, continued

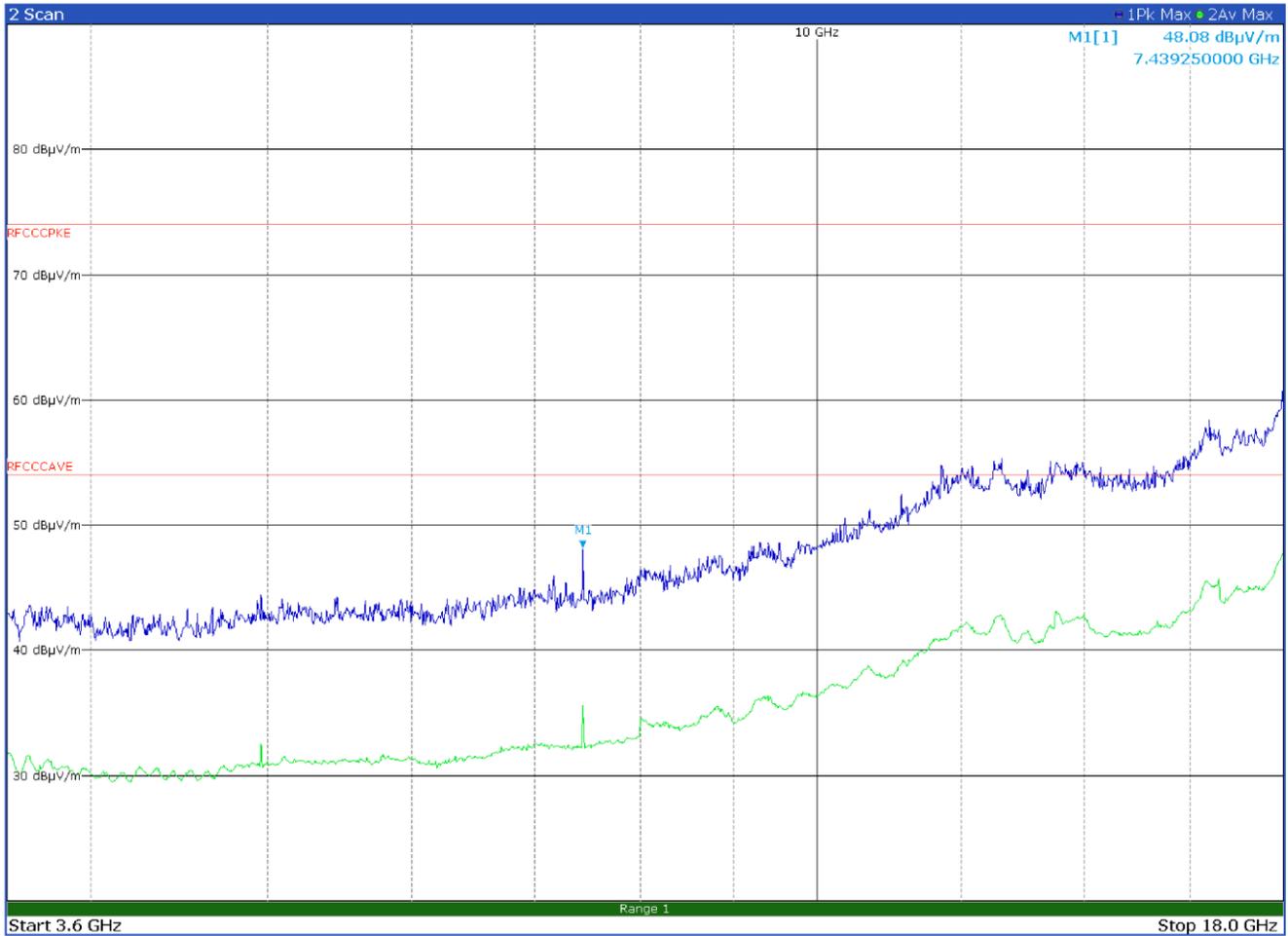


Figure 8.6-22: Radiated spurious emissions on high channel with antenna in vertical polarization

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
7.4392	48.1	74	-25.9	Pk
7.4392	44.3	54	-9.7	Av

Test data, continued

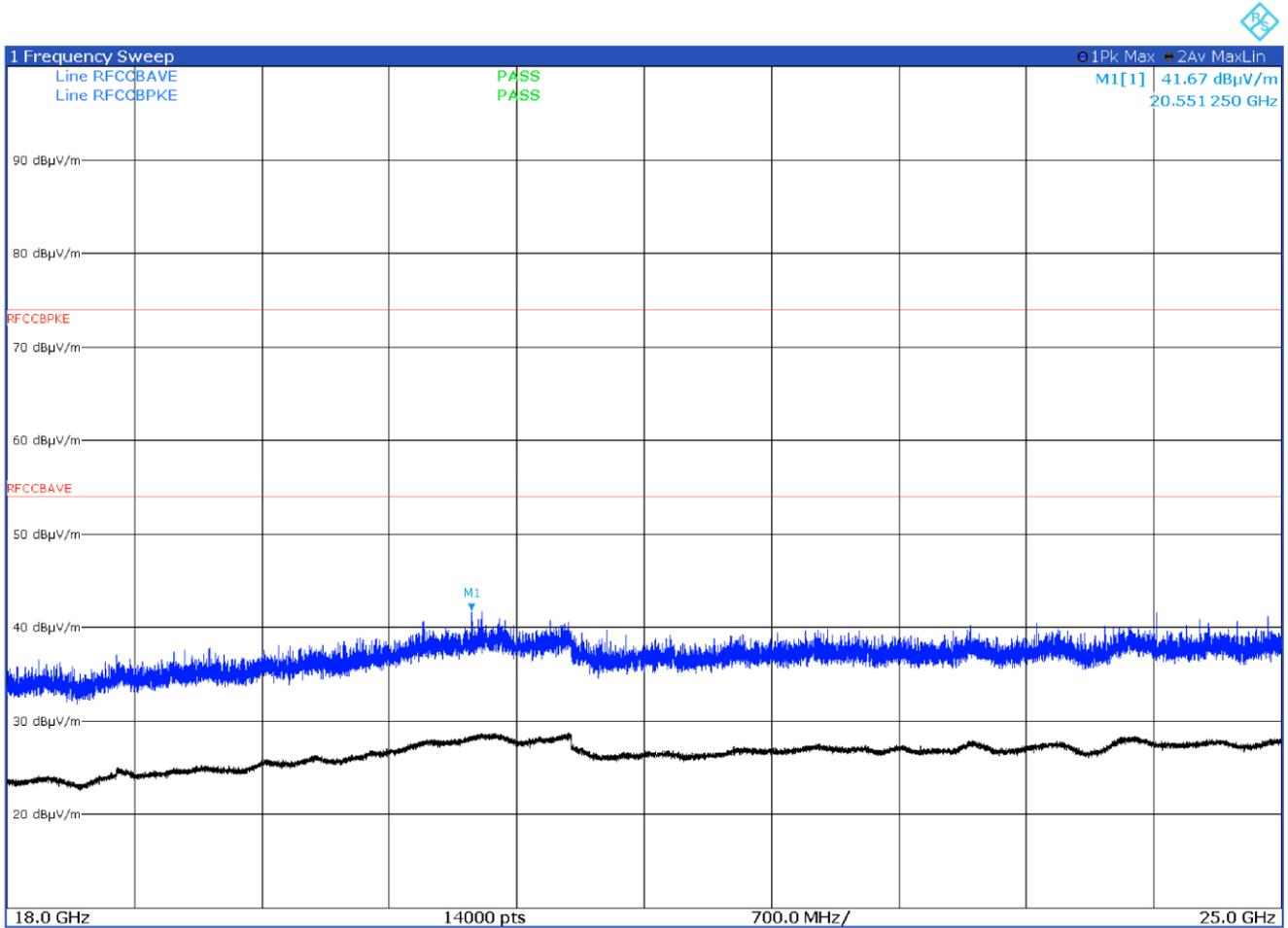


Figure 8.6-23: Radiated spurious emissions on high channel with antenna in horizontal polarization

No spurious detected in this range

Test data, continued

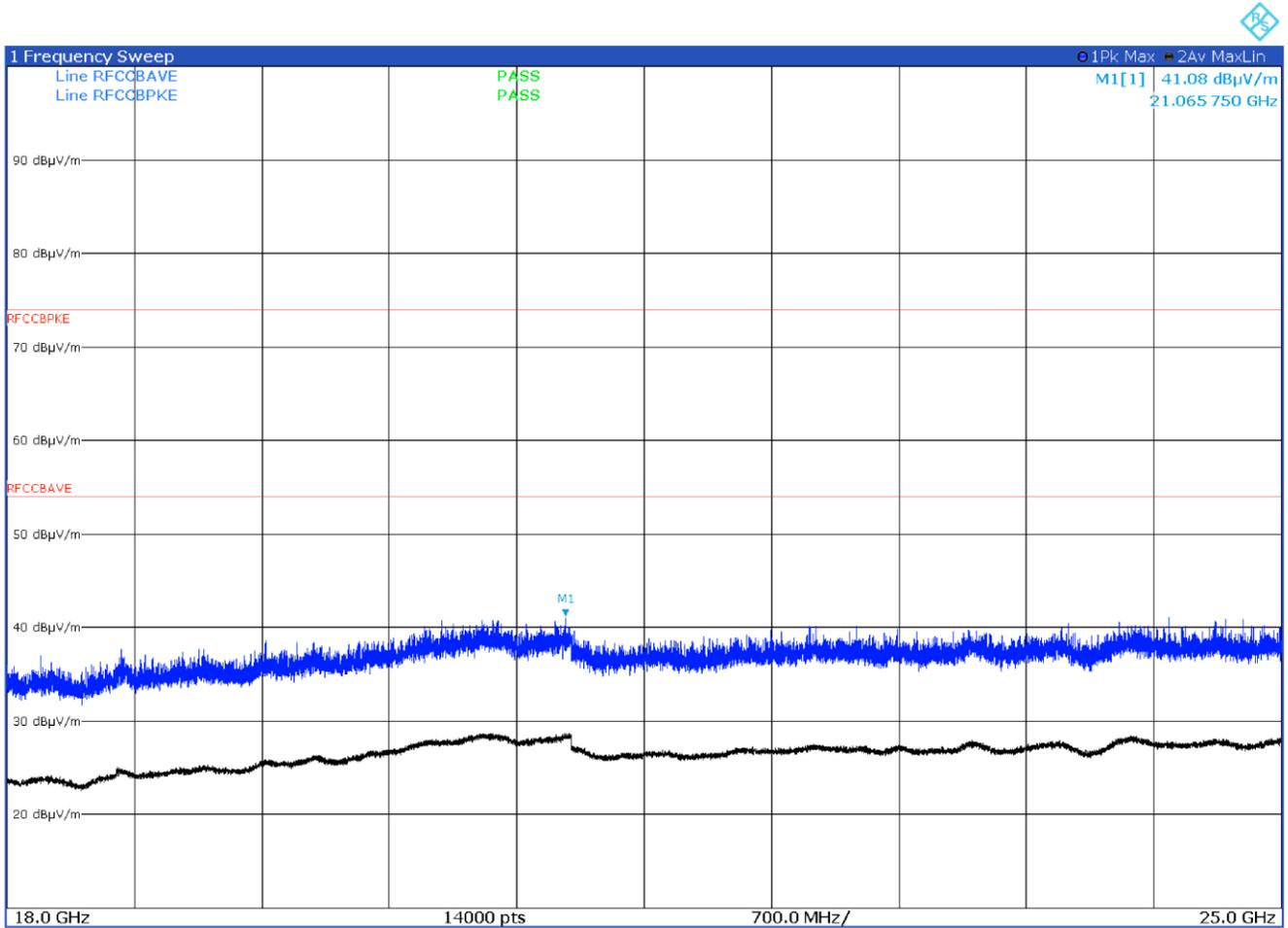


Figure 8.6-24: Radiated spurious emissions on high channel with antenna in vertical polarization

No spurious detected in this range

Test data, continued



Figure 8.6-25: Band edge spurious emissions at 2400 MHz

Test data, continued

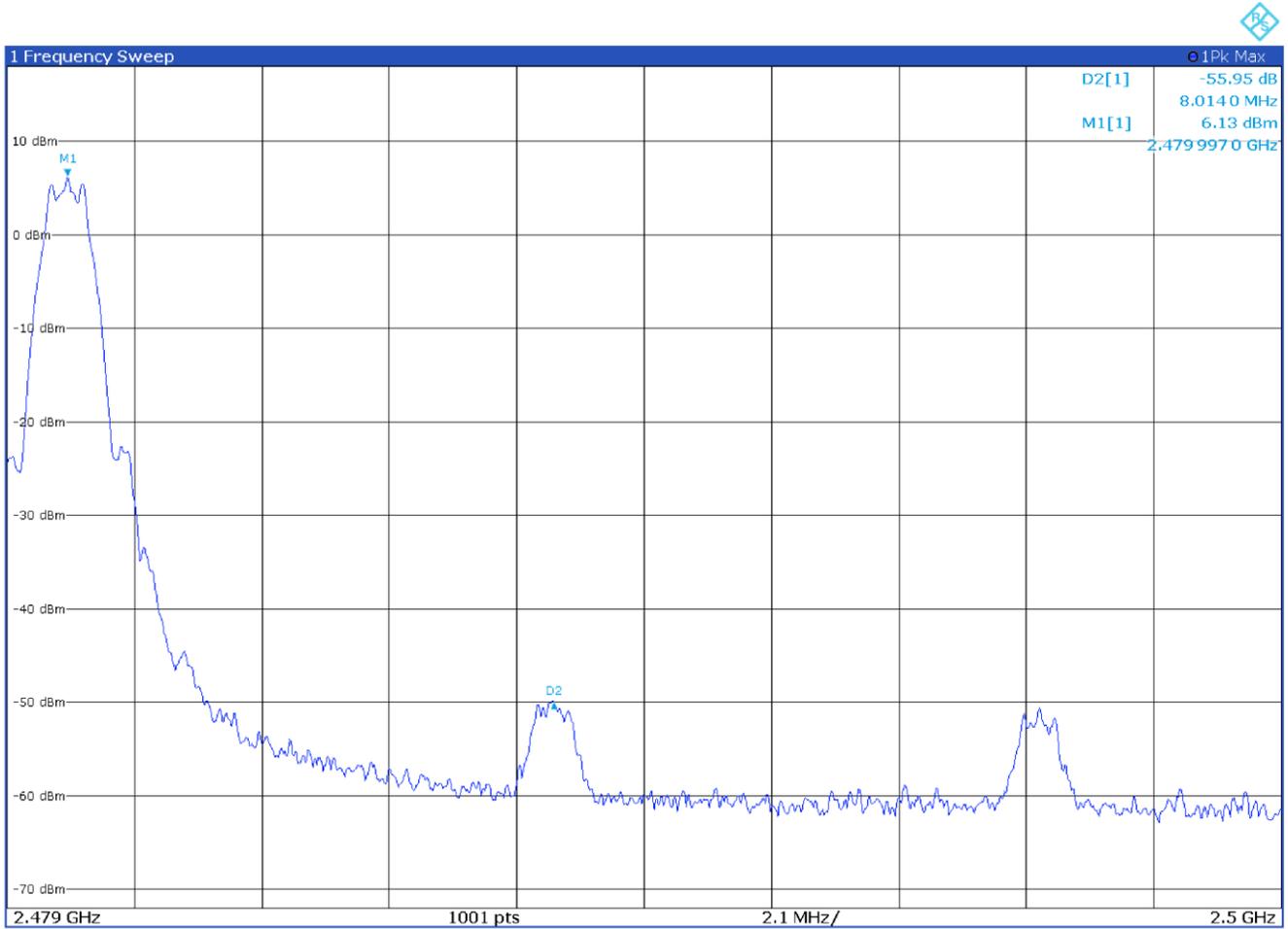


Figure 8.6-26: Band edge spurious emissions at 2483.5 MHz

8.7 Power spectral density for digitally modulated devices

8.7.1 References, definitions and limits

FCC §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.
- (f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

8.7.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	October 3, 2022
Sample tested	4744740003		

8.7.3 Observations, settings and special notes

Power spectral density test was performed as per KDB 558074, section 8.4 with reference to ANSI C63.10 subclause 11.10.

The test was performed using method PKPSD (peak PSD).

Spectrum analyser settings:

Resolution bandwidth:	3 kHz ≤ RBW ≤ 100 kHz
Video bandwidth:	≥3 × RBW
Frequency span:	1.5 times the DTS BW (Peak)
Detector mode:	Peak
Trace mode:	Max-Hold

8.7.4 Test equipment used

Equipment	Manufacturer	Model no.	Asset no.
Spectrum Analyzer	Rohde & Schwarz	FSW43	101767

8.7.5 Test data

Table 8.7-1: PSD results (conducted measurement)

Frequency, MHz	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
2402	-9.9	8	-17.9
2442	-10.1	8	-18.1
2480	-9.7	8	-17.7

Note:

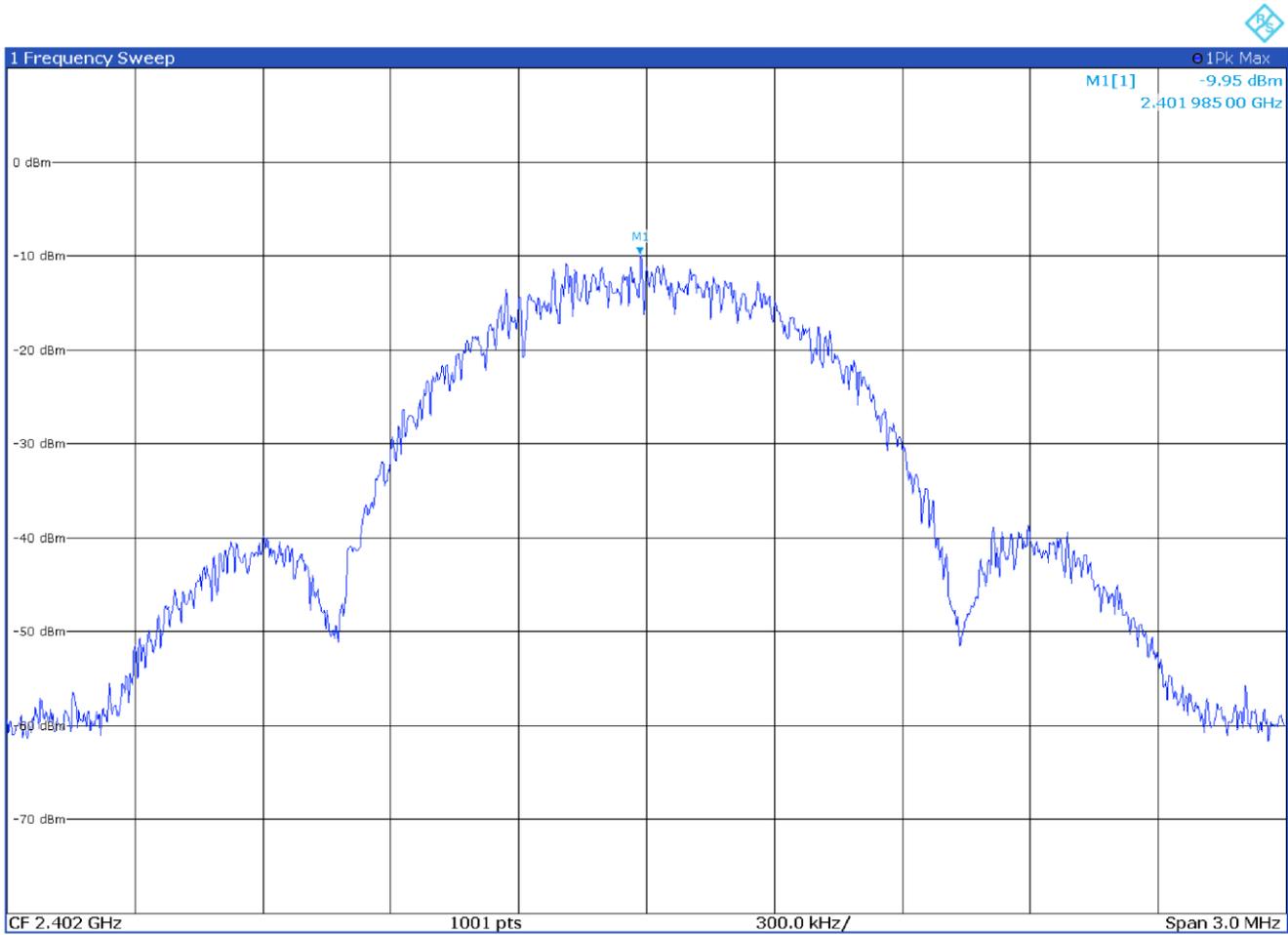


Figure 8.7-1: PSD on low channel

Test data, continued

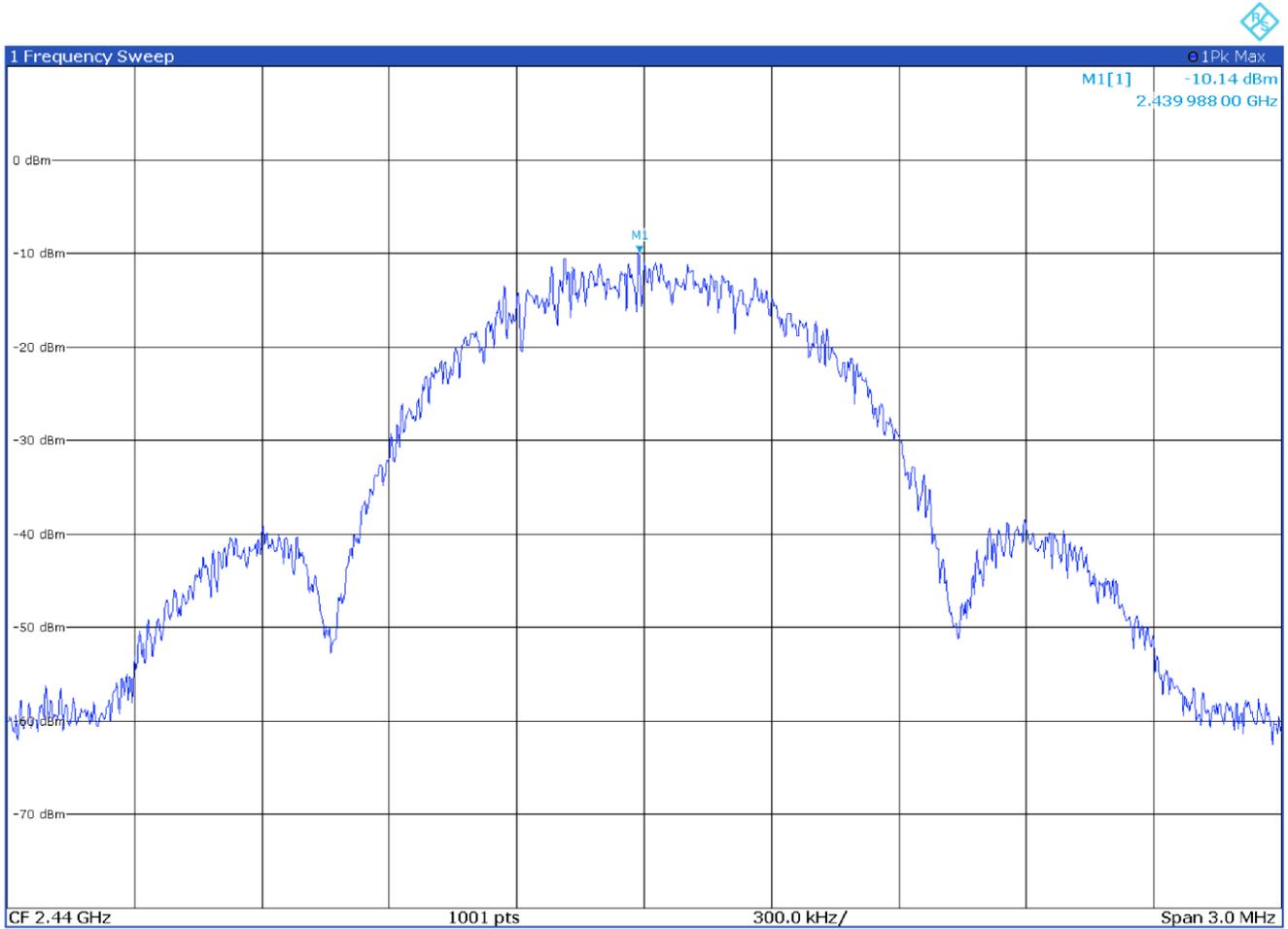


Figure 8.7-2: PSD on mid channel

Test data, continued

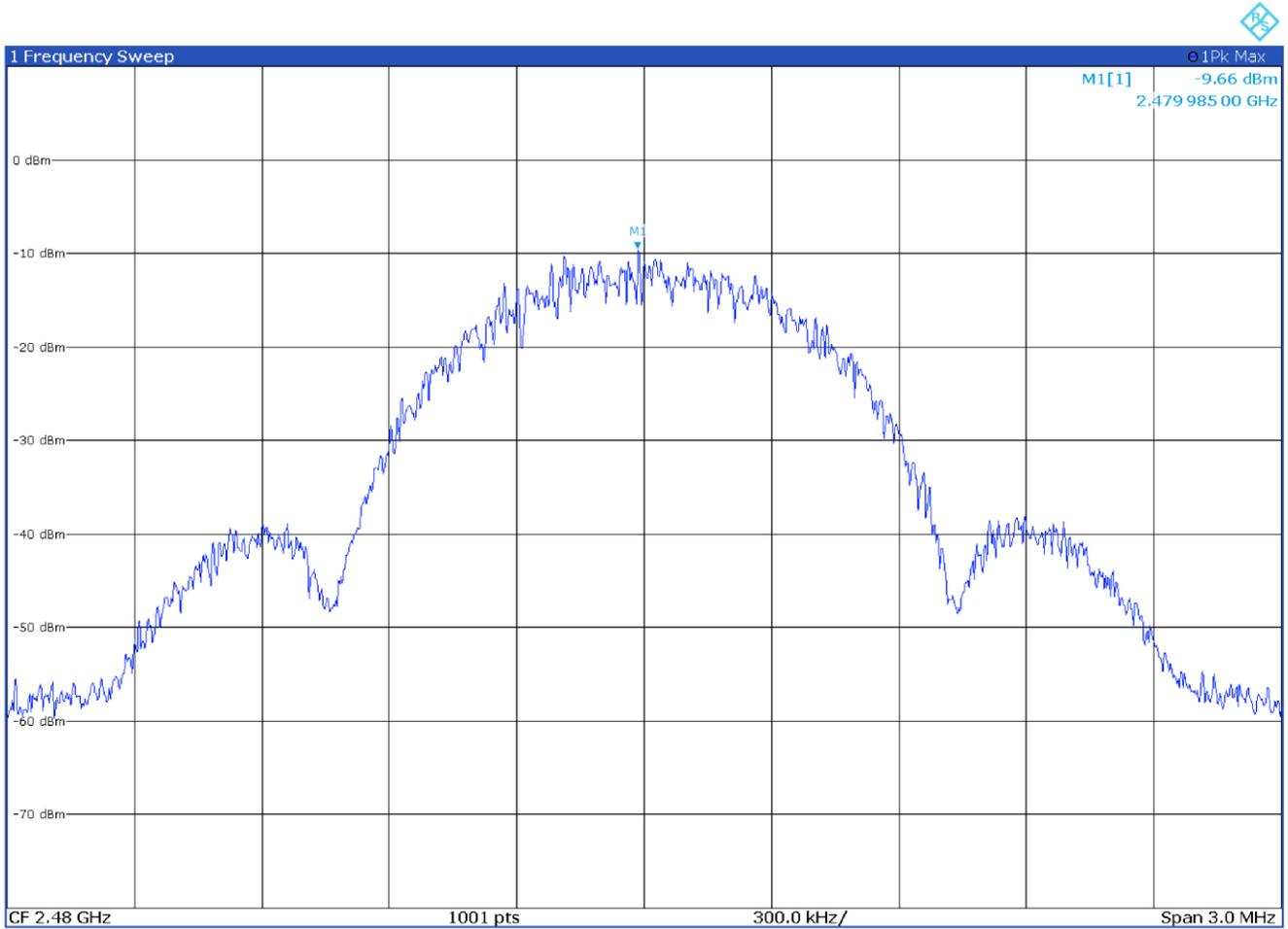


Figure 8.7-3: PSD on high channel

Section 9 EUT photos

9.1 Set-up photos



Figure 9.1-1: Radiated emissions set-up for frequencies below 1 GHz



Figure 9.1-2: Radiated emissions set-up for frequencies above 1 GHz

9.2 External photos



Figure 9.2-1: External view photo



Figure 9.2-2: External view photo

End of the test report