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RADIO TEST REPORT – REP044594

Type of assessment:

Final product testing

Applicant:

EchoStar Mobile Limited (EML)
3 Dublin Landings, North Wall Quay,
Dublin 1, D01 C4E0 - Ireland

Product:

OEM module sensor

Model:

EM2050

FCC ID:

2A8O9-EM2050

IC Registration number:

29249-EM2050

Specifications:

- FCC 47 CFR Part 25
- RSS-170, Issue 4, September 29, 2022
- RSS-Gen, Issue 5, April 2018, Amd 1 (March 2019), Amd 2 (Feb 2021)

Date of issue: June 17, 2024

P. Barbieri	
Tested by	Signature
D. Guarnone	
Reviewed by	Signature

Lab locations

Company name	Nemko Spa
Address	Via del Carroccio, 4
City	Biassono
Province	MB
Postal code	20853
Country	Italy
Telephone	+39 039 220 12 01
Facsimile	+39 039 220 12 21
Website	www.nemko.com
ISED number	9109A
FCC registration number	682159

Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report. This test report has been completed in accordance with the requirements of ISO/IEC 17025. All results contain in this report are within Nemko Spa ISO/IEC 17025 accreditation.

Copyright notification

Table of Contents

Section 1 Report summary

1.1 Test specifications

FCC 47 CFR Part 25	Satellite Communications
RSS-170, Issue 4, September 29, 2022	Mobile Earth Stations (MESs) and Ancillary Terrestrial Component (ATC) Equipment Operating in the Mobile-Satellite Service (MSS) Bands
RSS-Gen, Issue 5, April 2018, Amd 1 (March 2019), Amd 2 (Feb 2021)	General Requirements for Compliance of Radio Apparatus

1.2 Test methods

ANSI C63.26 v2015	American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services

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
REP044594	June 17, 2024	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	2022-12	2024-12
Thermo-hygrometer data loggers	Testo	175-H2	38203337/703	2022-12	2024-12
Barometer	Castle	GPB 3300	072015	2024-04	2025-04

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 ±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, ETSI TR 100 028-1, ETSI TR 100 028-2 and other specific test standards and is documented in Nemko Spa working manuals WML1002 and WML0078.
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	EchoStar Mobile Limited (EML)
Applicant address	3 Dublin Landings, North Wall Quay, Dublin 1, D01 C4E0 - Ireland
Manufacture name	Same as applicant
Manufacture address	Same as applicant

5.3 EUT information

Product	OEM module sensor
Model	EM2050
Serial number	4659020001 (Number assigned by Nemko Spa)
Power supply requirements	DC: 3.3 V
Product description and theory of operation	The EUT is an OEM module sensor capable of transmitting and receiving both multiband LoRa® and LR-FHSS signals in licensed S band and ISM band, for the intended scope of satellite communication.

5.4 Radio technical information

Frequency band	Up-link 2010 MHz to 2020 MHz Down-link 2185 MHz to 2200 MHz
Frequency Min (MHz)	2010.0625 MHz for LoRa 125 kHz BW 2010.1250 MHz for LoRa 250 kHz BW 2010.0680 MHz for LR-FHSS 137 kHz
Frequency Max (MHz)	2019.9375 MHz for LoRa 125 kHz BW 2019.8750 MHz for LoRa 250 kHz BW 2019.9320 MHz for LR-FHSS 137 kHz
RF power Max (W), Conducted	0.5 W and (27 dBm)
Field strength, dBµV/m @ 3 m	N/A
Measured BW (kHz), 99% OBW	136.0 kHz for LoRa 125 kHz BW 264.5 kHz for LoRa 250 kHz BW 138.4 kHz for LR-FHSS 137 kHz
Type of modulation	LoRa standard
Emission classification	W7D
Transmitter spurious, dBm @ 3 m	-29.5 dBm, @4039.75 MHz
Antenna information	Antenna not provided (U.FL connector)

5.5 EUT setup details

5.5.1 Radio exercise details

Operating conditions	The EUT has been forced in TX mode with the following AT commands send by Tera Term application: LoRa 125 kHz BW AT+TCW=30,2010062500,27,1 AT+TCW=30,2015000000,27,1 AT+TCW=30,2019937500,27,1 LoRa 250 kHz BW AT+TXRAW=0,0,2010125000,27,0,1,12,1,100 AT+TXRAW=0,0,2015000000,27,0,1,12,1,100 AT+TXRAW=0,0,2019875000,27,0,1,12,1,100 LR-FHSS 137 kHz AT+TCW=30,2010068000,27,2 AT+TCW=30,2015000000,27,2 AT+TCW=30,2019932000,27,2
Transmitter state	Transmitter set in to continuous mode with AT commands

5.5.2 EUT setup configuration

Table 5.5-1: *EUT sub assemblies*

Description	Brand name	Model, Part number, Serial number, Revision level
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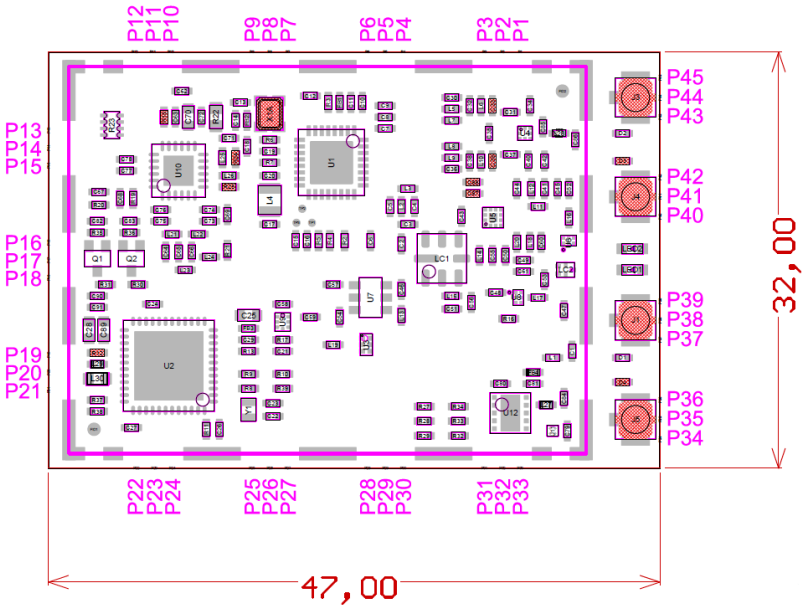
Table 5.5-2: *EUT interface ports*

Description	Qty.
Pin 1 to 45	1



EUT setup configuration, continued

Pin number	Pin Name	Pin Type / Direction	Description
P1	UART_RX	DIG. INPUT	UART RXD input from external application MCU
P2	GND	PWR	
P3	UART_TX	DIG. OUTPUT	UART TXD output to external application MCU
P4	TX_2G_CE	DIG. OUTPUT	H=TX S-BAND active L=TX S-BAND inactive
P5	GND	PWR	
P6	LNA_GPS_ON	DIG. OUTPUT	H=Enable External GPS LNA L=Disable External GPS LNA
P7	SW_ON	DIG. OUTPUT	H=Enable External S-BAND Switch L=Disable External S-BAND Switch
P8	GND	PWR	
P9	VCC	PWR	3.3VDC supply
P10	MCU_RSTn	DIG. INPUT	Apply an external GND level to reset the radio MCU. Internal 10Kohm pullup.
P11	MCU_PH3	DIG. I/O	Reserved, internal 10K pulldown
P12	DNC		
P13	DNC		
P14	DNC		
P15	GND	PWR	
P16	VCC	PWR	3.3VDC supply
P17	GND	PWR	
P18	DNC		
P19	MCU_BUSY / CTSn / EN_BOOTLOADER	DIG. I/O	H=Radio MCU in sleep mode L=Radio MCU in active mode Internal 100Kohm pullup Sampled after reset for bootloader activation
P20	RTSn	DIG. I/O	H=Application MCU in sleep mode L=Application MCU in active mode Requires external 100kohm pullup for low-power operation. If low-power operation is not required, connect to GND through a 10kohm pulldown.
P21	GND	PWR	
P22	GND	PWR	
P23	I2C_SDA	DIG. I/O	I2C bus, SDA line. Internal 1K8 pullup
P24	I2C_SCL	DIG. i/o	I2C bus, SCL line. Internal 1K8 pullup
P25	GND	PWR	
P26	GND	PWR	
P27	GND	PWR	
P28	VCC	PWR	3.3VDC supply
P29	GND	PWR	
P30	GND	PWR	
P31	GND	PWR	

EUT setup configuration, continued

P32	GND	PWR	
P33	VCC_PA	PWR	3.3VDC supply to the Power Amplifier, max. current 500mA. Tracks must be kept as short as possible to minimize voltage drops.
P34	GND	PWR	
P35	TX_S-BAND_ANT	RF OUT	S-Band TX output port
P36	GND	PWR	
P37	GND	PWR	
P38	RX_GPS_ANT	RF INPUT	RF input for GNSS signal
P39	GND	PWR	
P40	GND	PWR	
P41	RX_S-BAND_ANT	RF INPUT	S-Band RX input port
P42	GND	PWR	
P43	GND	PWR	
P44	868_915_RF	RF I/O	TX/RX port for sub-GHz ISM bands (868 / 915MHz)
P45	GND	PWR	

Table 5.5-3: *Support equipment*

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

Table 5.5-4: *Inter-connection cables*

Cable description	From	To	Length (m)
USB (USB/UART TTL converter)	EUT	PC	1.5

EUT setup configuration, continued

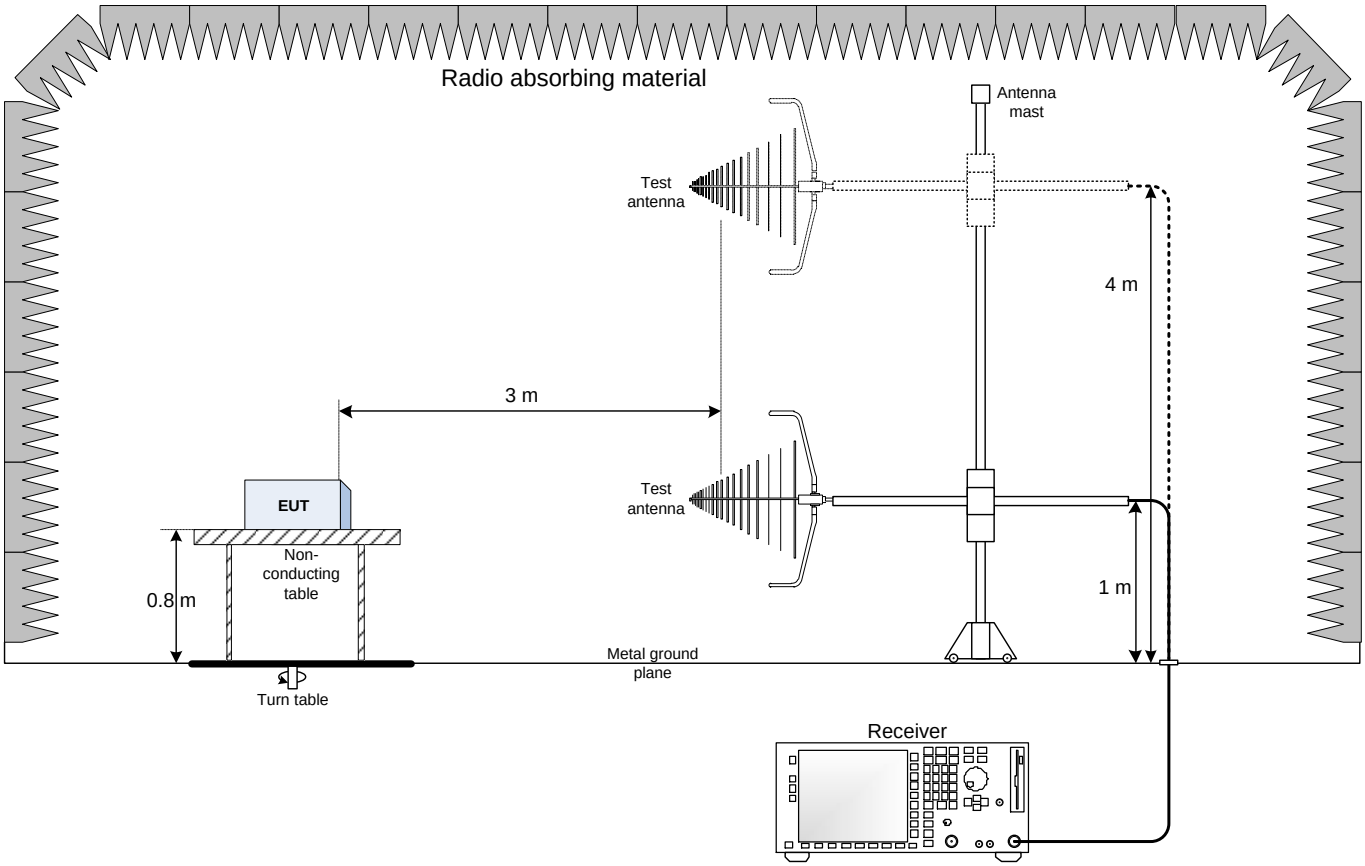


Figure 5.5-1: *Radiated testing block diagram (below 1 GHz)*

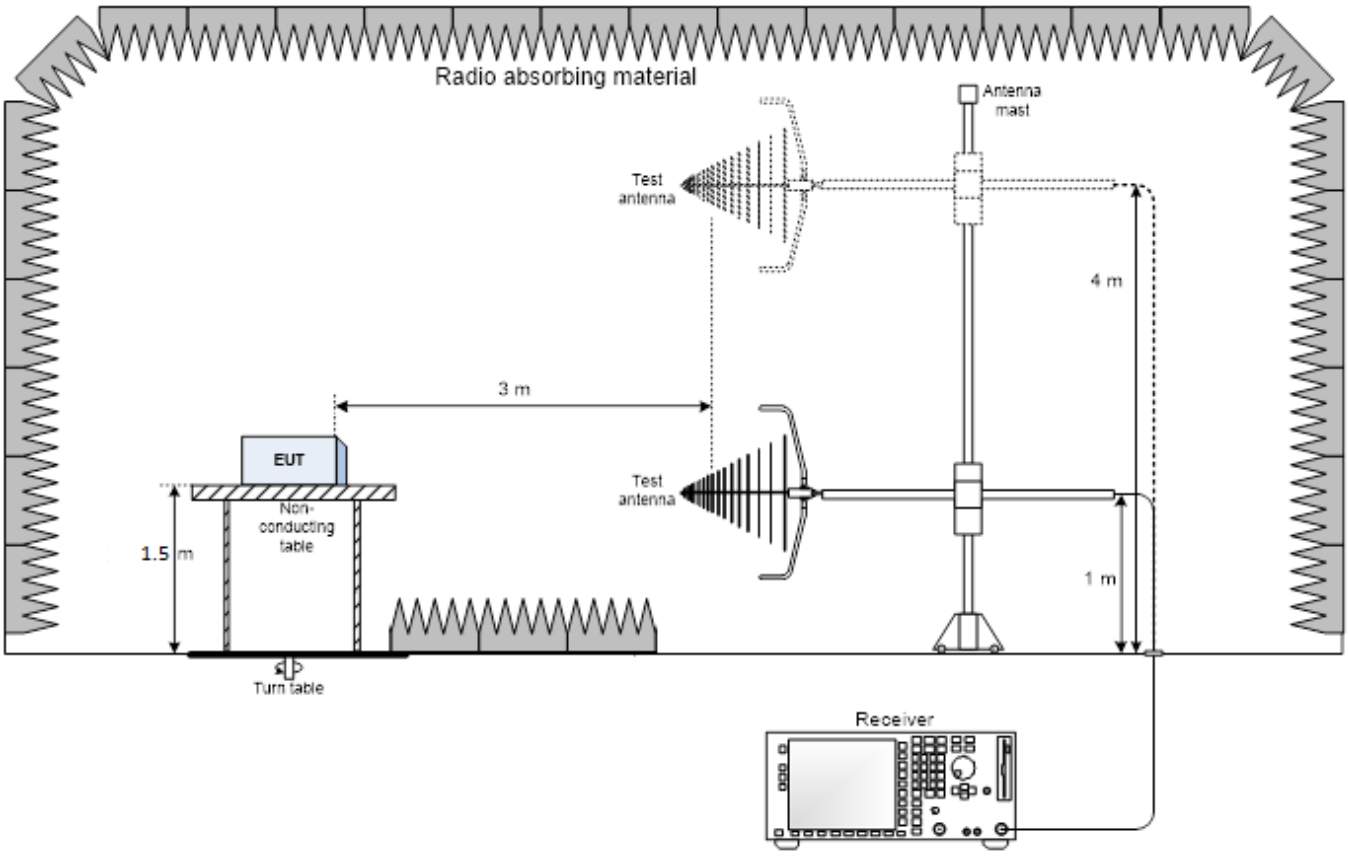


Figure 5.5-2: *Radiated testing block diagram (above 1 GHz)*

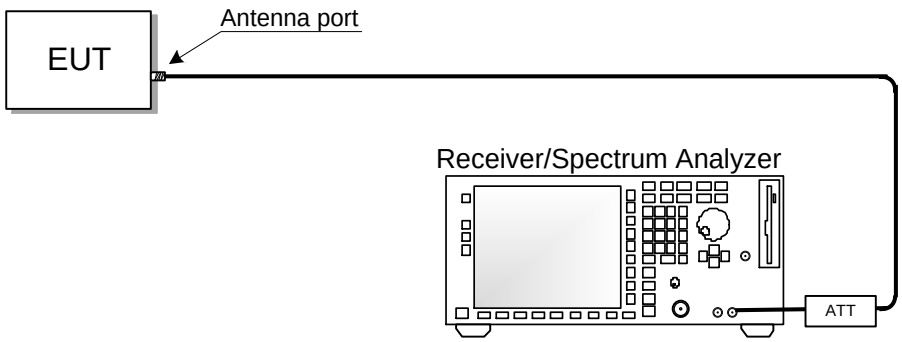


Figure 5.5-3: *Antenna port testing block diagram*

Section 6 Summary of test results

6.1 Testing location

Test location (s)	Nemko S.p.A. Via Del Carroccio, 4 20853 Biassono (MB) Italy

6.2 Testing period

Test start date	May 27, 2024	Test end date	June 14, 2024

6.3 Sample information

Receipt date	June 7, 2022	Nemko sample ID number(s)	4659020001

6.4 FCC Part §25

Table 6.4-1: *FCC requirements results*

Part	Test description	Verdict
§25.204	RF power output	Pass
§25.202(f)	Occupied bandwidth mask	Pass
§25.202(f)(3)	Spurious emissions at antenna terminals	Pass
§25.202(f)(3)	Field strength of spurious radiation	Pass
§25.202(d)	Frequency stability	Pass

Notes: --

6.5 ISED RSS-170, Issue 4, test results

Table 6.5-1: *ISED requirements results*

Part	Test description	Verdict
5.4	RF power output	Pass
5.4	Occupied bandwidth mask	Pass
5.4	Spurious emissions at antenna terminals	Pass
5.4	Field strength of spurious radiation	Pass
5.3	Frequency stability	Pass

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	2023-12	2024-12
EMI Receiver	Rohde & Schwarz	ESW44	101620	2023-08	2024-08
EMI Receiver	Rohde & Schwarz	ESU8	100202	2021-07	2024-07
Antenna Trilog 25MHz - 8GHz	Schwarzbeck Mess-Elektronik	VULB9162	9162-025	2021-09	2024-09
Antenna 1 - 18 GHz	Schwarzbeck Mess-Elektronik	STLP9148	STLP 9148-152	2023-04	2026-04
Double Ridge Horn Antenna	RFSpin	DRH40	061106A40	2024-03	2025-03
Broadband Amplifier	Schwarzbeck Mess-Elektronik	BBV9718C	00121	2024-05	2025-05
Broadband Bench Top Amplifier	Sage	STB-1834034030-KFKF-L1	18490-01	NCR	NCR
Controller	Maturo	FCU3.0	10041	NCR	NCR
Tilt antenna mast	Maturo	TAM4.0-E	10042	NCR	NCR
Turntable	Maturo	TT4.0-5T	2.527	2023-09	2025-09
Semi-anechoic chamber	Nemko S.p.a.	10m semi-anechoic chamber	530	2023-09	2024-09
EMI receiver	R&S	ESU8	100202	2023-07	2024-07
Attenuator	Aeroflex / Weinschel	2	CC8577	2024-03	2025-03
LISN 9 kHz ÷ 30 MHz	R&S	ESH2-Z5	881 362/006	NCR	NCR
Shielded room	Siemens	Conducted emission test room	1862	2023-10	2024-10
Climatic chamber	espec	ARS-1100	4100000067	NCR	NCR
Cable set	Rosenberger	ST.ALO-02	1.650	2023-12	2024-12
Software turntable and mast	Maturo	mcApp	8.1.0.5410	2023-08	2024-08

Notes: NCR - no calibration required, VOU - 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	May 28, 2024

8.1.3 Observations, settings and special notes

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

a) 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.
b) For devices, where operating at a supply voltage deviating ±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.
c) 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.
d) 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:	☐ AC	☒ DC	☐ Battery
If EUT is an AC or a DC powered, was the noticeable output power variation observed?	☐ YES	☒ NO	☐ N/A
If EUT is battery operated, was the testing performed using fresh batteries?	☐ YES	☐ NO	☒ N/A
If EUT is rechargeable battery operated, was the testing performed using fully charged batteries?	☐ YES	☐ NO	☒ 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.

RSS-Gen, Clause 6.9:

Except where otherwise specified, measurements shall be performed for each frequency band of operation for which the radio apparatus is to be certified, with the device operating at the frequencies in each band of operation shown in table below. The frequencies selected for measurements shall be reported in the test report.

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	May 28, 2024

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:

a) 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.

b) 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.

c) 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:

a) 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).

b) 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).

c) 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 for LoRa 125 kHz BW*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
2010	2020	10	2010.0625	2015.0000	2019.9375

Table 8.2-3: *Test channels selection for LoRa 250 kHz BW*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
2010	2020	10	2010.1250	2015.0000	2019.8750

Table 8.2-3: *Test channels selection for LoRa LR-FHSS 137 kHz*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
2010	2020	10	2010.0680	2015.0000	2019.9320

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.

RSS-Gen, Clause 6.8:

The applicant for equipment certification shall provide a list of all antenna types that may be used with the transmitter, where applicable (i.e. for transmitters with detachable antenna), indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna. The test report shall demonstrate the compliance of the transmitter with the limit for maximum equivalent isotropically radiated power (e.i.r.p.) specified in the applicable RSS, when the transmitter is equipped with any antenna type, selected from this list.

For expediting the testing, measurements may be performed using only the antenna with highest gain of each combination of transmitter and antenna type, with the transmitter output power set at the maximum level. However, the transmitter shall comply with the applicable requirements under all operational conditions and when in combination with any type of antenna from the list provided in the test report.

8.3.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	May 28, 2024

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	Maximum gain	Connector type
--	--	--	--	--

Note: Antenna not provided. The EUT is a chip to be use in a hosting device.

8.4 RF power output

8.4.1 References, definitions and limits

FCC §25.204:

(a) In bands shared coequally with terrestrial radio communication services, the equivalent isotropically radiated power transmitted in any direction towards the horizon by an earth station, other than an ESV, operating in frequency bands between 1 and 15 GHz, shall not exceed the following limits except as provided for in paragraph (c) of this section:
+ 40 dBW in any 4 kHz band for θ ≤0°
where θ is the angle of elevation of the horizon viewed from the center of radiation of the antenna of the earth station and measured in degrees as positive above the horizontal plane and negative below it.

RSS-170, Clause 5.4:

The maximum e.i.r.p. of ATC mobile equipment transmitting in the band 1610-1626.5 MHz shall not exceed 1 dBW in a 1.25 MHz bandwidth.
The maximum e.i.r.p. of ATC mobile equipment transmitting in the band 1626.5-1660.5 MHz shall not exceed 0 dBW in a channel.
The maximum e.i.r.p. of ATC mobile and base station equipment transmitting in the band 2483.5 2495 MHz shall not exceed 6 dBW per channel bandwidth, and the maximum conducted transmitter output power shall not exceed 0 dBW.
The maximum e.i.r.p. of ATC base stations transmitting in the band 2000-2020 MHz shall not exceed 65 dBm/MHz. For base stations equipped with active antenna systems (AAS), the maximum TRP shall not exceed 46 dBm/MHz.
The limits in this RSS are specified for the purpose of certification and may not apply to all deployment scenarios. For more details, consult Standard Radio System Plan SRSP-519, Technical Requirements for the Ancillary Terrestrial Component of Mobile-Satellite Service Systems Operating in the Bands 2000 2020 MHz and 2180-2200 MHz.

8.4.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	May 29, 2024

8.4.3 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth	4 kHz
Video bandwidth	≥ 3 x RBW
Frequency span	≥ 2 x OBW
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: *Output power and EIRP results*

Modulation	Frequency, MHz	Output power, dBm	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
LoRa 125 kHz BW	2010.0625	23.2	0	23.2	70.00	-46.8
	2015.0000	23.3	0	23.3	70.00	-46.7
	2019.9375	22.0	0	22.0	70.00	-48.0
LoRa 250 kHz BW	2010.1250	19.9	0	19.9	70.00	-50.1
	2015.0000	21.5	0	21.5	70.00	-48.5
	2019.8750	18.8	0	18.8	70.00	-51.2
LR-FHSS 137 kHz	2010.0680	27.0	0	27.0	70.00	-43.0
	2015.0000	27.0	0	27.0	70.00	-43.0
	2019.9320	26.8	0	26.8	70.00	-43.2

Notes: EIRP = Output power + Antenna gain (assuming a maximum antenna gain of 0 dBi)

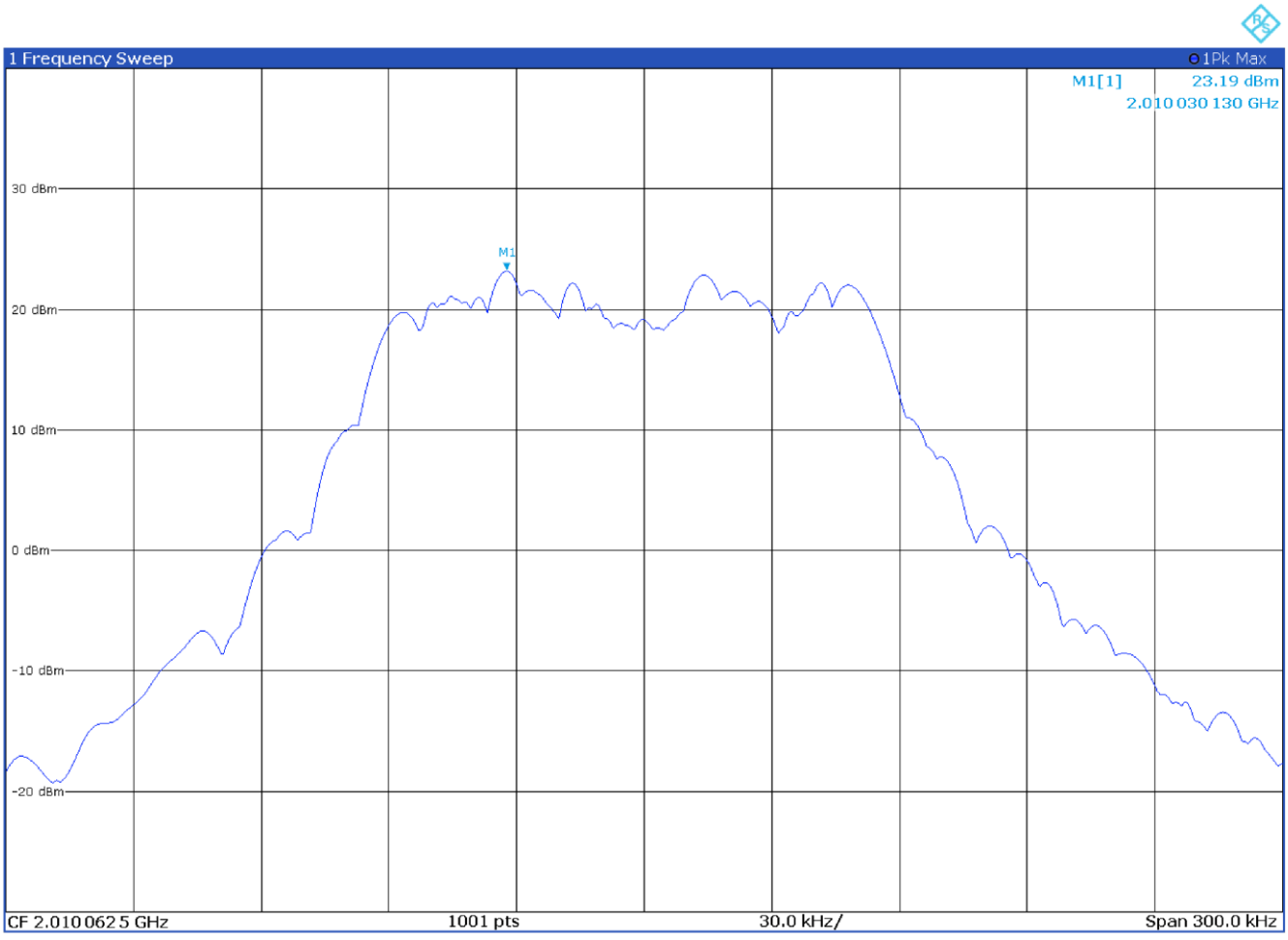


Figure 8.4-1: *Output power on low channel - LoRa 125 kHz BW*

Test data, continued

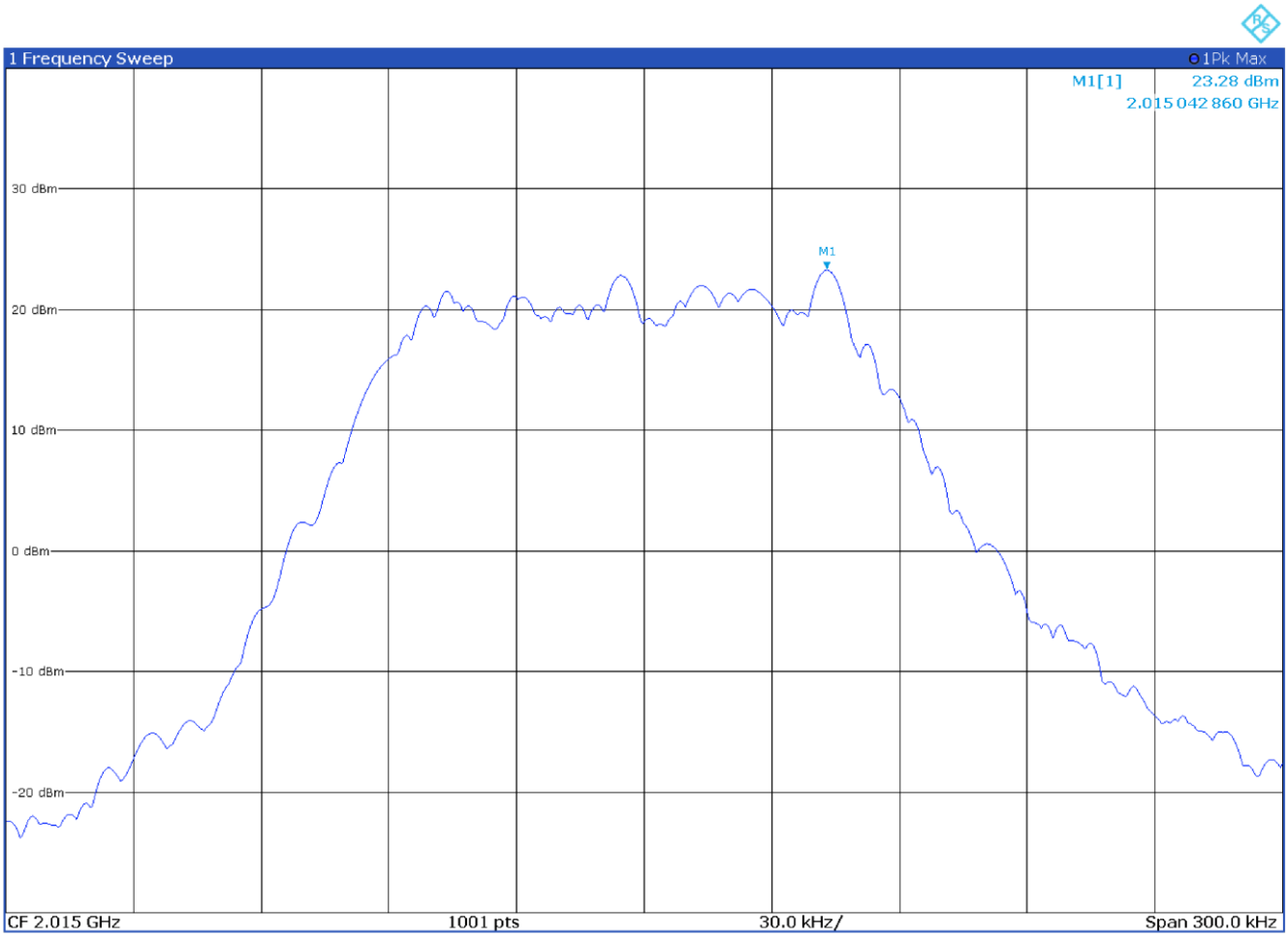


Figure 8.4-2: *Output power on mid channel - LoRa 125 kHz BW*

Test data, continued

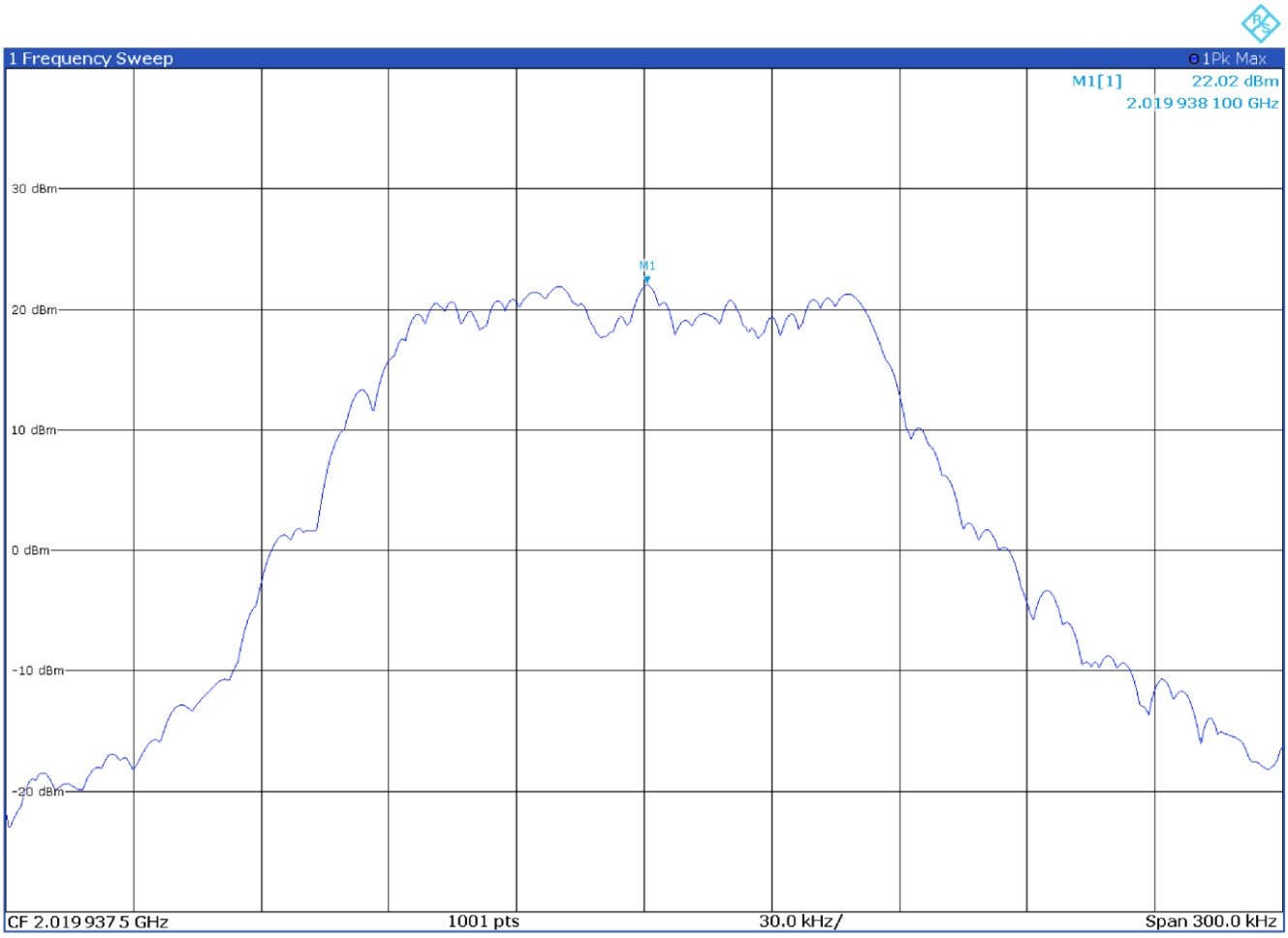


Figure 8.4-3: *Output power on high channel - LoRa 125 kHz BW*

Test data, continued

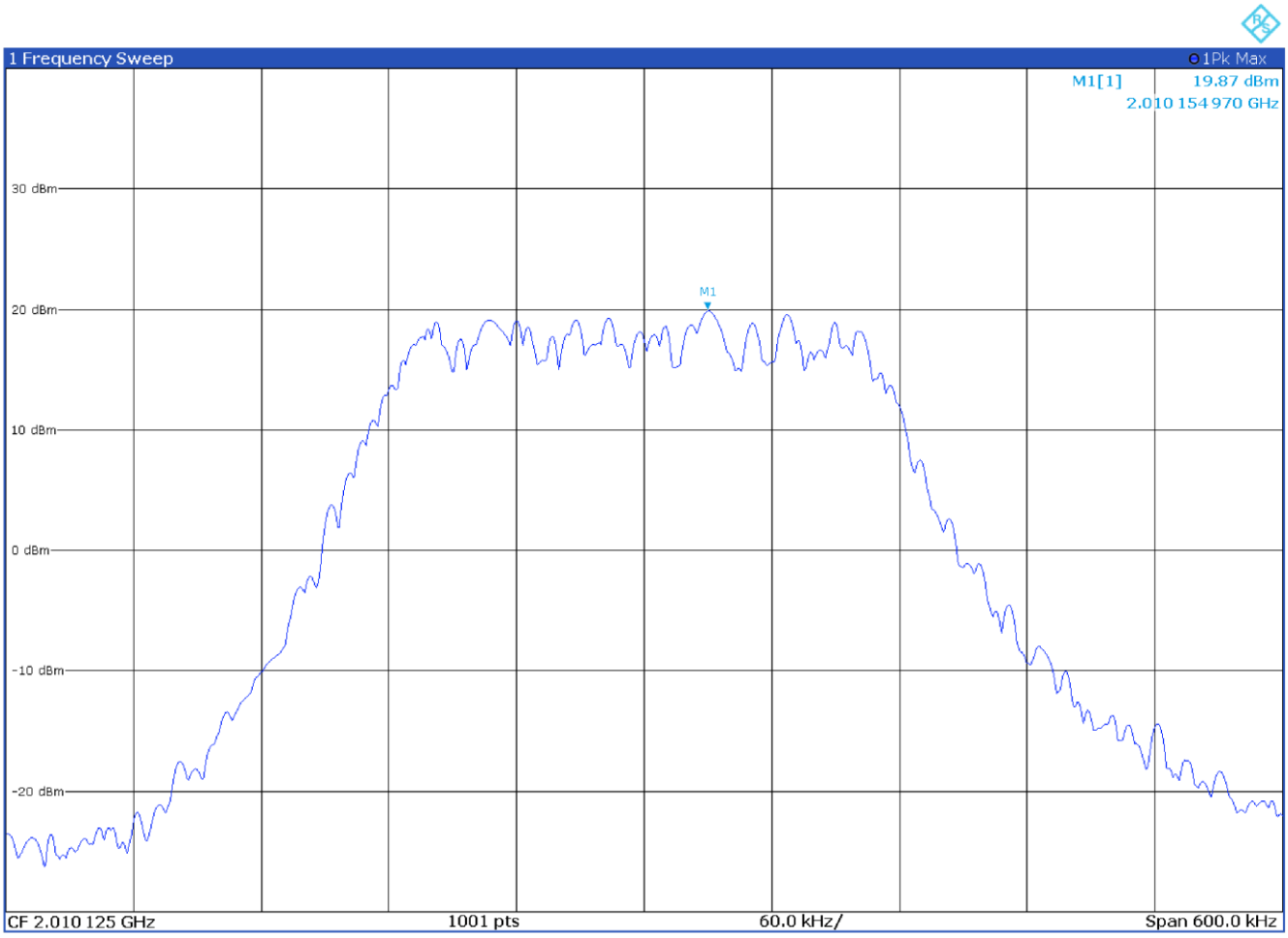


Figure 8.4-4: *Output power on low channel - LoRa 250 kHz BW*

Test data, continued

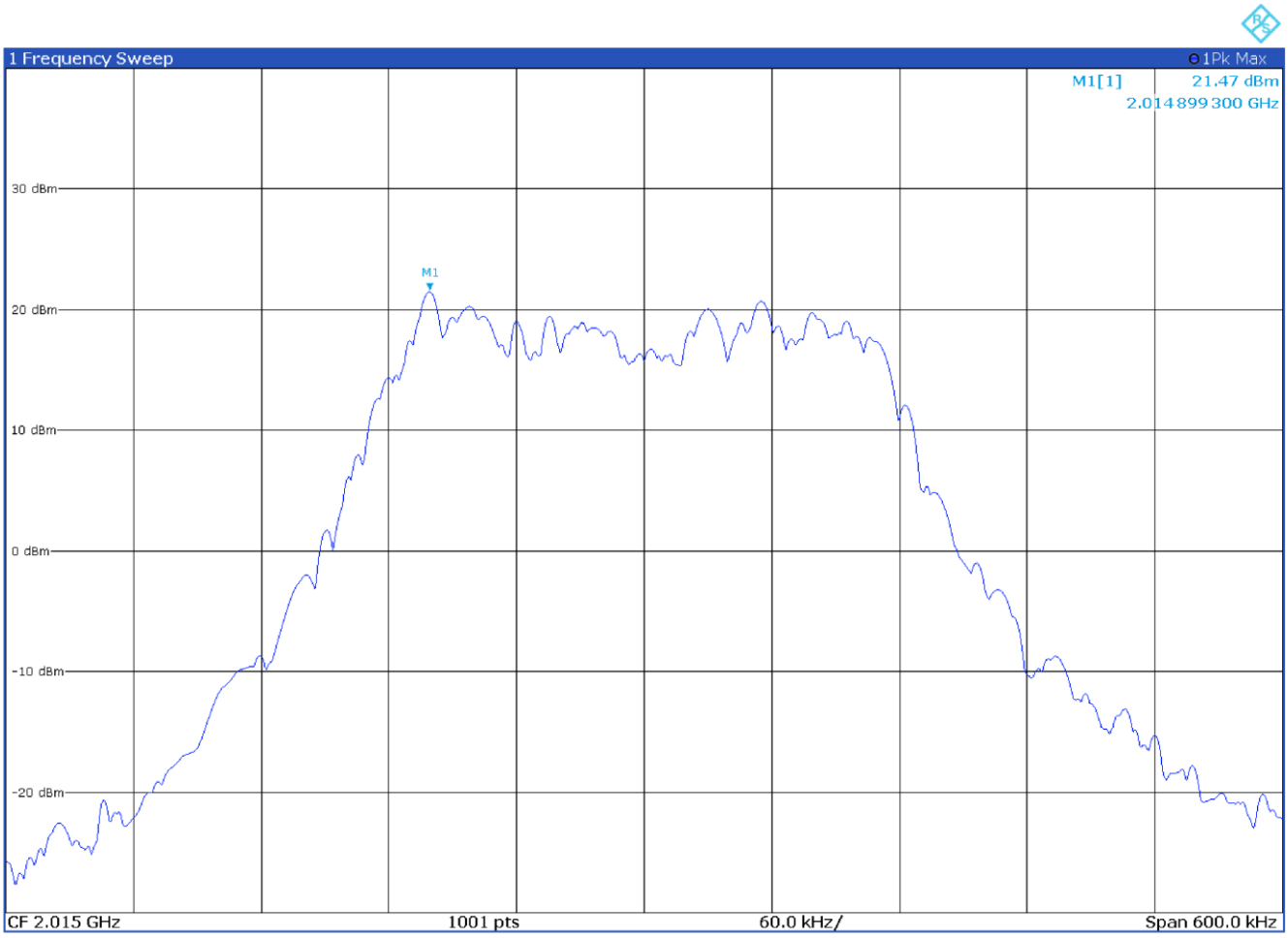


Figure 8.4-5: *Output power on mid channel - LoRa 250 kHz BW*

Test data, continued

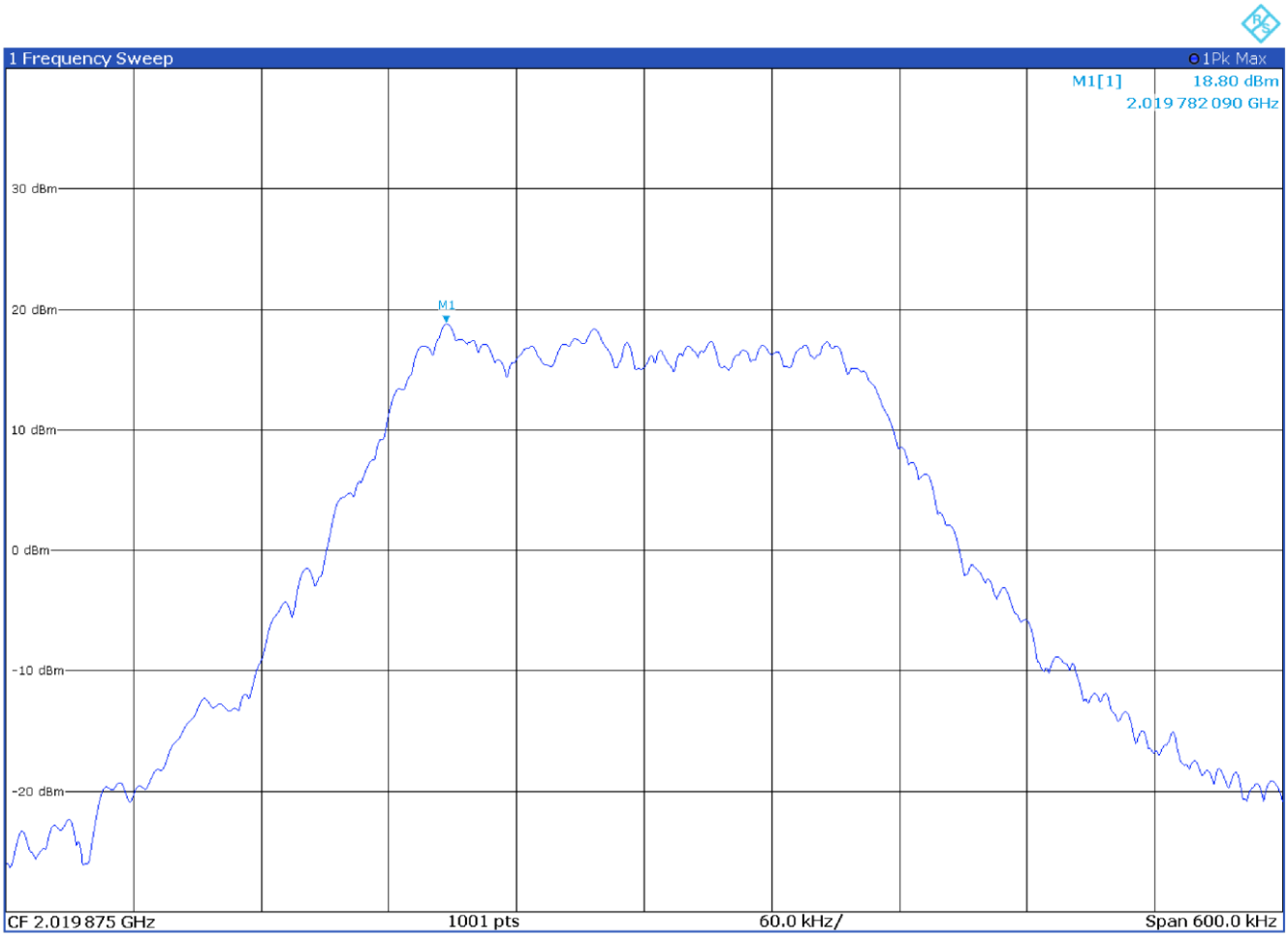


Figure 8.4-6: *Output power on high channel - LoRa 250 kHz BW*

Test data, continued

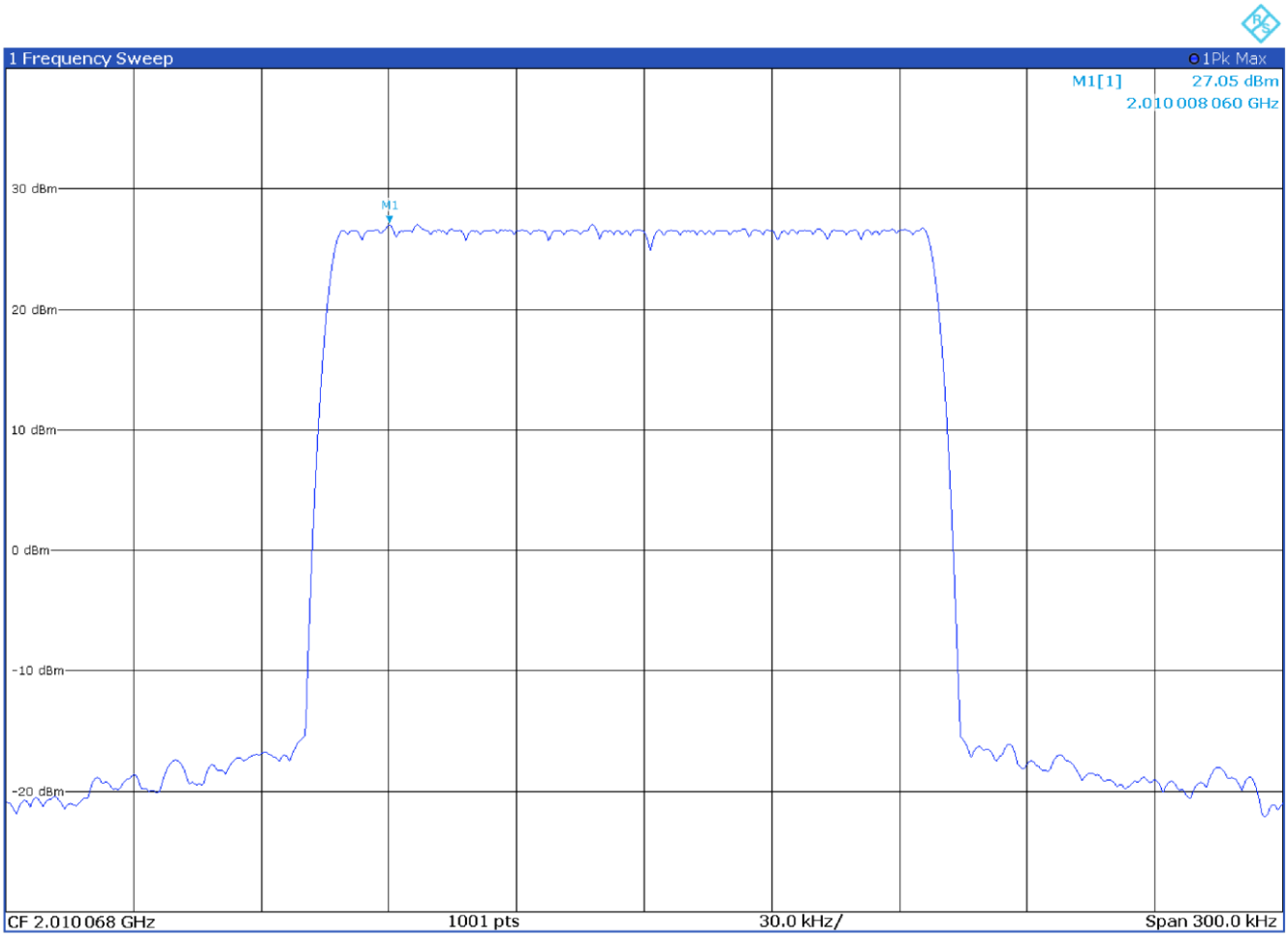


Figure 8.4-7: *Output power on low channel - LR-FHSS 137 kHz*

Test data, continued

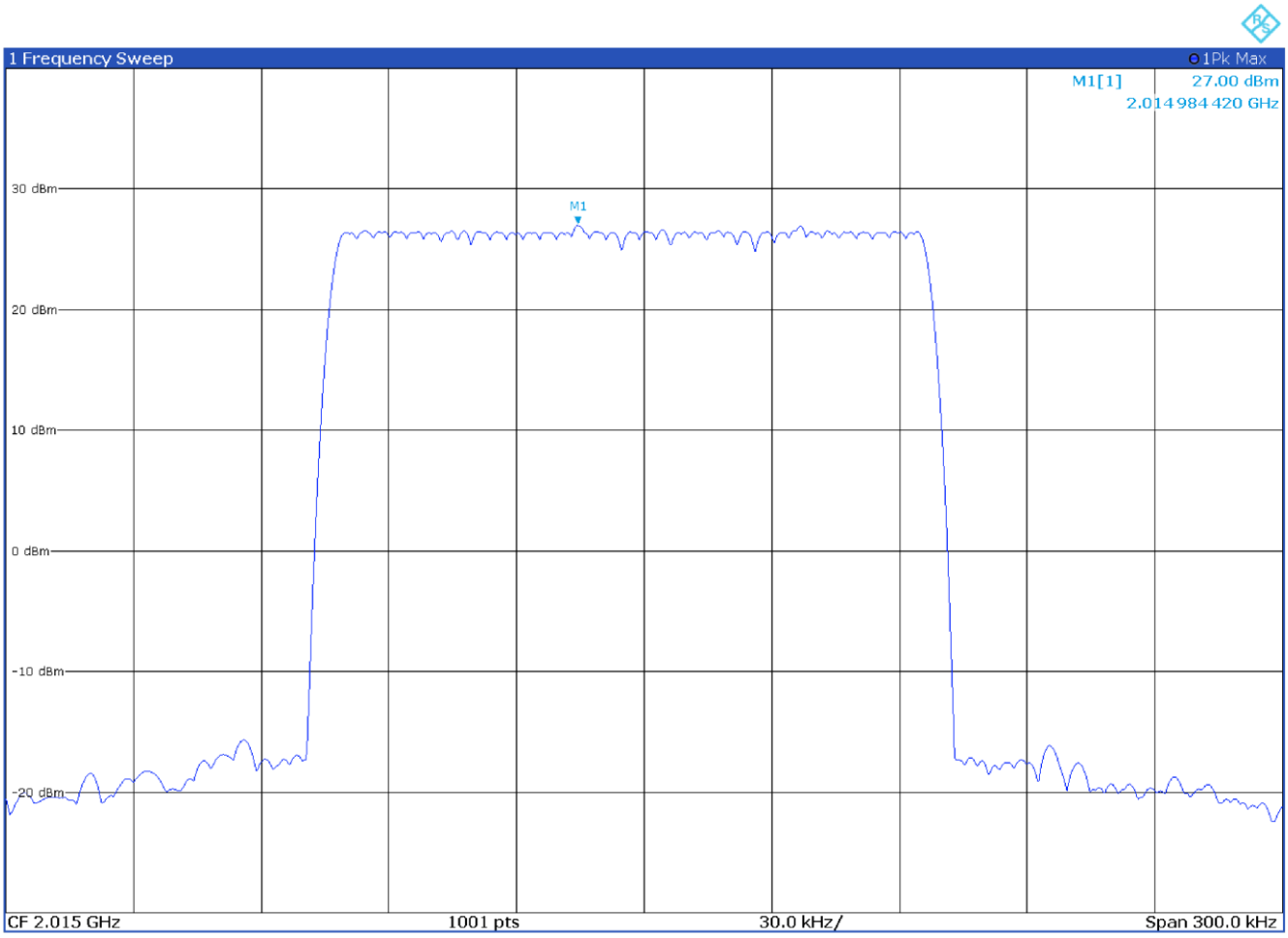


Figure 8.4-8: *Output power on mid channel - LR-FHSS 137 kHz*

Test data, continued

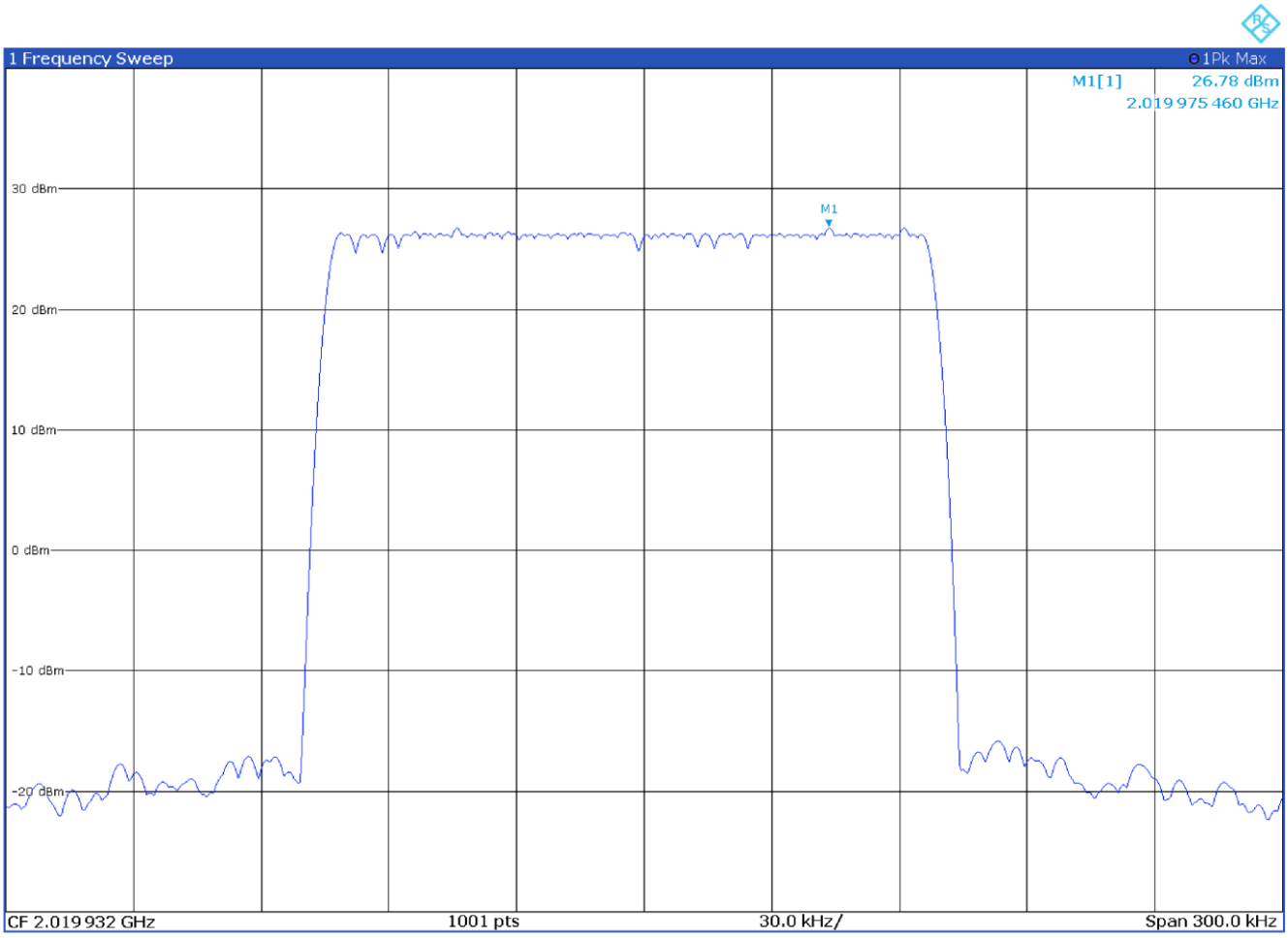


Figure 8.4-9: *Output power on high channel - LR-FHSS 137 kHz*

Test data, continued

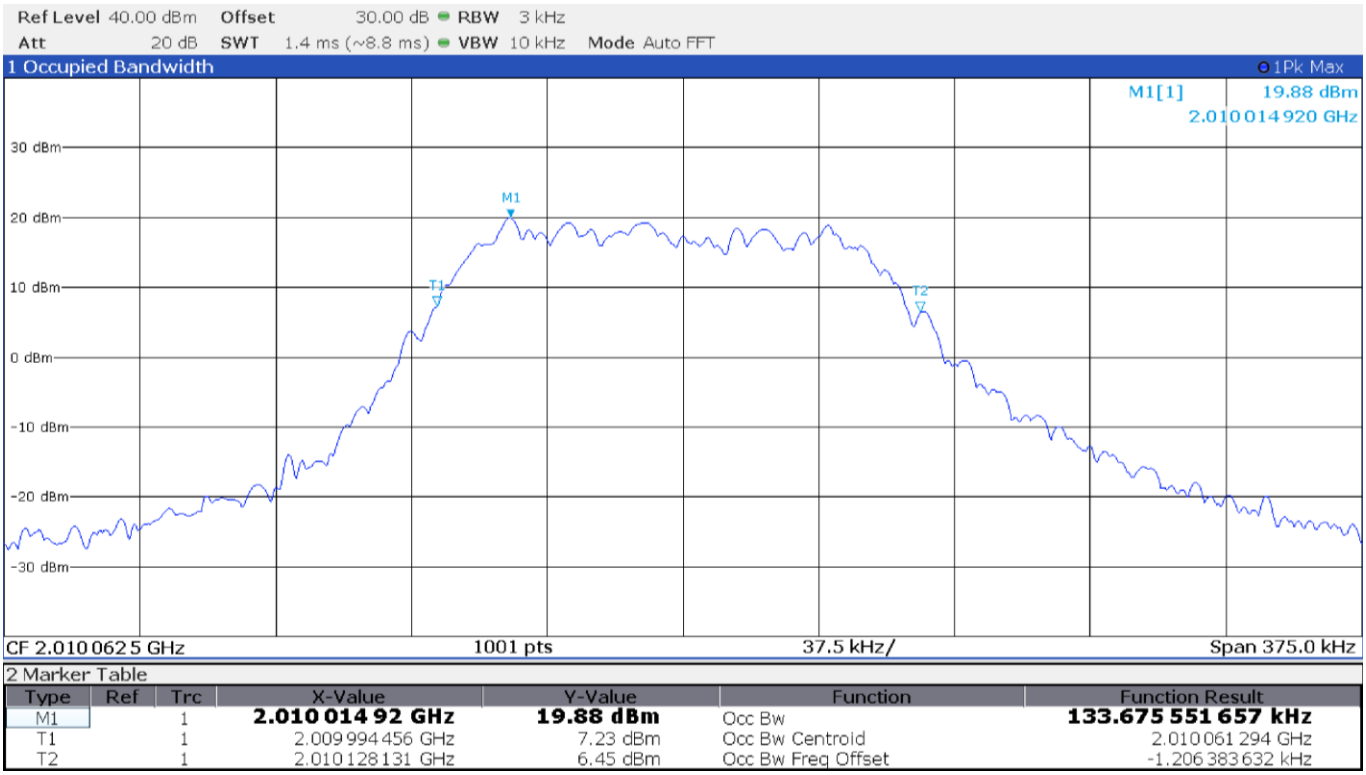


Figure 8.4-10: *99% bandwidth on low channel for LoRa 125 kHz BW*

Test data, continued

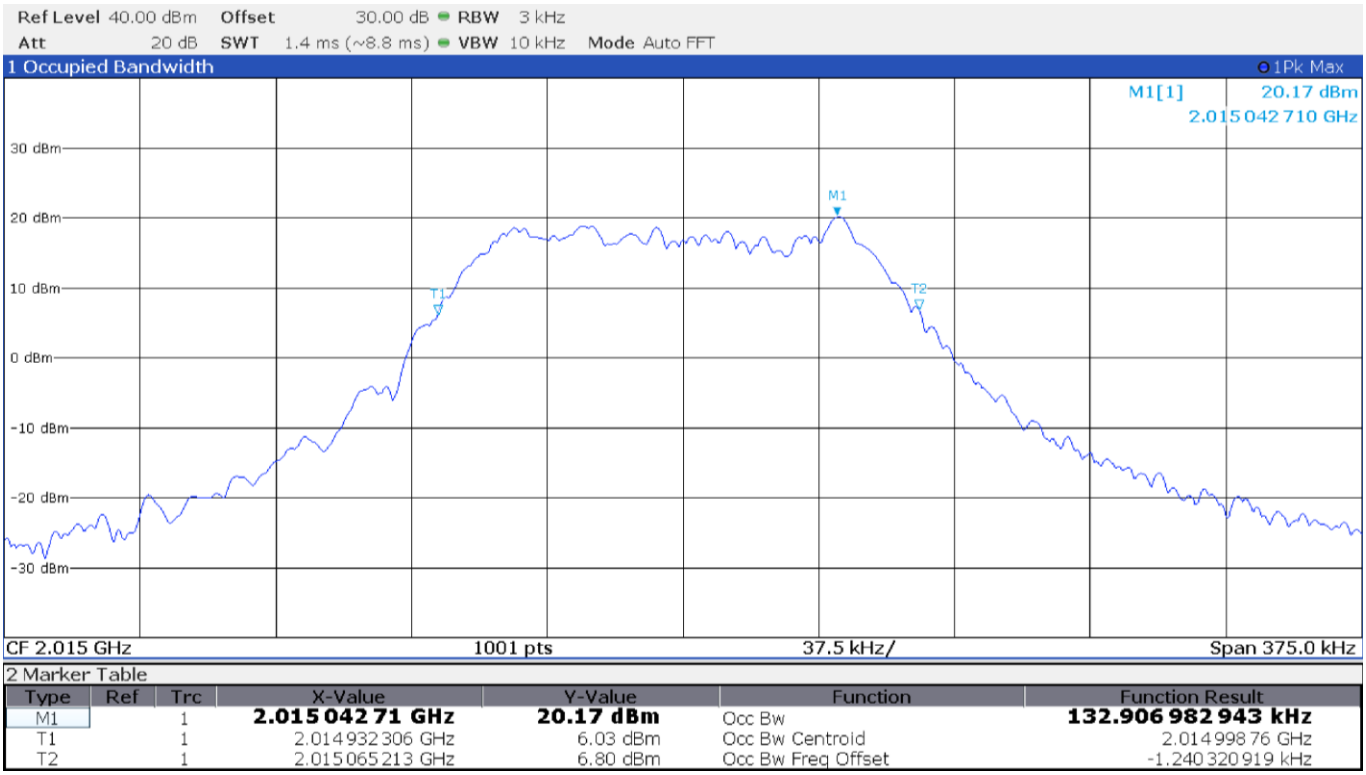


Figure 8.4-11: *99% bandwidth on mid channel for LoRa 125 kHz BW*

Test data, continued

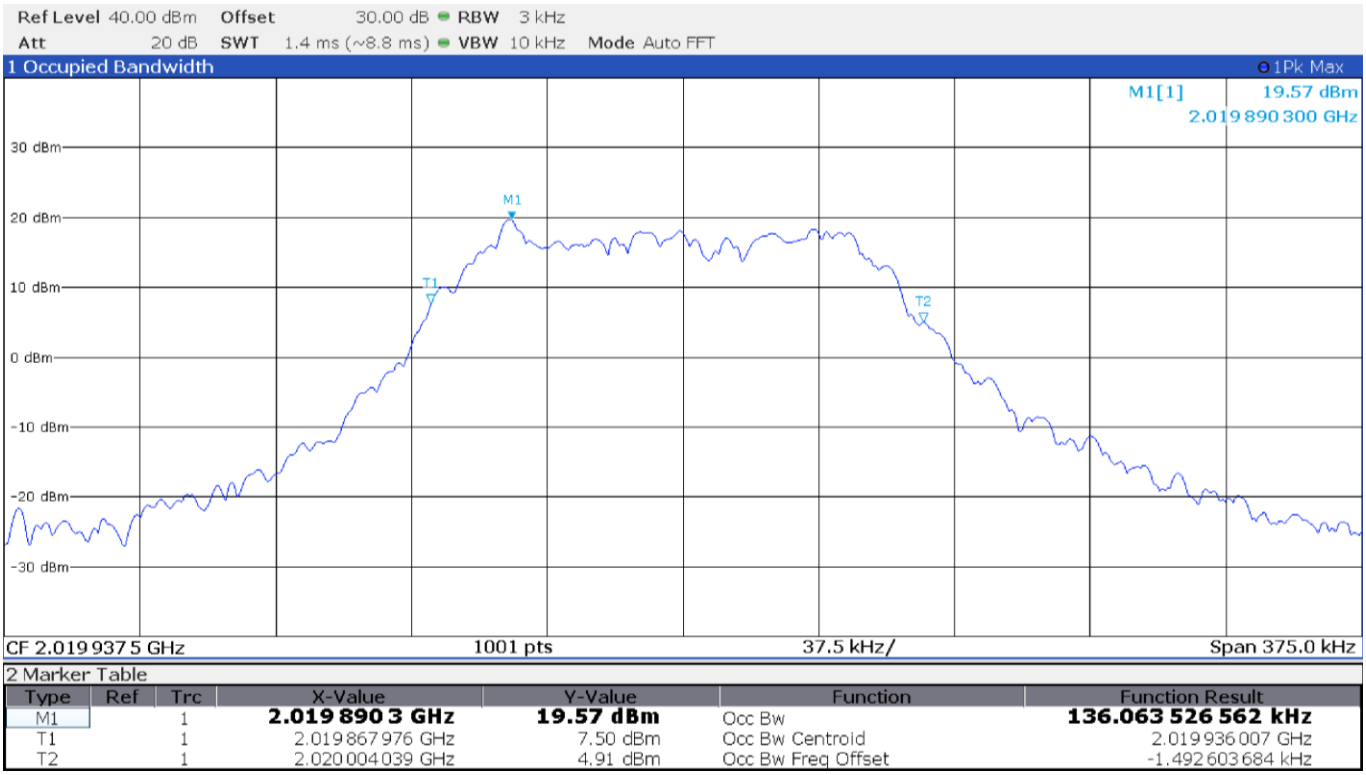


Figure 8.4-12: *99% bandwidth on high channel for LoRa 125 kHz BW*

Test data, continued

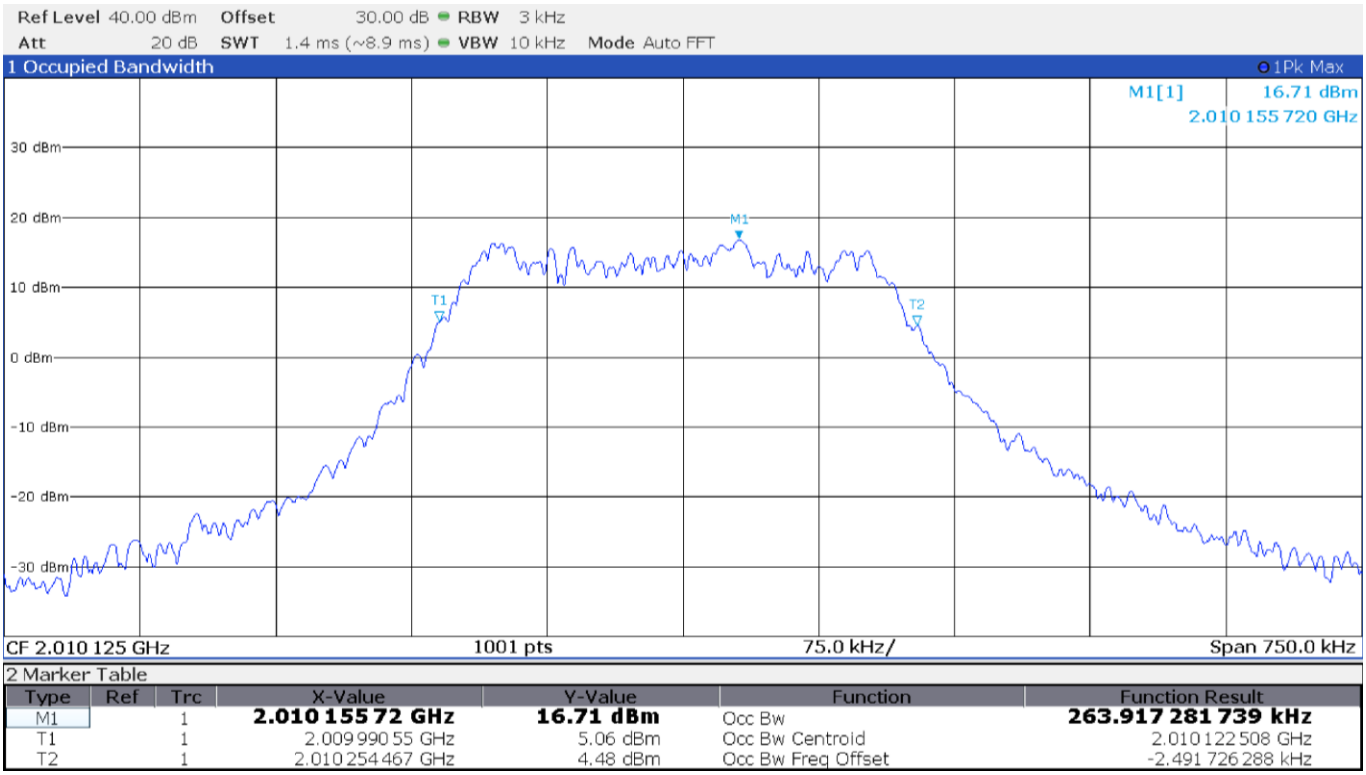


Figure 8.4-13: *99% bandwidth on low channel for LoRa 250 kHz BW*

Test data, continued

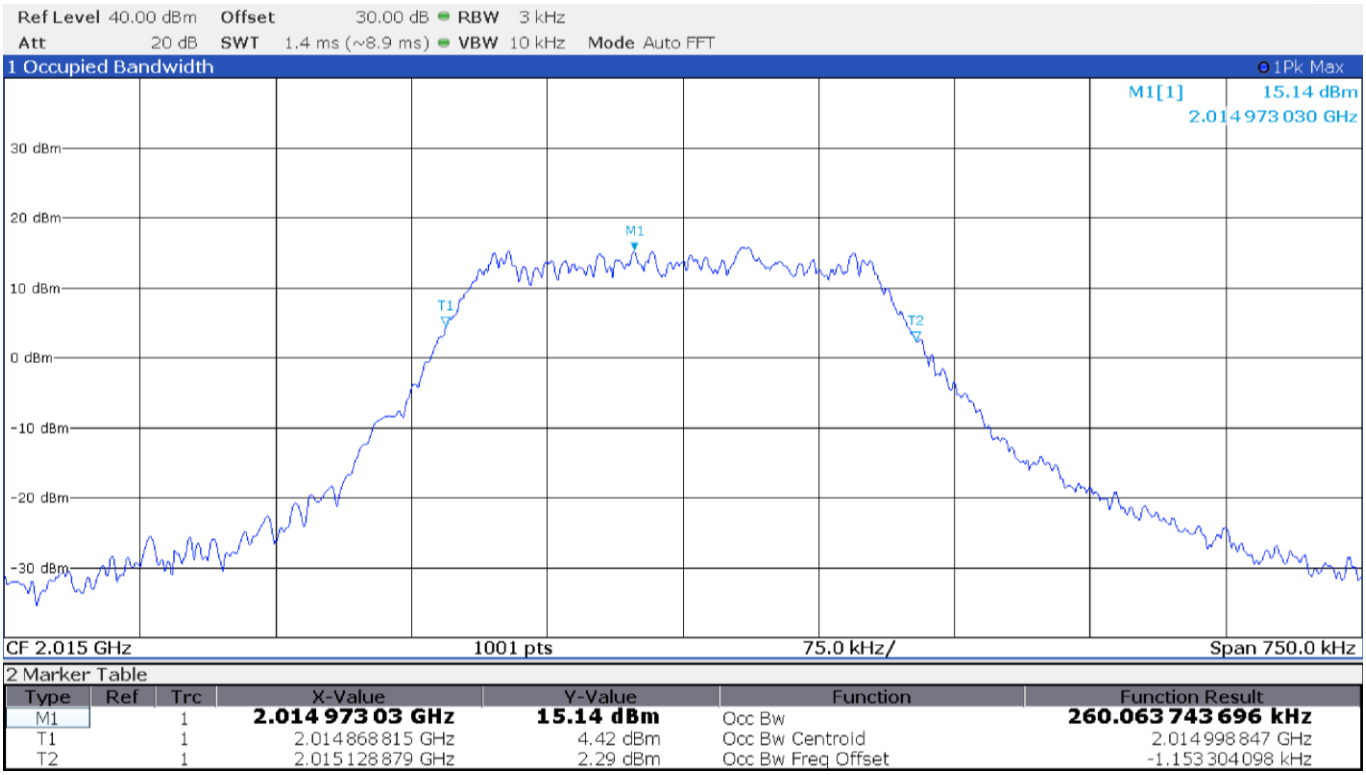


Figure 8.4-14: *99% bandwidth on mid channel for LoRa 250 kHz BW*

Test data, continued

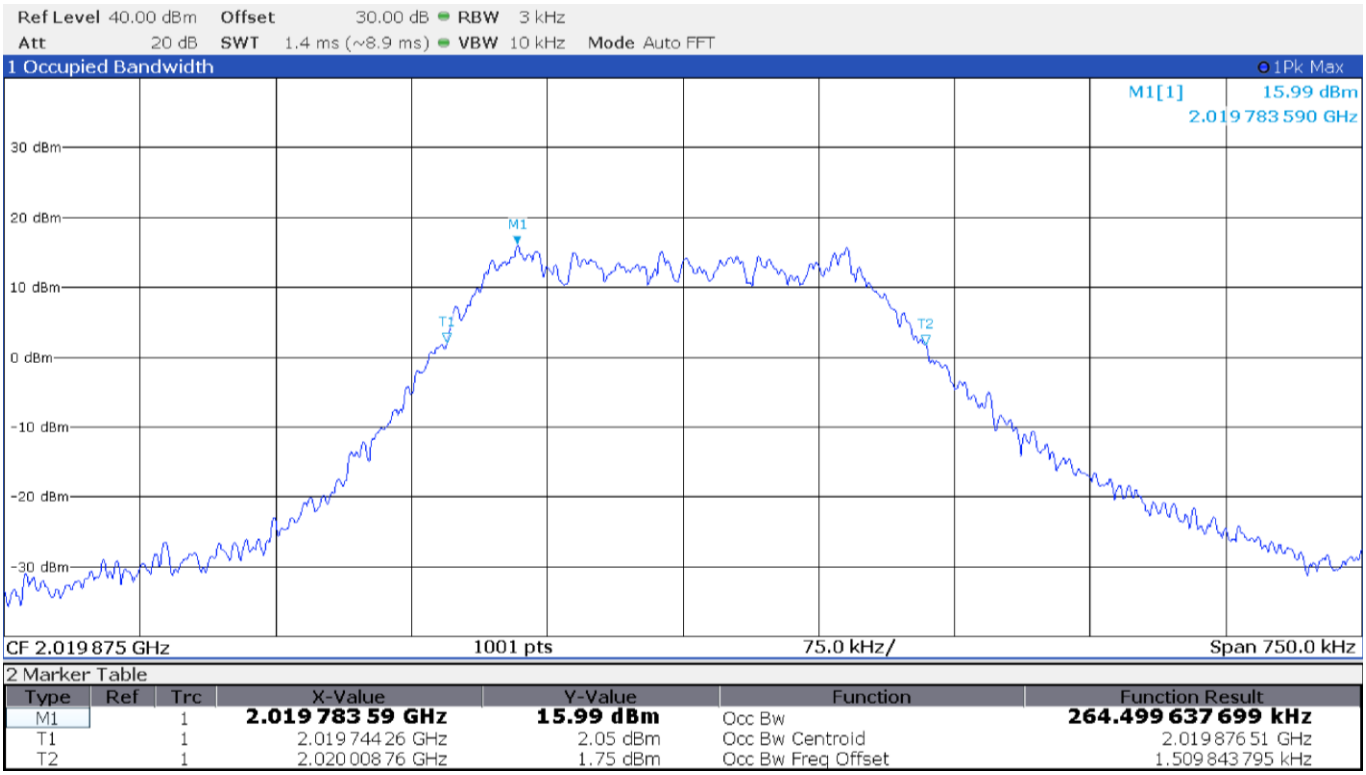


Figure 8.4-15: *99% bandwidth on high channel for LoRa 250 kHz BW*

Test data, continued

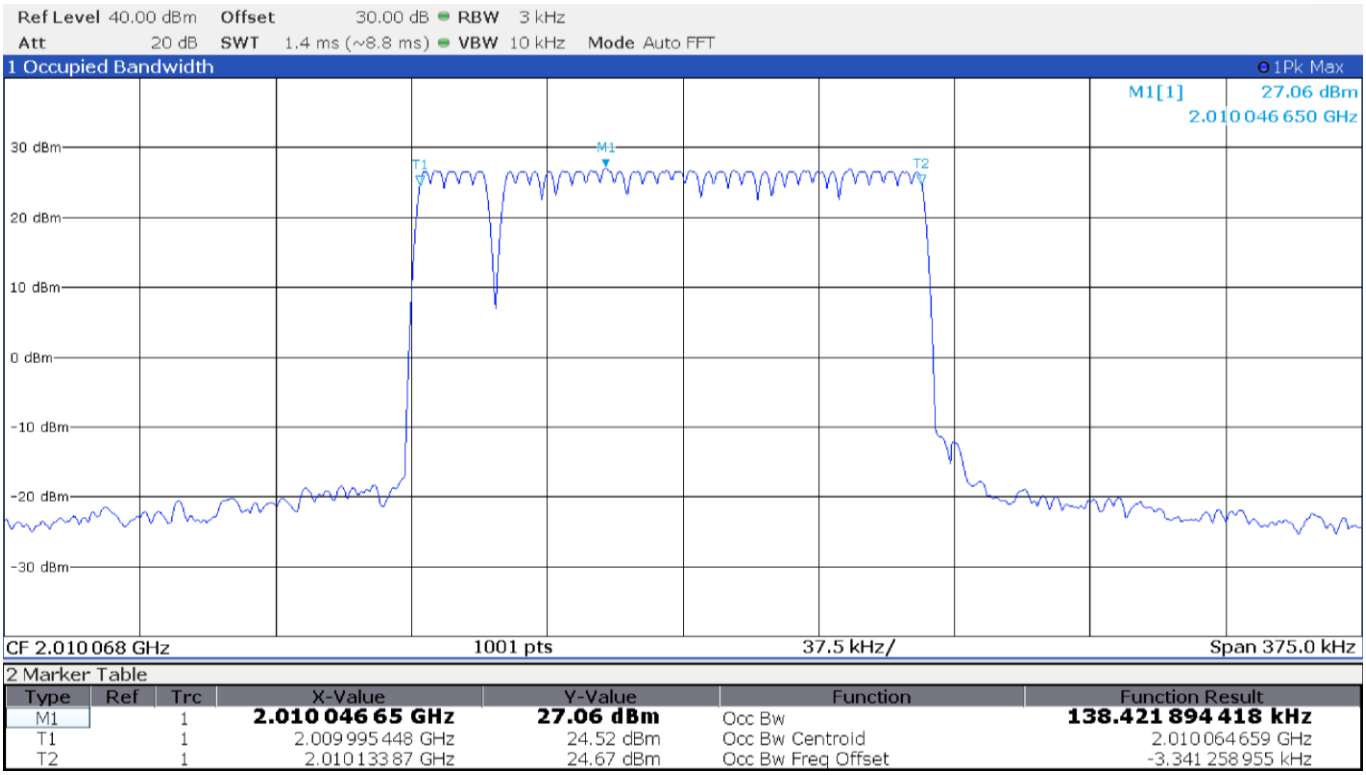


Figure 8.4-16: *99% bandwidth on low channel for LR-FHSS 137 kHz*

Test data, continued

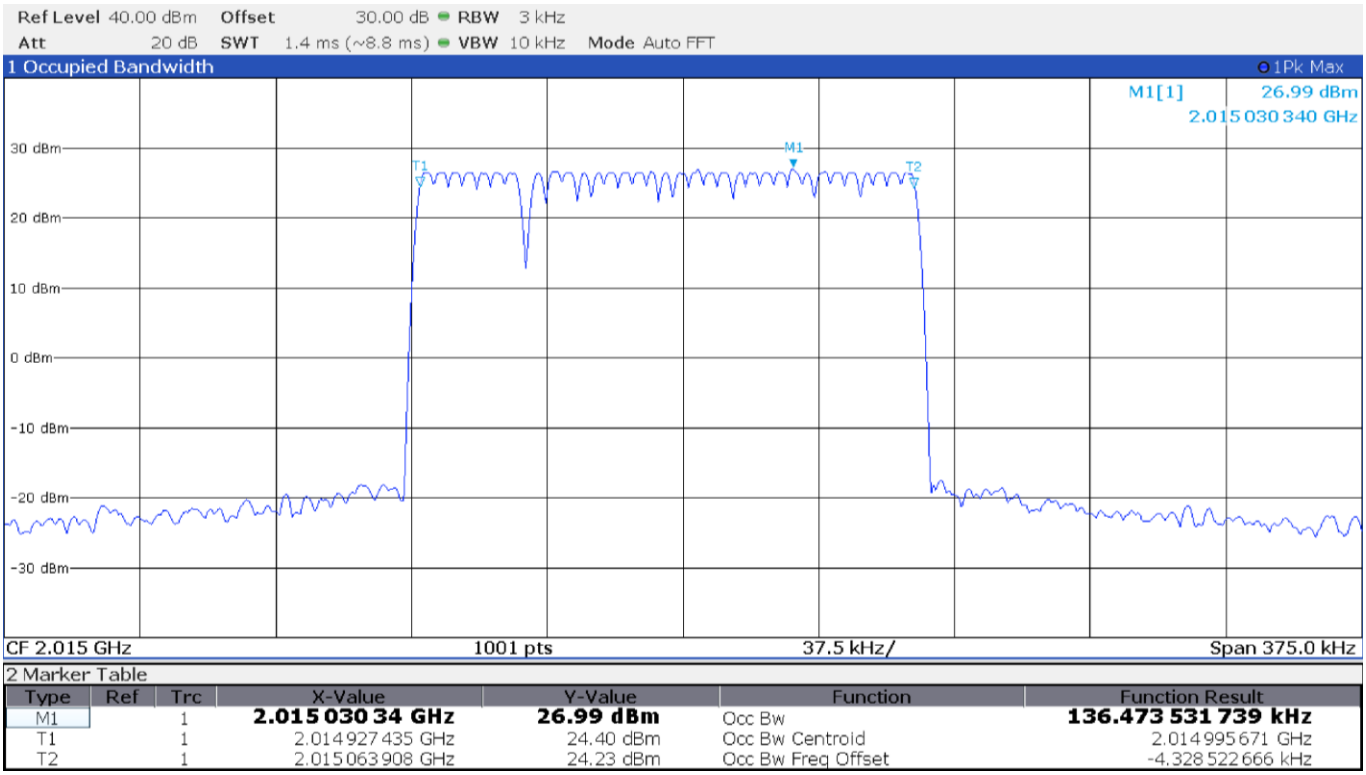


Figure 8.4-17: *99% bandwidth on mid channel for LR-FHSS 137 kHz*

Test data, continued

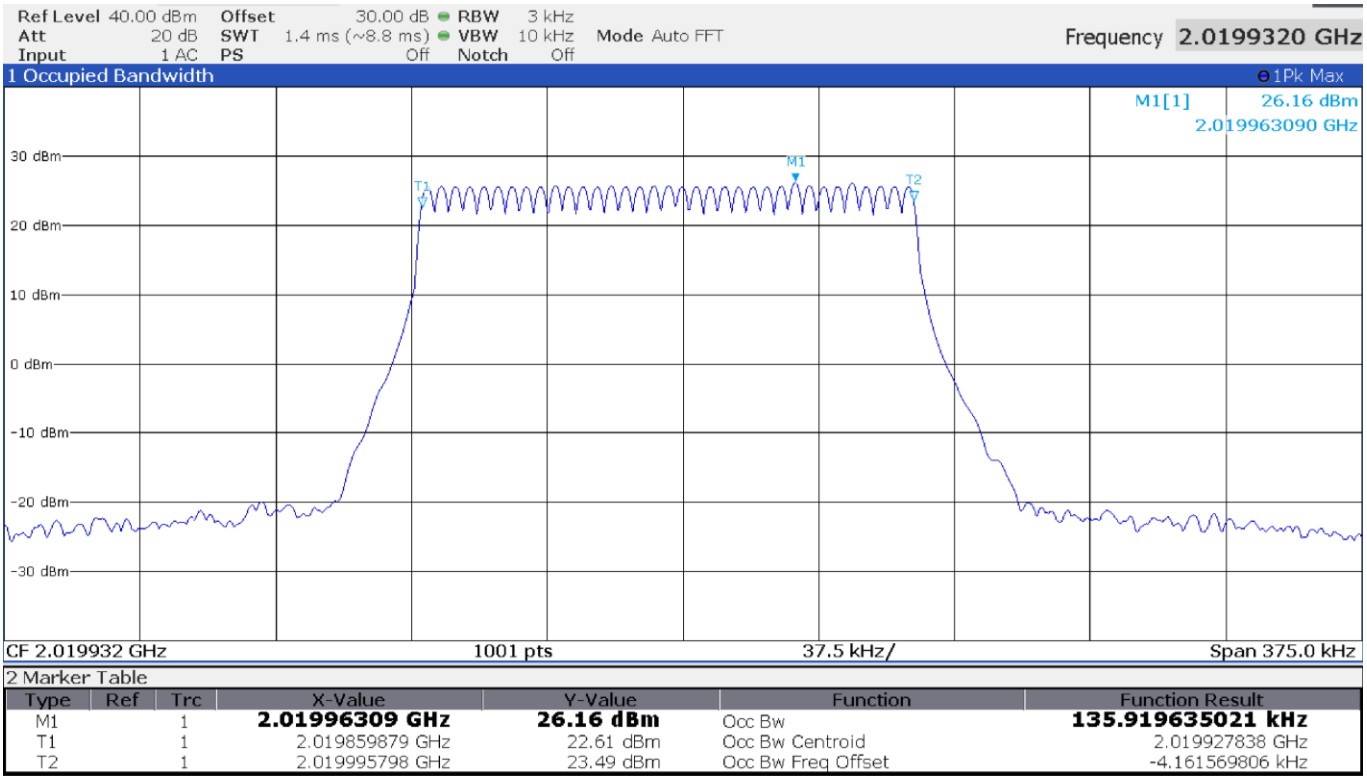


Figure 8.4-18: *99% bandwidth on high channel for LR-FHSS 137 kHz*

8.5 Occupied bandwidth mask

8.5.1 References, definitions and limits

FCC §25.202(f):

Emission limitations. Except for SDARS terrestrial repeaters and as provided for in paragraph (i), the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the schedule set forth in paragraphs (f)(1) through (f)(4) of this section. The out-of-band emissions of SDARS terrestrial repeaters shall be attenuated in accordance with the schedule set forth in paragraph (h) of this section.

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;

(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts;

(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (f) (1), (2) and (3) of this section.

RSS-170, Clause 5.4:

The unwanted emissions of ATC base station equipment transmitting in the bands 2000-2020 MHz and 2180-2200 MHz shall comply with the following:

(1) The power of any unwanted emissions at frequencies outside the equipment's operating frequency block shall be attenuated below the transmitter power P (dBW), by 43 + 10 log p (watts), dB

(2) For equipment operating in the band 2180-2200 MHz, in addition to (1), the power of any emissions on all frequencies between 2200 MHz and 2290 MHz shall not exceed an e.i.r.p. of -100.6 dBW/4 kHz.

8.5.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	May 29, 2024

8.5.3 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth	4 kHz
Video bandwidth	≥ 3 × RBW
Frequency span	≥ 250% of the OBW
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

8.5.5 Test data

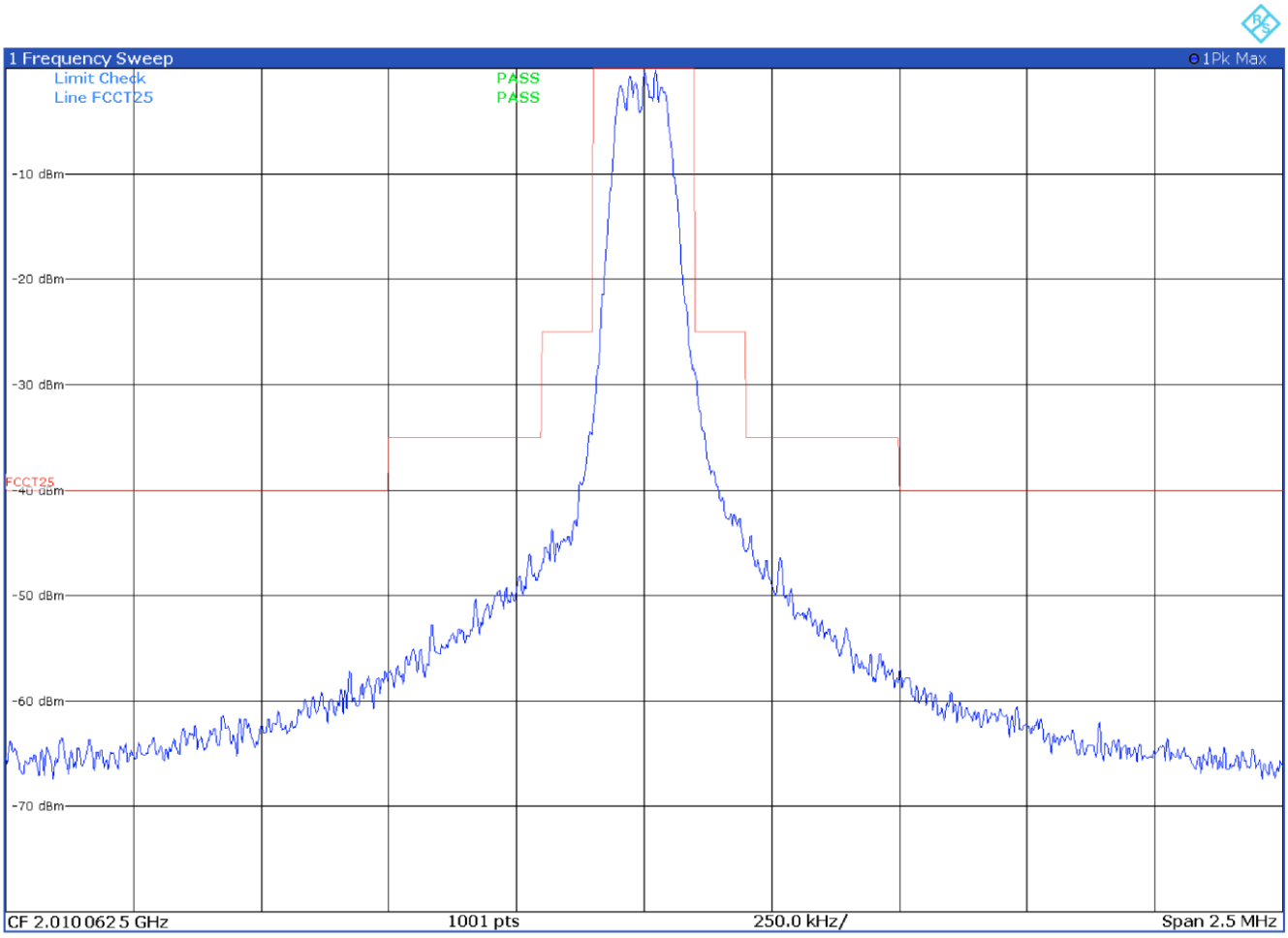


Figure 8.5-1: *Occupied bandwidth mask on low channel for LoRa 125 kHz BW*

Test data, continued

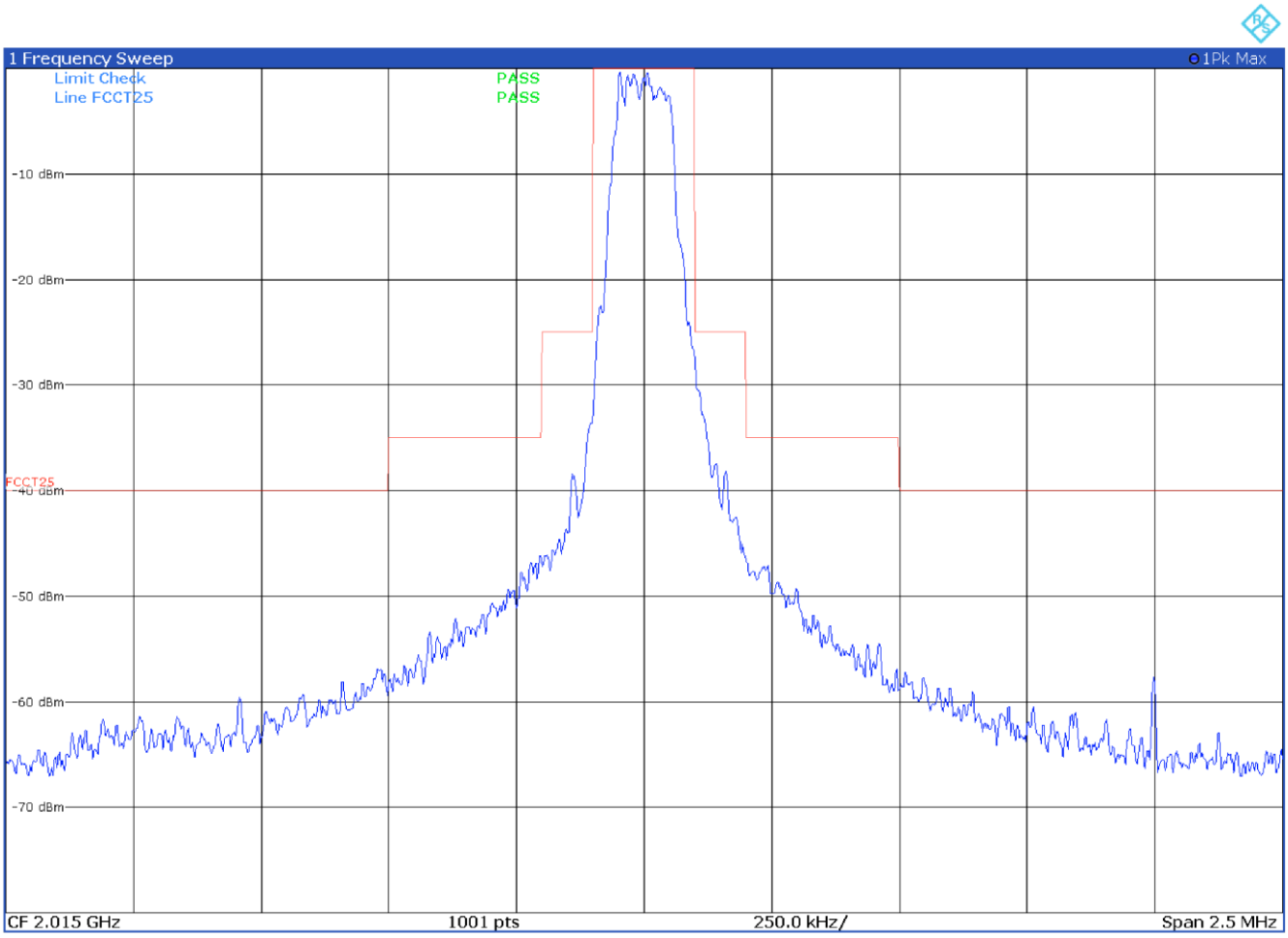


Figure 8.5-2: *Occupied bandwidth mask on mid channel for LoRa 125 kHz BW*

Test data, continued

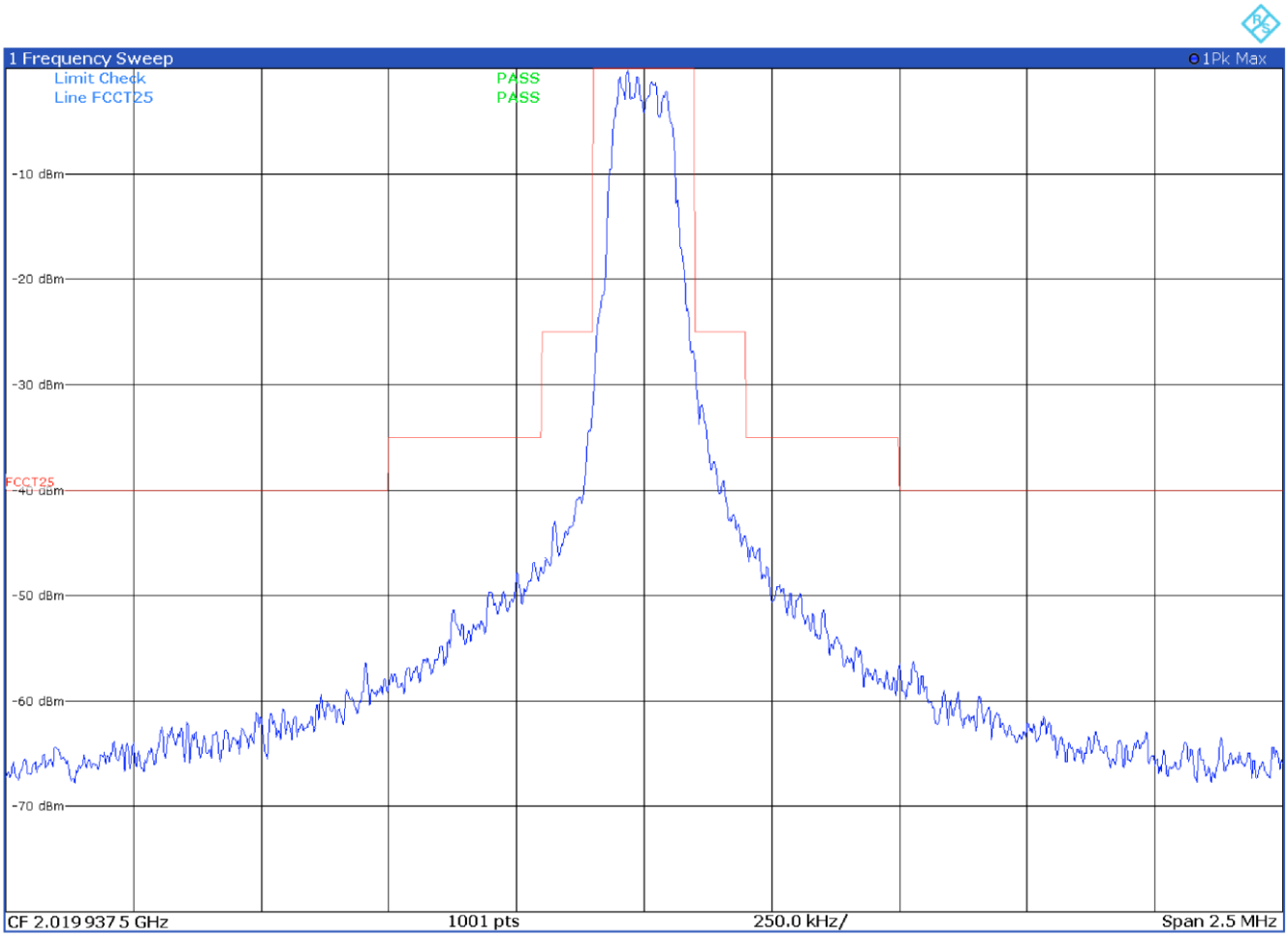


Figure 8.5-3: *Occupied bandwidth mask on high channel for LoRa 125 kHz BW*

8.5.1 Test data

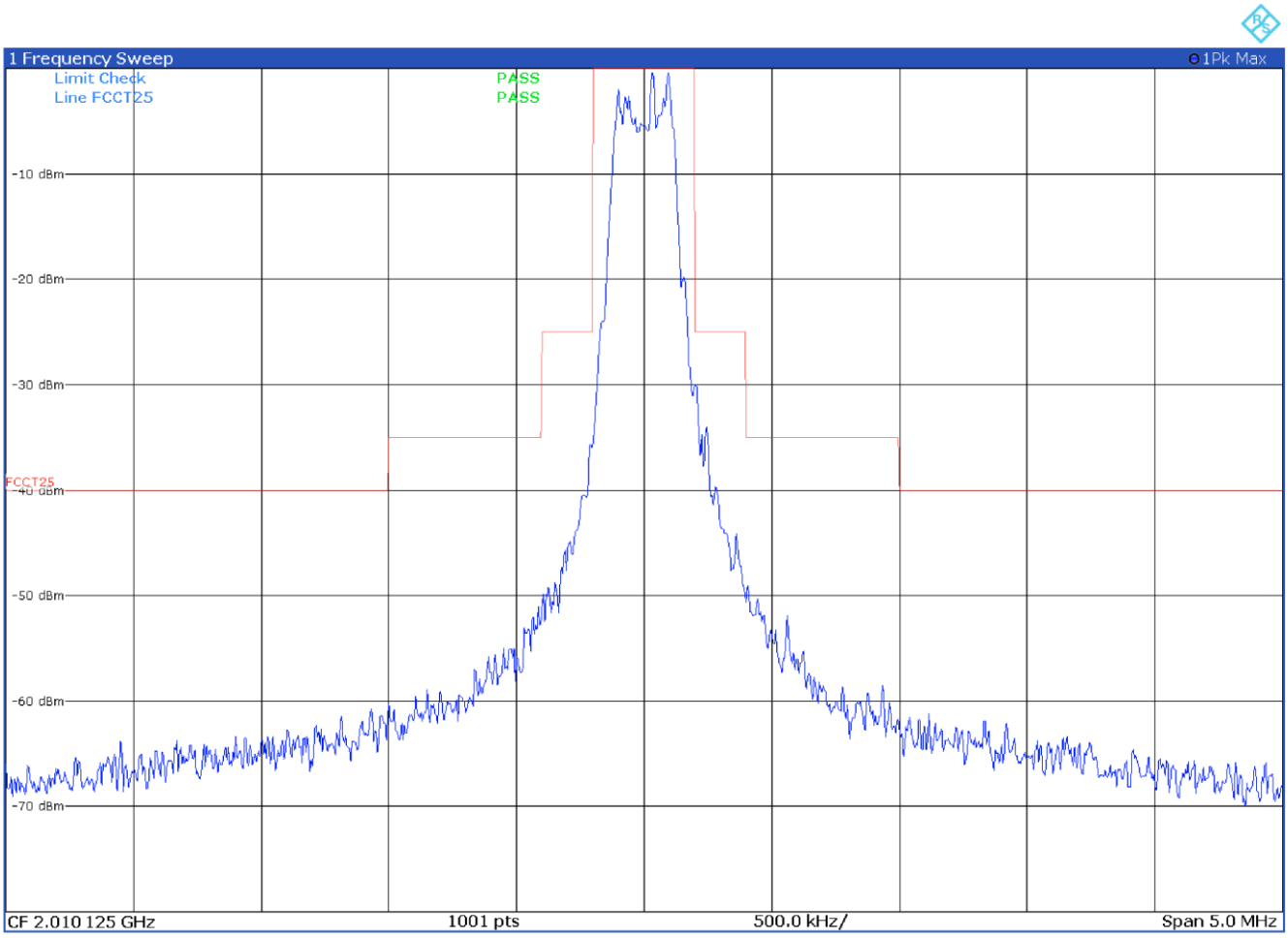


Figure 8.5-4: *Occupied bandwidth mask on low channel for LoRa 250 kHz BW*

Test data, continued

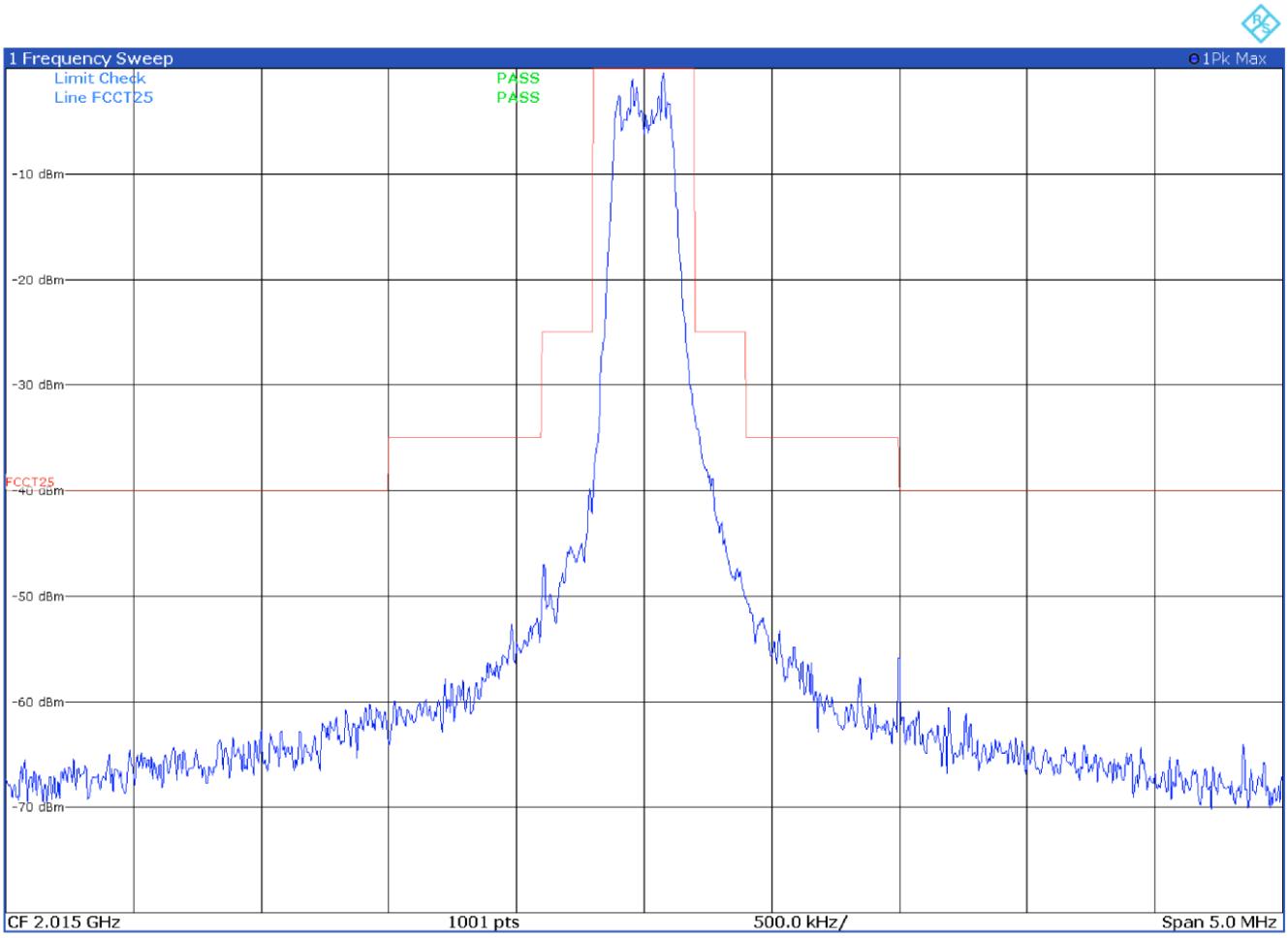


Figure 8.5-5: *Occupied bandwidth mask on mid channel for LoRa 250 kHz BW*

Test data, continued

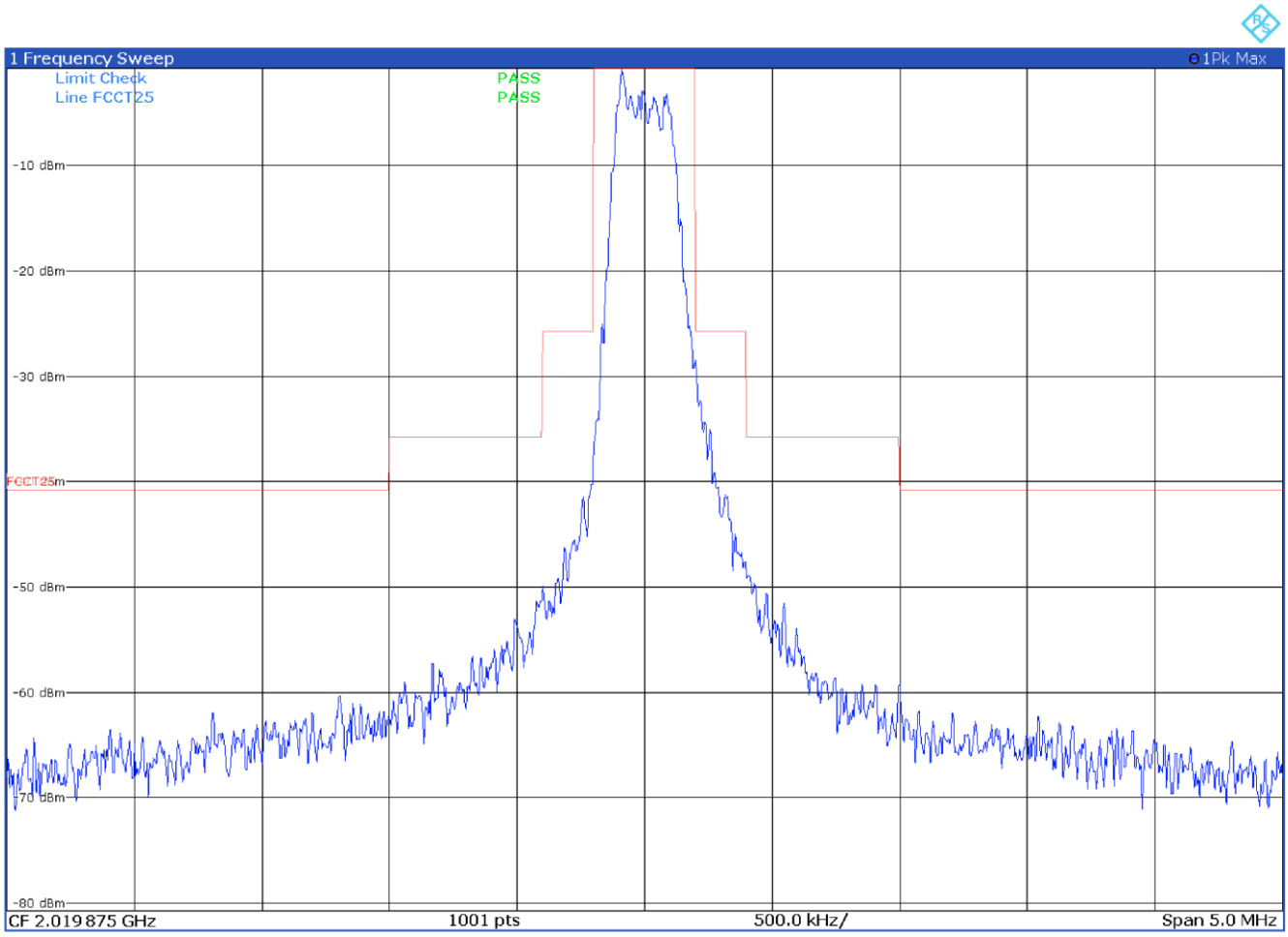


Figure 8.5-6: *Occupied bandwidth mask on high channel for LoRa 250 kHz BW*

8.5.1 Test data

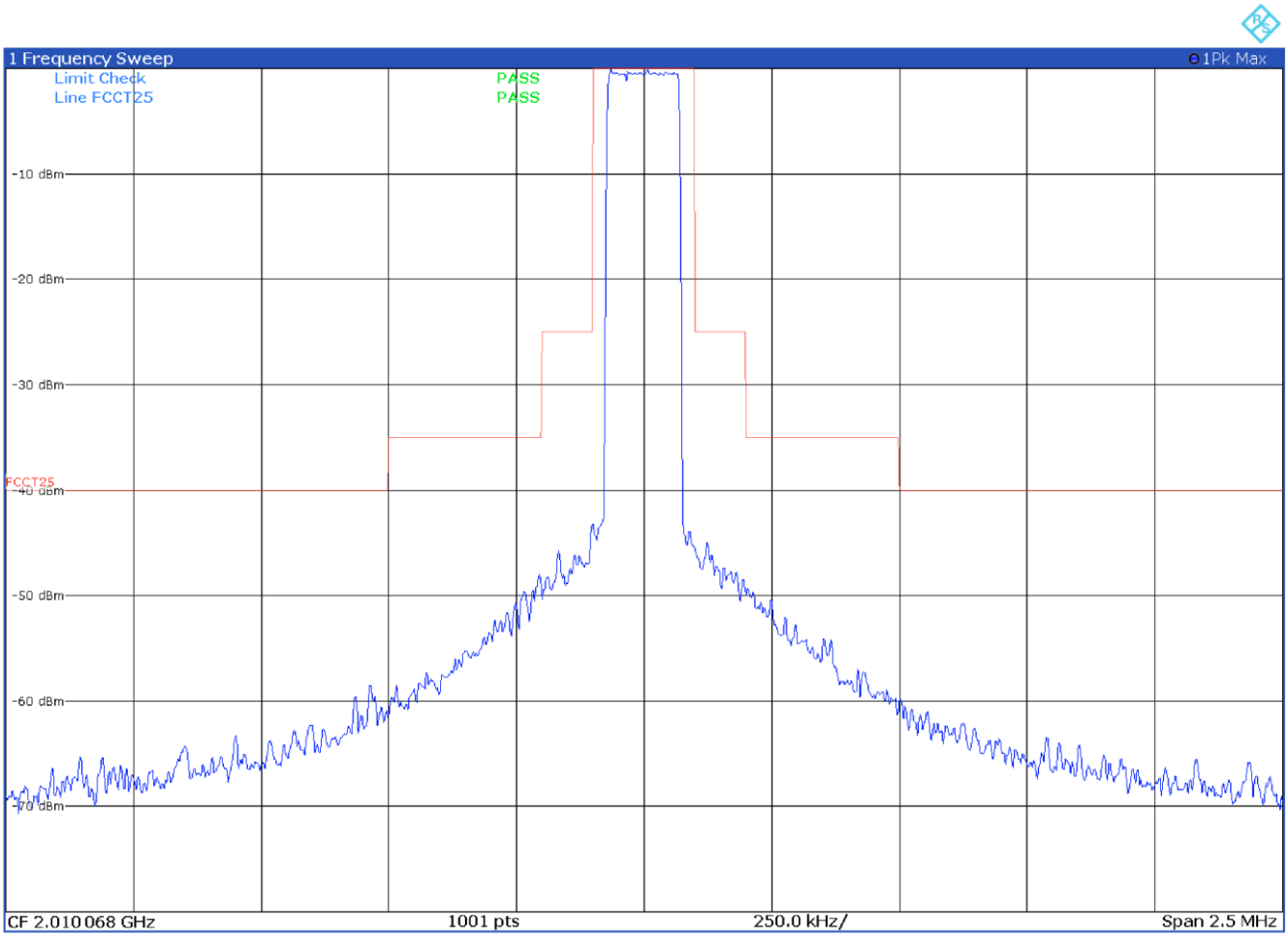


Figure 8.5-7: *Occupied bandwidth mask on low channel for LR-FHSS 137 kHz*

Test data, continued

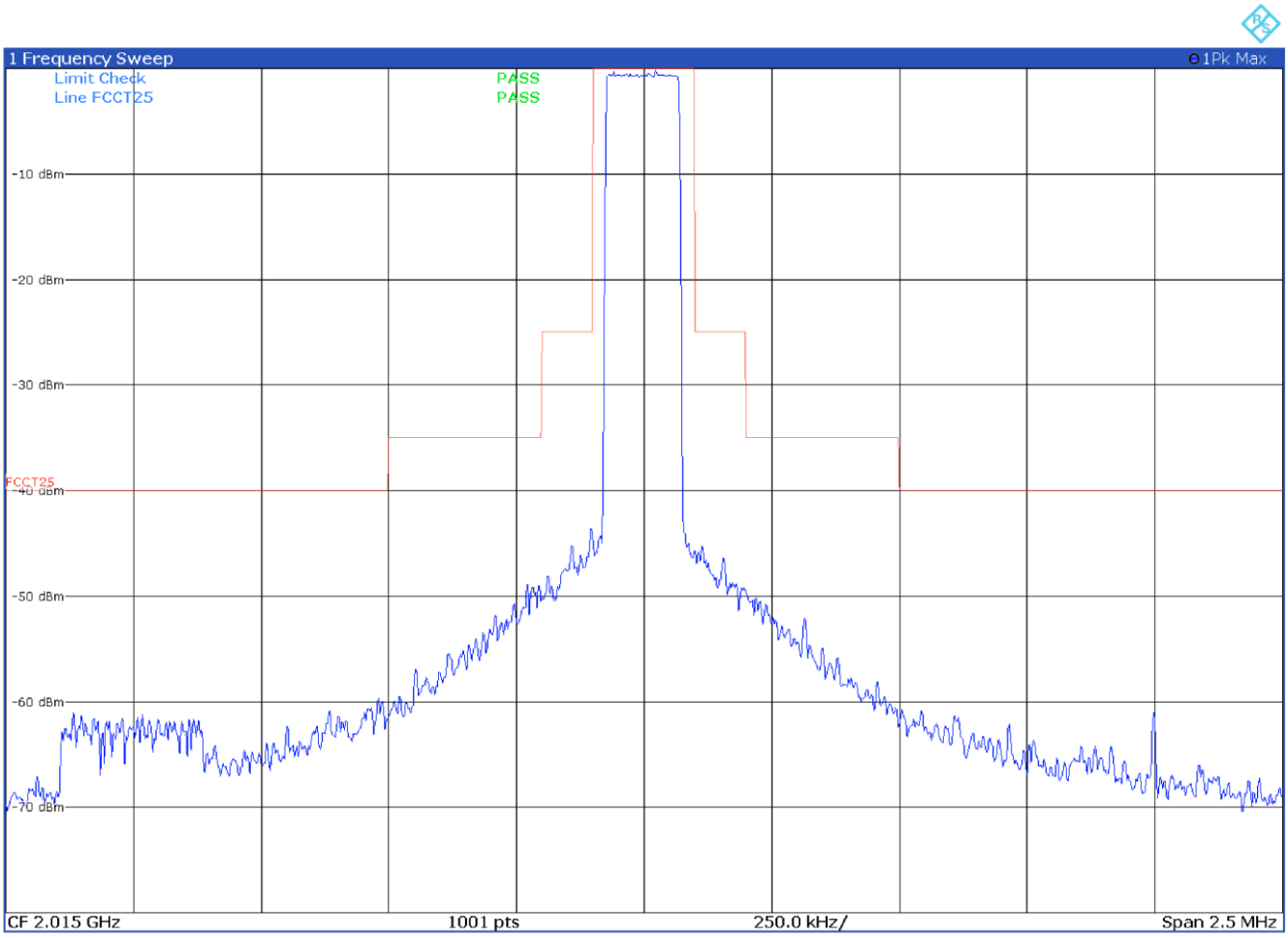


Figure 8.5-8: *Occupied bandwidth mask on mid channel for LR-FHSS 137 kHz*

Test data, continued

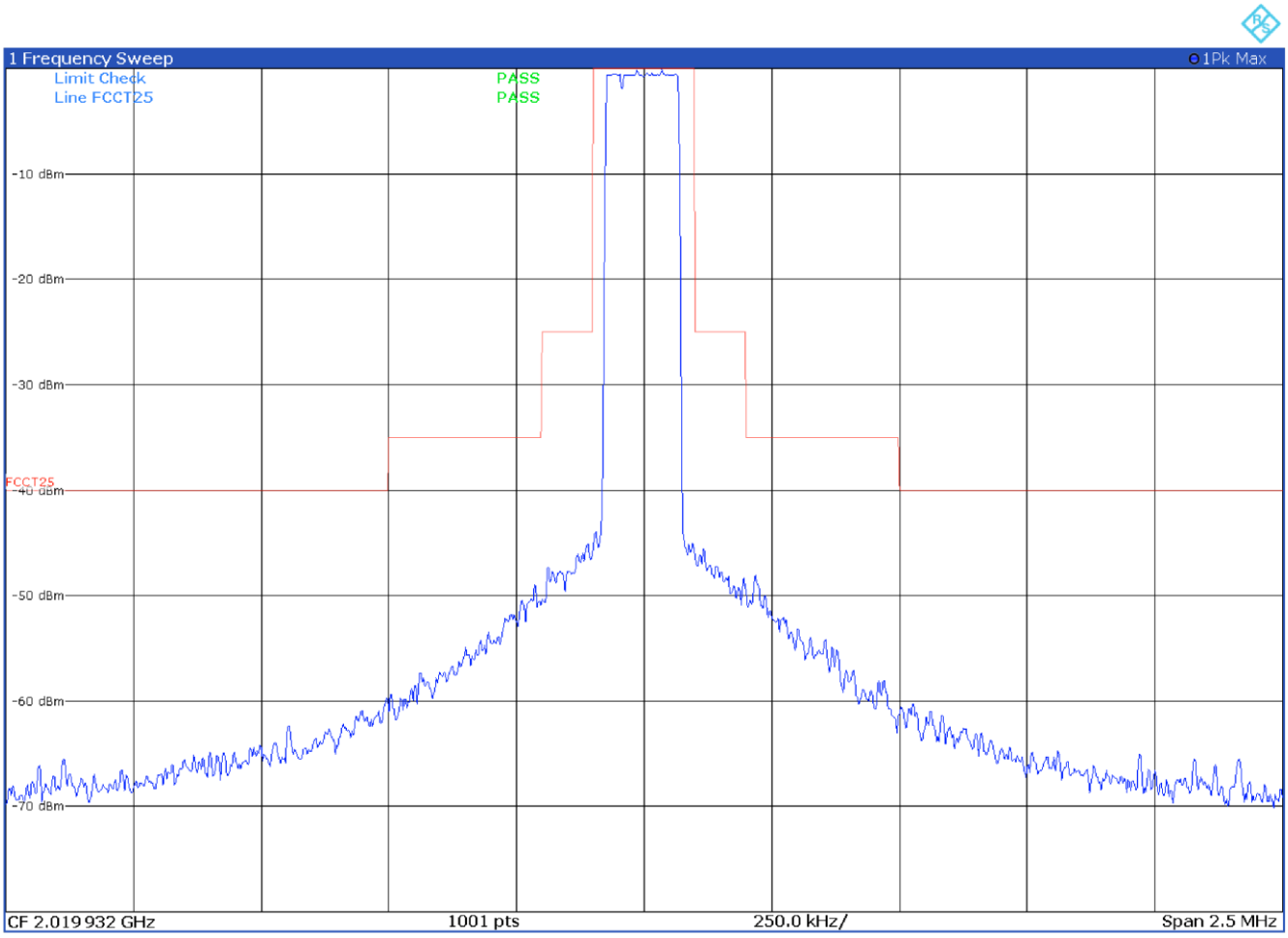


Figure 8.5-9: *Occupied bandwidth mask on high channel for LR-FHSS 137 kHz*

8.6 Spurious emissions at antenna terminals

8.6.1 References, definitions and limits

FCC §25.202(f):

Emission limitations. Except for SDARS terrestrial repeaters and as provided for in paragraph (i), the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the schedule set forth in paragraphs (f)(1) through (f)(4) of this section. The out-of-band emissions of SDARS terrestrial repeaters shall be attenuated in accordance with the schedule set forth in paragraph (h) of this section.

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;

(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts;

(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (f) (1), (2) and (3) of this section.

RSS-170, Clause 5.4:

The unwanted emissions of ATC base station equipment transmitting in the bands 2000-2020 MHz and 2180-2200 MHz shall comply with the following:

(1) The power of any unwanted emissions at frequencies outside the equipment's operating frequency block shall be attenuated below the transmitter power P (dBW), by 43 + 10 log p (watts), dB

(2) For equipment operating in the band 2180-2200 MHz, in addition to (1), the power of any emissions on all frequencies between 2200 MHz and 2290 MHz shall not exceed an e.i.r.p. of -100.6 dBW/4 kHz.

8.6.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	June 10, 2024

8.6.3 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth	4 kHz
Video bandwidth	≥ 3 × RBW
Frequency range	30 MHz to 22 GHz
Detector mode	Peak
Trace mode	Max Hold

8.6.4 Test equipment used

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

8.6.5 Test data

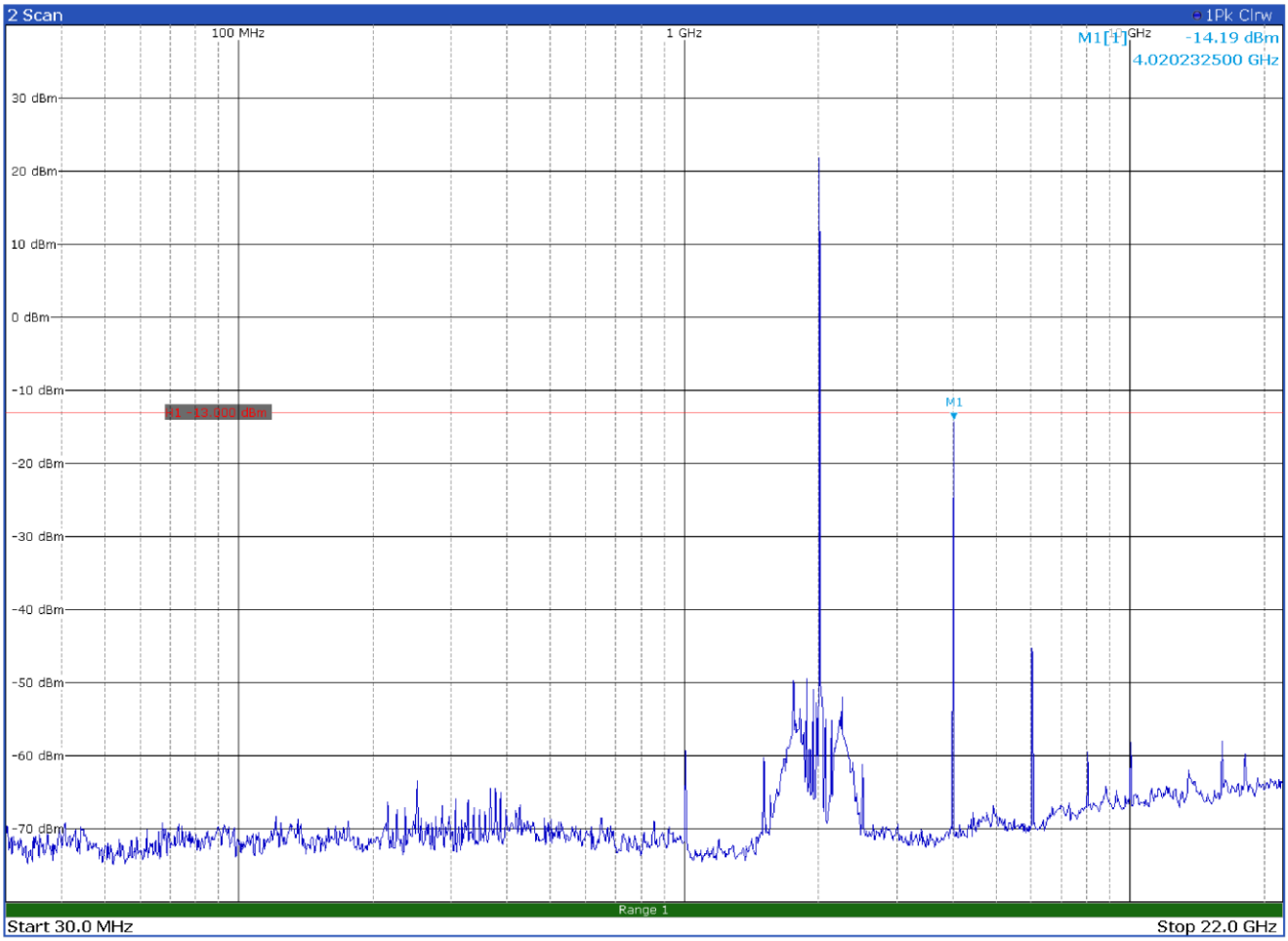


Figure 8.6-1: *Spurious emissions at antenna terminals on low channel for LoRa 125 kHz BW*

Limits exceed by the carrier

Test data, continued

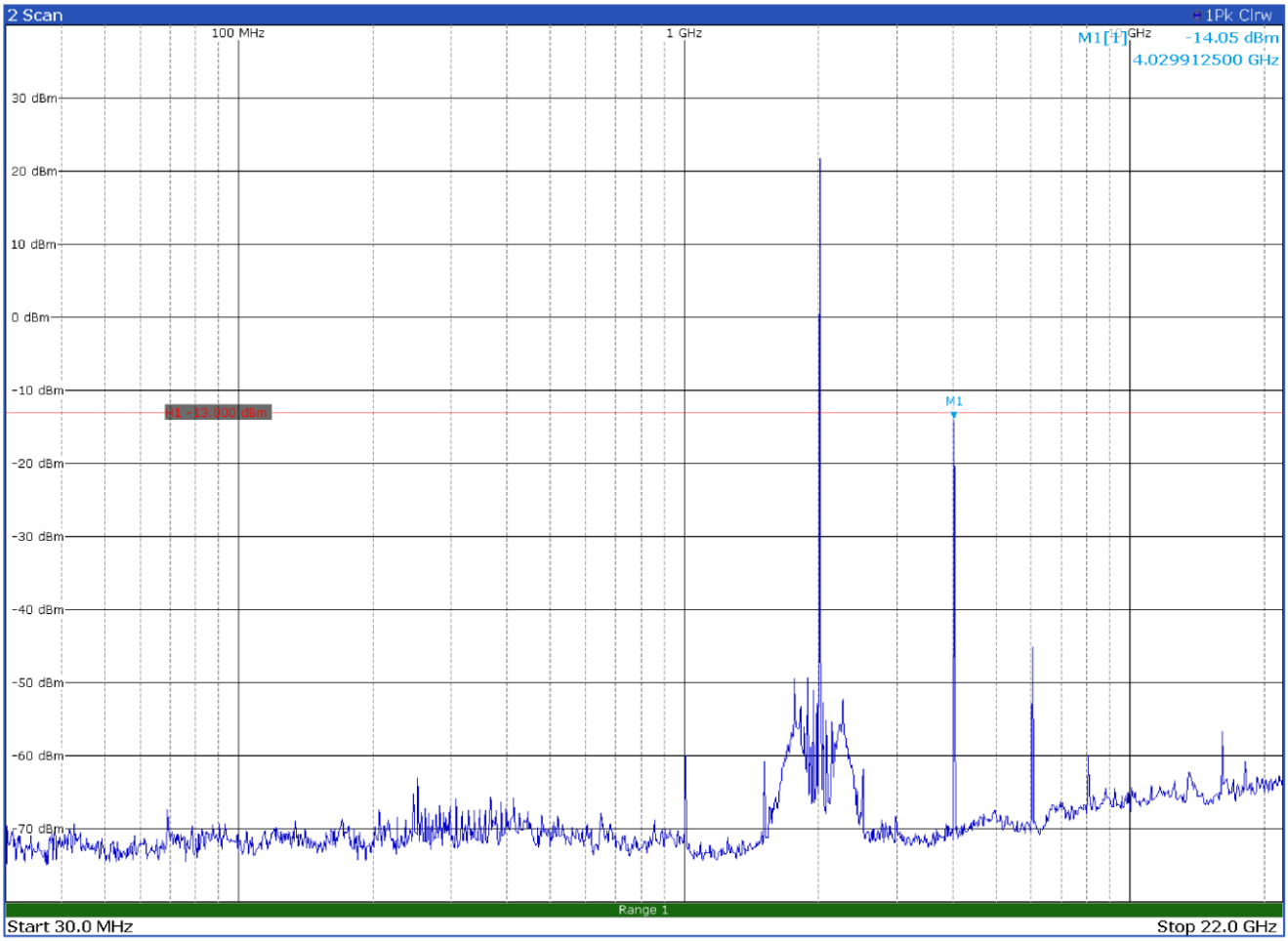


Figure 8.6-2: *Spurious emissions at antenna terminals on mid channel for LoRa 125 kHz BW*

Limits exceed by the carrier

Test data, continued

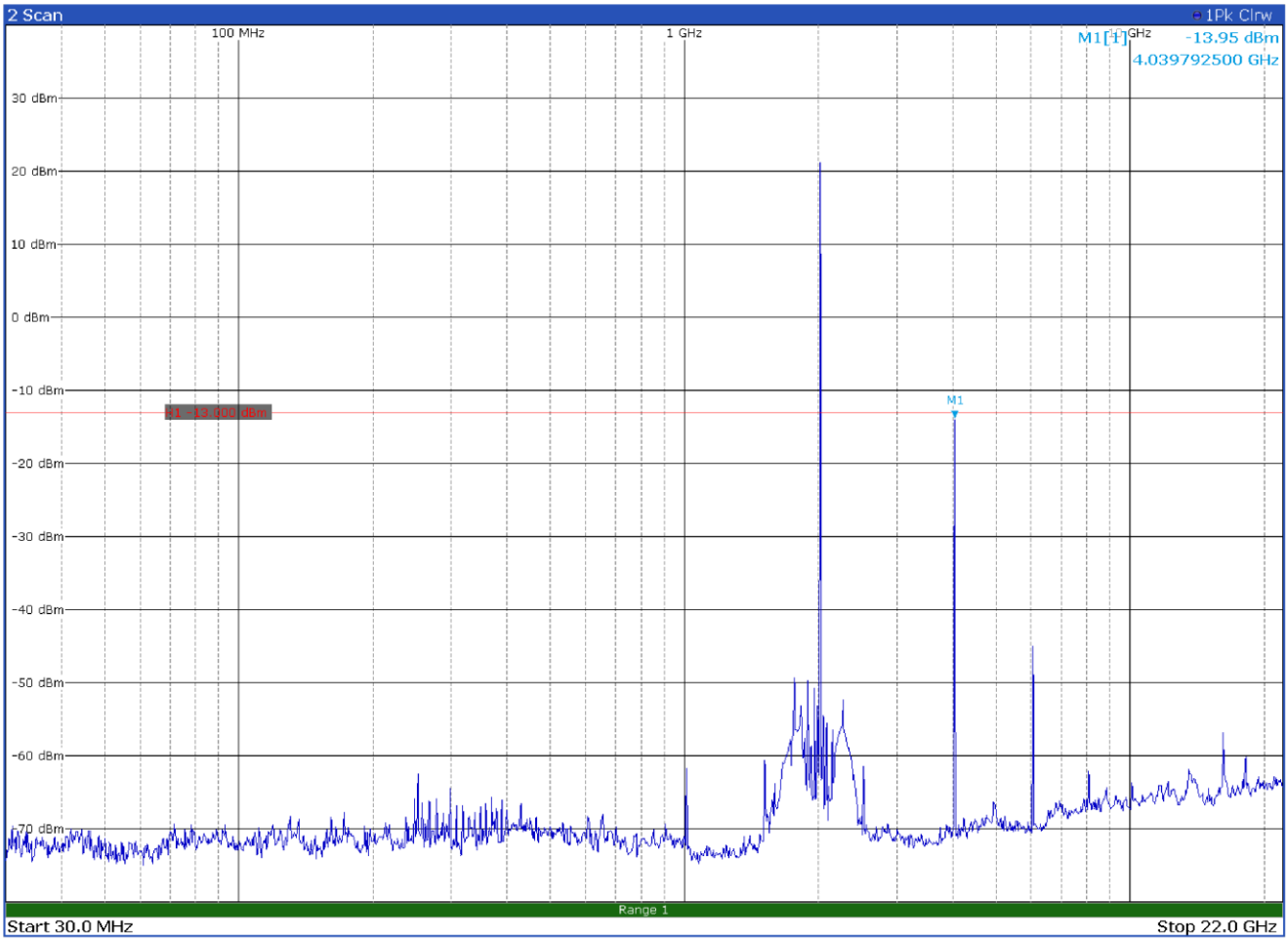


Figure 8.6-3: *Spurious emissions at antenna terminals on high channel for LoRa 125 kHz BW*

Limits exceed by the carrier

Test data, continued

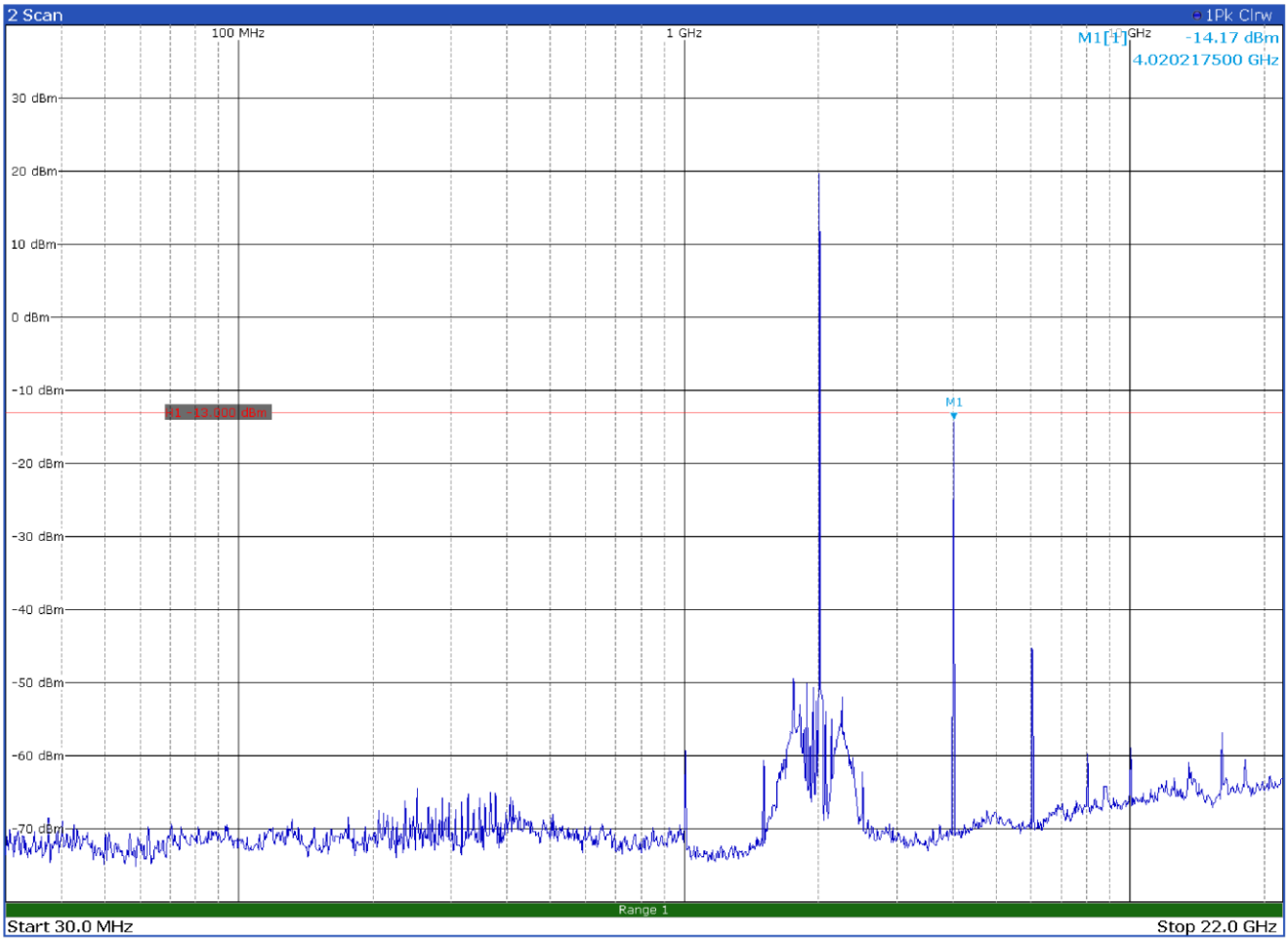


Figure 8.6-4: *Spurious emissions at antenna terminals on low channel for LoRa 250 kHz BW*

Limits exceed by the carrier

Test data, continued

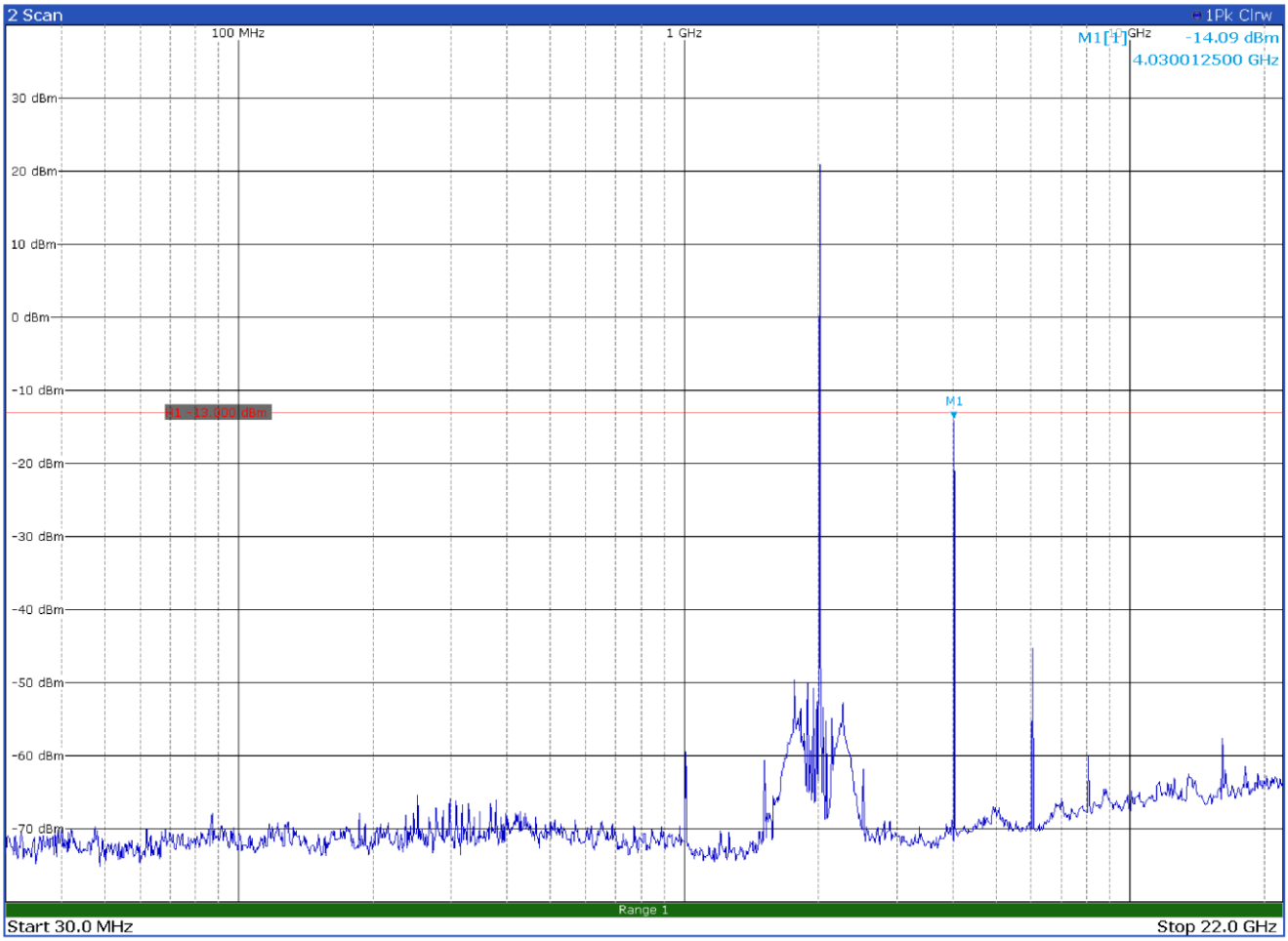


Figure 8.6-5: *Spurious emissions at antenna terminals on mid channel for LoRa 250 kHz BW*

Limits exceed by the carrier

Test data, continued

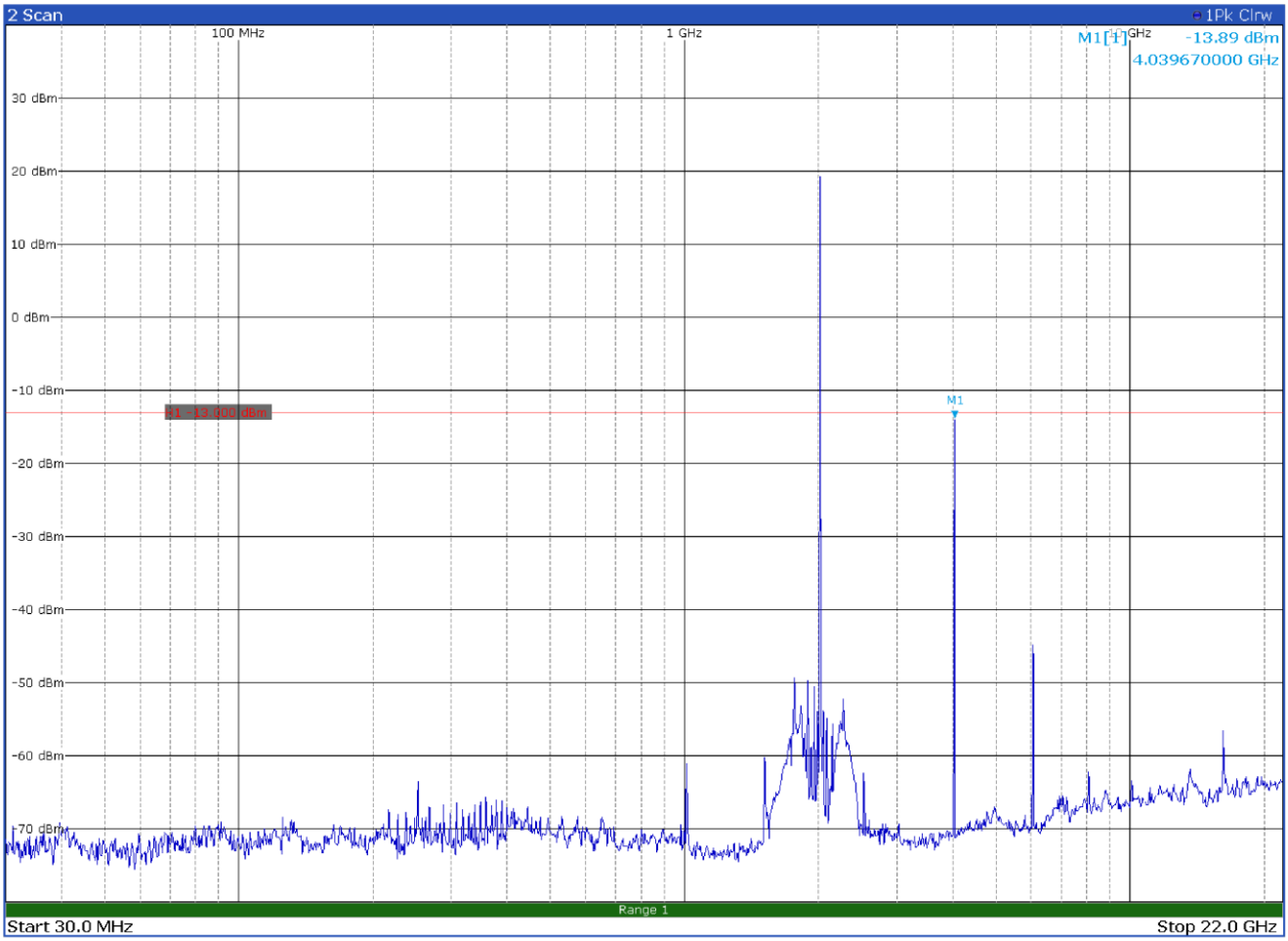


Figure 8.6-6: *Spurious emissions at antenna terminals on high channel for LoRa 250 kHz BW*

Limits exceed by the carrier

Test data, continued

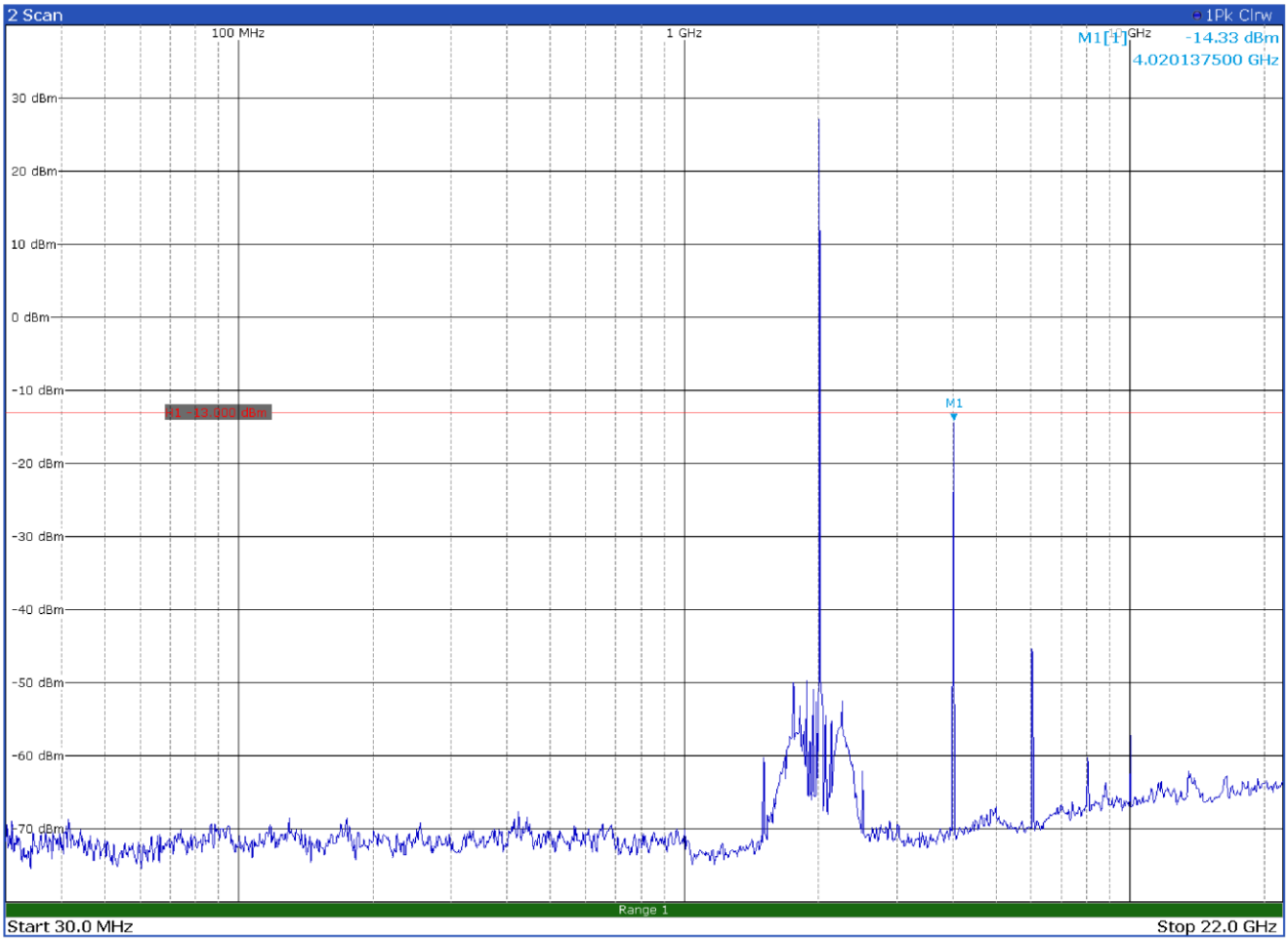


Figure 8.6-7: *Spurious emissions at antenna terminals on low channel for LR-FHSS 137 kHz*

Limits exceed by the carrier

Test data, continued

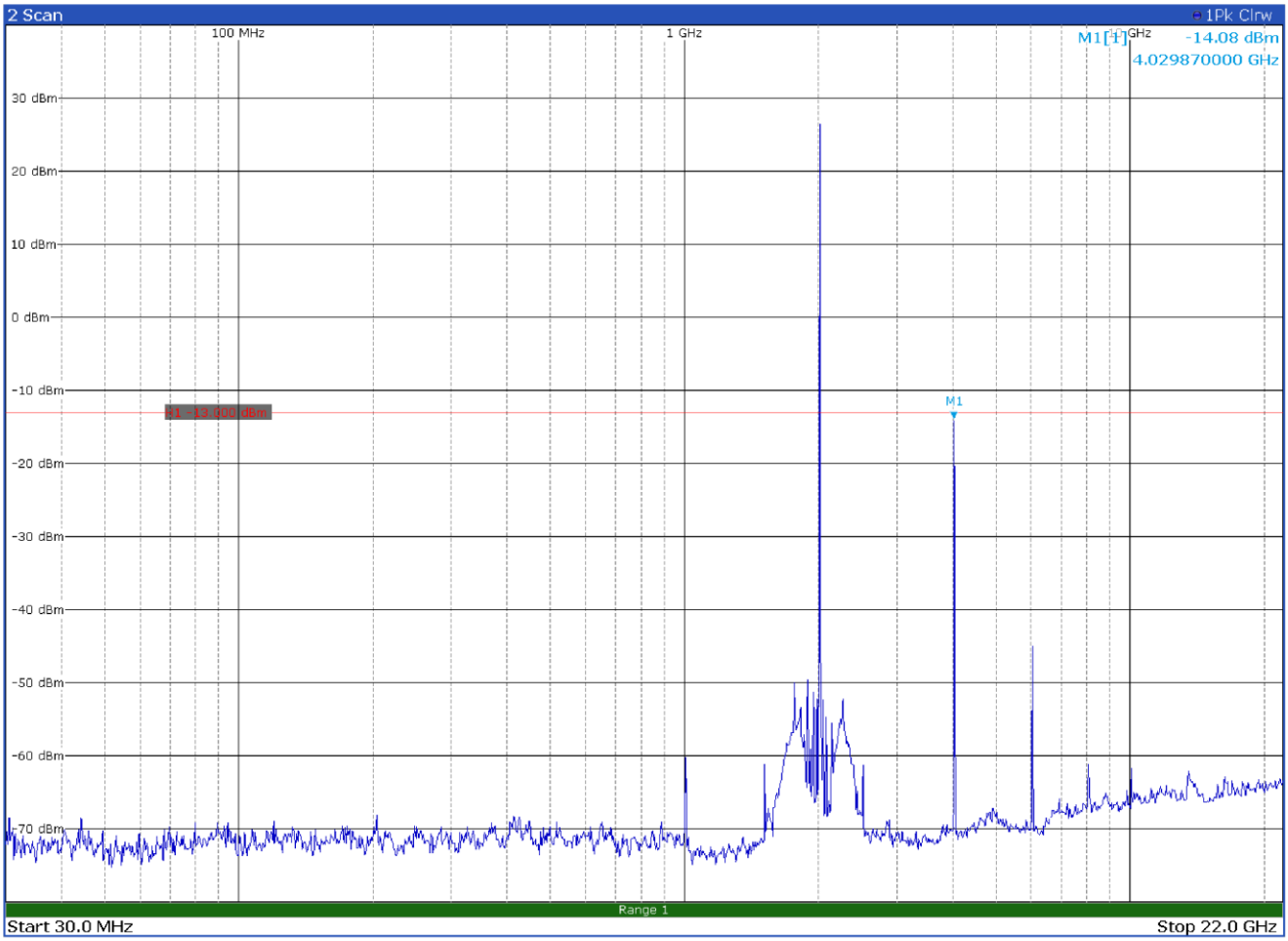


Figure 8.6-8: *Spurious emissions at antenna terminals on mid channel for LR-FHSS 137 kHz*

Limits exceed by the carrier

Test data, continued

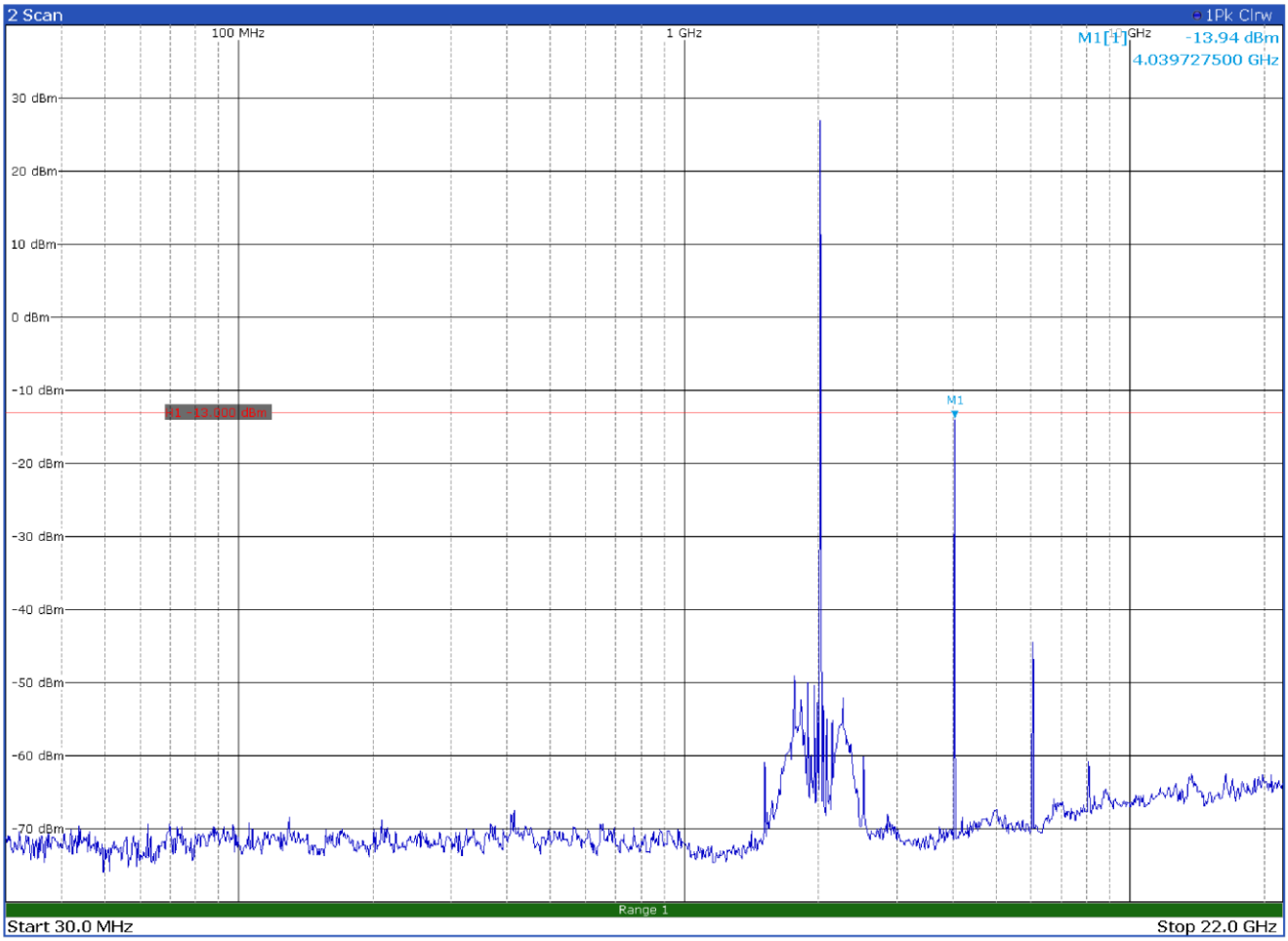


Figure 8.6-9: *Spurious emissions at antenna terminals on high channel for LR-FHSS 137 kHz*

Limits exceed by the carrier

8.7 Field strength of spurious radiation

8.7.1 References, definitions and limits

FCC §25.202(f):

Emission limitations. Except for SDARS terrestrial repeaters and as provided for in paragraph (i), the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the schedule set forth in paragraphs (f)(1) through (f)(4) of this section. The out-of-band emissions of SDARS terrestrial repeaters shall be attenuated in accordance with the schedule set forth in paragraph (h) of this section.

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;

(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts;

(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (f) (1), (2) and (3) of this section.

RSS-170, Clause 5.4:

The unwanted emissions of ATC base station equipment transmitting in the bands 2000-2020 MHz and 2180-2200 MHz shall comply with the following:

(1) The power of any unwanted emissions at frequencies outside the equipment's operating frequency block shall be attenuated below the transmitter power P (dBW), by 43 + 10 log p (watts), dB

(2) For equipment operating in the band 2180-2200 MHz, in addition to (1), the power of any emissions on all frequencies between 2200 MHz and 2290 MHz shall not exceed an e.i.r.p. of -100.6 dBW/4 kHz.

8.7.2 Test summary

Verdict	Pass		
Tested by	P. Barbieri	Test date	June 11, 2024

8.7.3 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.

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

8.7.4 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
Cable set	Rosenberger	ST.ALO-02	1.650
Software turntable and mast	Maturo	mcApp	8.1.0.5410

8.7.5 Test data

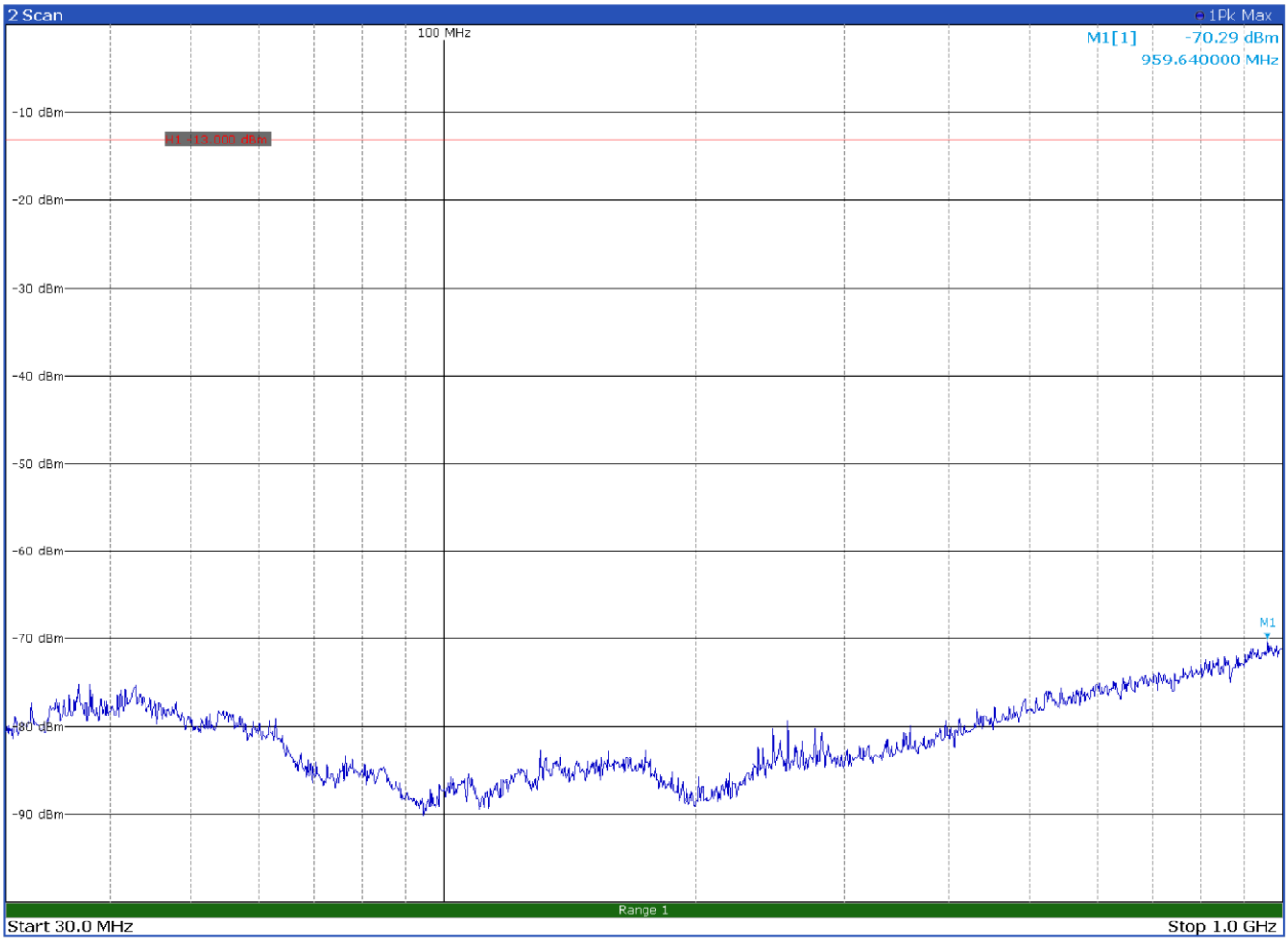


Figure 8.7-1: *Radiated spurious emissions on low channel - LoRa 125 kHz BW – Antenna in horizontal polarization*

Test data, continued

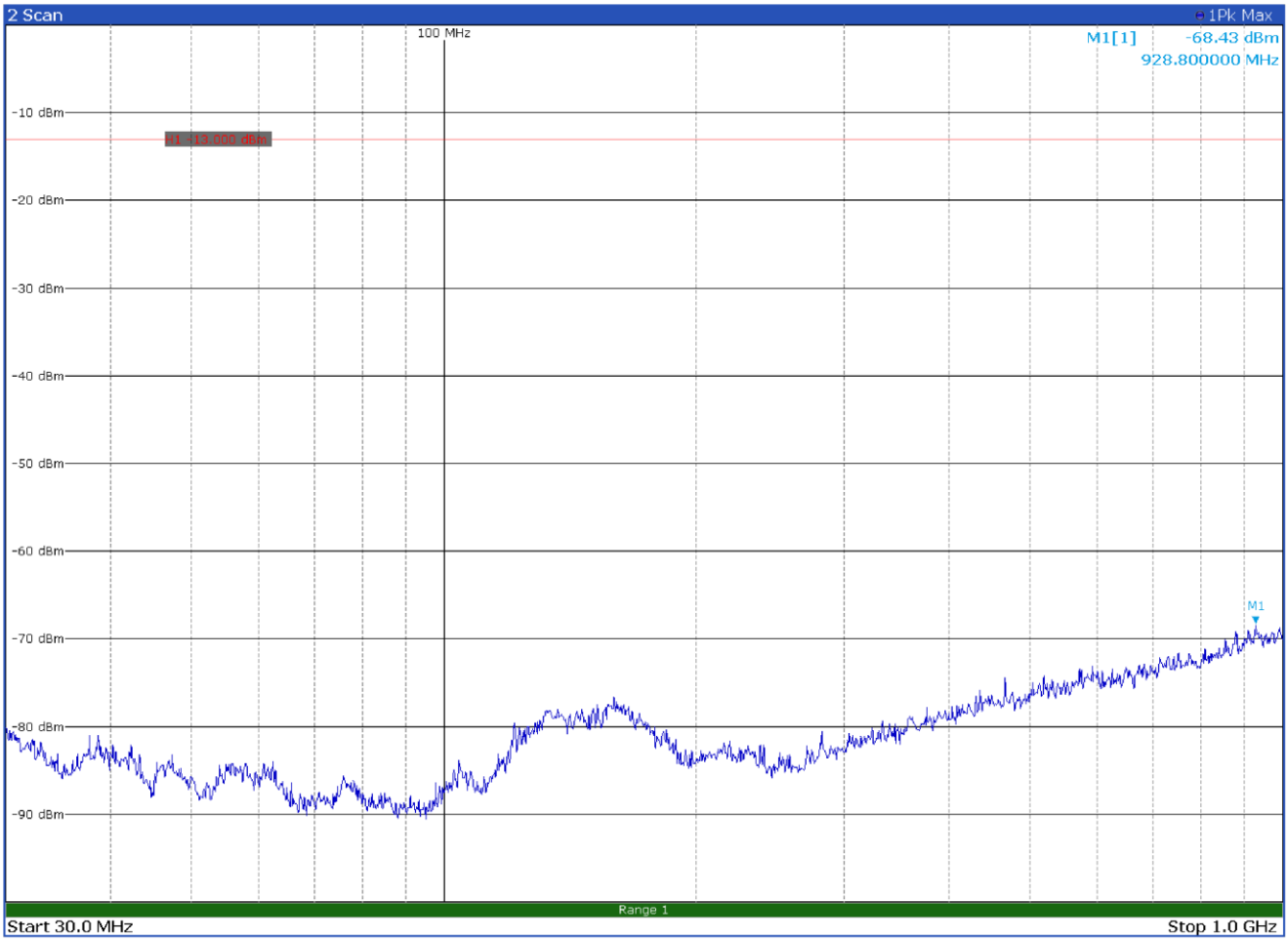


Figure 8.7-2: *Radiated spurious emissions on low channel - LoRa 125 kHz BW – Antenna in vertical polarization*

Test data, continued

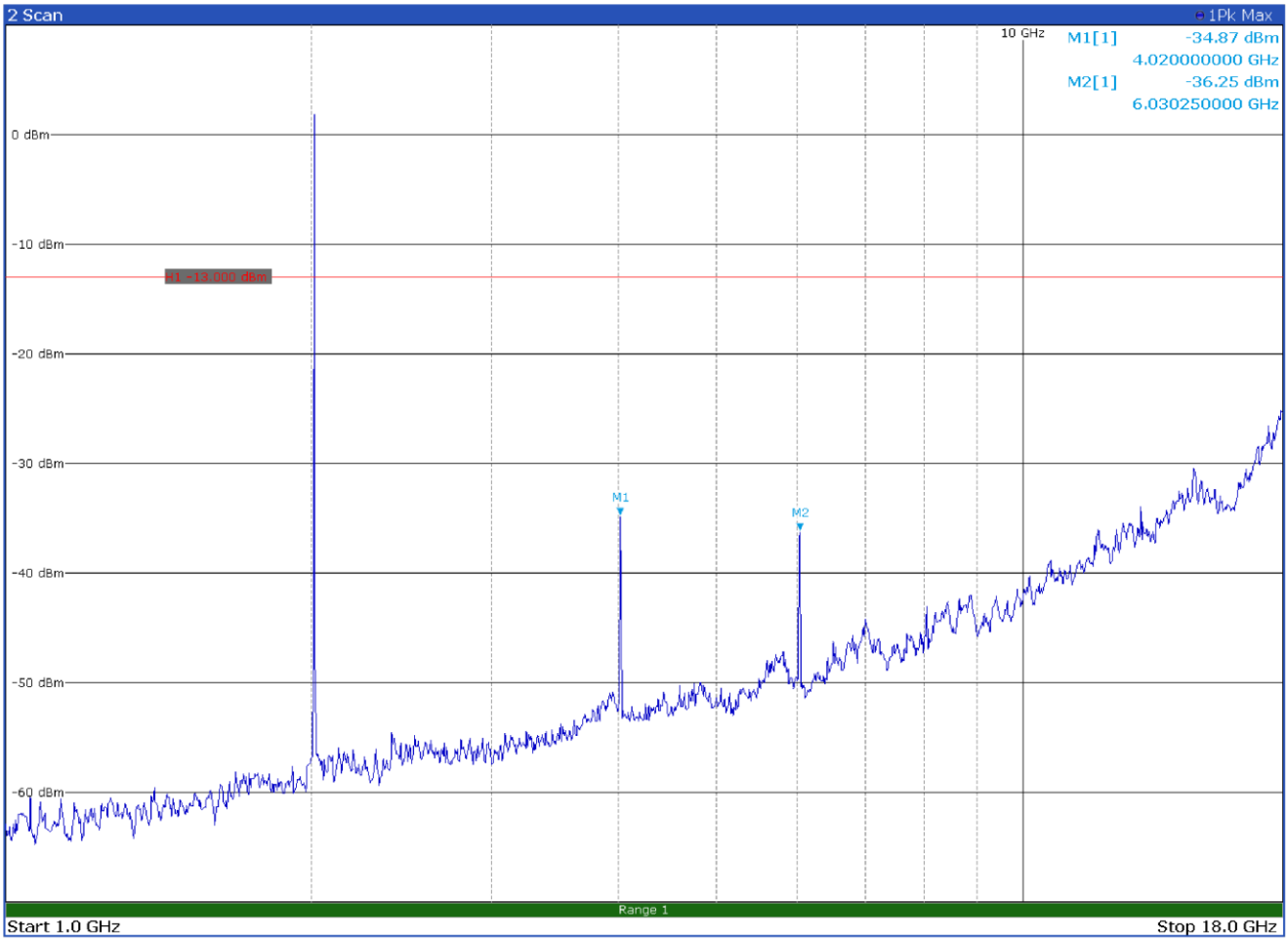


Figure 8.7-3: *Radiated spurious emissions on low channel - LoRa 125 kHz BW – Antenna in horizontal polarization*

Limit exceeded by the carrier

Test data, continued

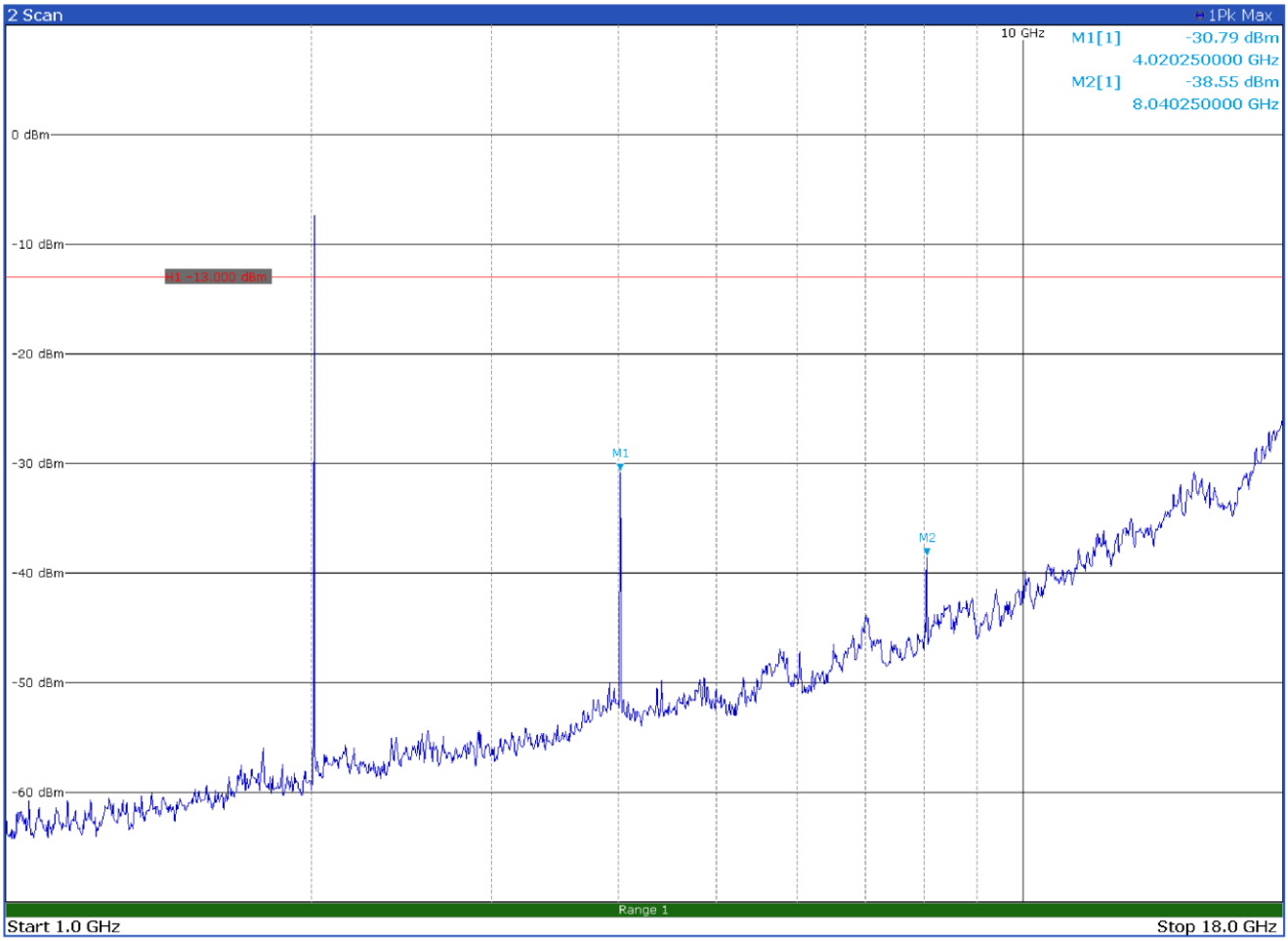


Figure 8.7-4: *Radiated spurious emissions on low channel - LoRa 125 kHz BW – Antenna in vertical polarization*

Limit exceeded by the carrier