Test Report

Finnish Accreditation Service
T004 (EN ISO/IEC 17025)

INTENTIONAL RADIATOR TESTS ACCORDING TO FCC PART 15 C AND ISED CANADA REQUIREMENTS

Equipment Under Test:	Temperature/humidity sensor with LoRa radio
Model:	WLT 311
Manufacturer:	Lapp Automaatio Oy Martinkyläntie 52 FI-01720 VANTAA FINLAND
Customer:	Lapp Automaatio Oy Martinkyläntie 52 FI-VANTAA FINLAND
FCC Rule Part:	15.247: 2019
IC Rule Part:	RSS-247, Issue 2, 2017 RSS-GEN Issue 5, 2018
KDB:	558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019)

Date:	10 December 2019	Date:	10 December 2019
Issued by:	Rauno Repo Senior EMC/RF Specialist	Checked by:	Mikko Halonen Development Engineer

RELEASE HISTORY

Version	Changes	Issued
1.0	Initial release	10 December 2019

Equipment Under Test (EUT)

Trade mark:	IoTKey WLT311
Model:	WLT 311
Serial no:	-
FCC ID:	2AQYD-WLT311
IC ID:	24221-WLT311

Description of the EUT

Temperature/humidity sensor with LoRa radio. Power supply with Internal 3.6 V Lithium battery or 12/24 VDC external supply. Operating in frequency band 902-928 MHz.

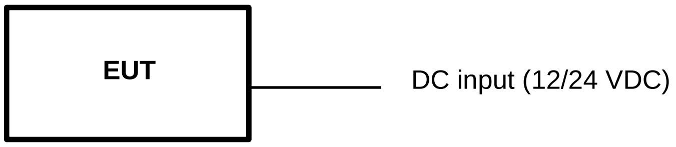

Figure 1: Test setup blocking diagram

Classification of the device

Fixed device	☒
Mobile Device (Human body distance > 20cm)	☐
Portable Device (Human body distance < 20cm)	☐

Modifications Incorporated in the EUT

Ferrite tape (Würth Elektronik 304 10S A6) assembled between enclosure and PCB-module.

Ratings and Declarations

Operating Frequency Range (125kHz):	902.3 – 914.9 MHz
Operating Frequency Range (500kHz):	903.0 – 914.2 MHz
Channels:	64 (125kHz) / 8 (500kHz)
Channel separation:	200 kHz (125kHz) / 1.6 MHz (500kHz)
Effective conducted power:	11.24 dBm (Peak)
Modulation:	CSS, O-QPSK
Antenna model:	916-cw-rah
Antenna gain:	2.2 dBi (Max)

Power Supply

Operating voltage range: 3.6 V Internal lithium battery or 12/24 VDC supply

Separate AC/DC adaptor, XP Power model: VER12US120-JA (120 V, 60 Hz input / 12 V output) was used during AC emissions test. Supply is not provided by the manufacturer. In other tests the EUT was supplied with laboratory power supply.

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Unless otherwise stated the results shown in this test report refer only to the sample(s) tested and such sample(s) are retained for 30 days only.

SUMMARY OF TESTING

Test Specification	Description of Test	Result
§15.203	Antenna requirement	PASS
§15.207(a) / RSS-GEN 8.8	Conducted Emissions on Power Supply Lines	PASS
§15.247(b)(3) / RSS-247 5.4(d)	Maximum Peak Conducted Output Power	PASS
§15.247(a)(2) / RSS-247 5.2(a)	Occupied/DTS Bandwidth	PASS
§15.247(e) / RSS-247 5.2(b)	Power Spectral Density	PASS
RSS-GEN 6.7	99% Occupied Bandwidth	PASS
§15.247(d) / RSS-247 5.5	100 kHz Bandwidth of Frequency Band Edges and Conducted Spurious Emissions	PASS
§15.209(a), §15.247(d) / RSS-247 5.5	Radiated Emissions Within the Restricted Bands	PASS
§15.247(a) / RSS-247 5.1(b)	Carrier Frequency Separation	PASS
§15.247(a) / RSS-247 5.1(c)	Number of Hopping Frequencies	PASS
§15.247(a) / RSS-247 5.1(c)	Time of Occupancy (Dwell Time)	PASS

The decision rule applied for the tests results stated in this test report is according to the requirements of section 1.3 of ANSI C63.10-2013.

EUT Test Conditions during Testing

The EUT was in continuous transmit mode during the tests where hopping was stopped. The hopping was stopped and the EUT was configured into the wanted channel using software provided by the manufacturer.

Following channels and settings were used during the tests

Table 1: Channels and setting used in tests when the hopping was stopped.

Channel	Frequency (MHz)	Channel BW (kHz)	Spreading Factor	Mode
0	902.3	125	12	FHSS
31	908.5	125	12	
63	914.9	125	12	
64	903.0	500	12	DTS
67	907.8	500	12	
71	914.2	500	12	

Test Facility

Testing Laboratory / address: FCC designation number: **FI0002** **ISED CAB identifier: T004**	SGS Fimko Ltd Takomotie 8 FI-00380, HELSINKI FINLAND
Test Site:	☐ Kara 10, ISED Canada registration number: **8708A-1** ☒ Kara 5, ISED Canada registration number: **8708A-2** ☐ Kallio 10

TEST RESULTS

Antenna requirement

Standard: FCC Rule §15.203
Tested by: HEM
Date: 26 November 2019

FCC Rule: 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.

Specification	Requirement (at least one of the following shall be applied)	Conclusion
§15.203	1. Permanently attached antenna 2. Unique coupling to the intentional radiator 3. Professionally installed radio. The installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.	PASS
Note	Option 2 is used (RP SMA)	

Conducted Emissions In The Frequency Range 150 kHz - 30 MHz

Standard:	ANSI C63.10	(2013)
Tested by:	HEM	
Date:	1 November 2019	
Temperature:	22 ± 3°C	
Humidity:	20 - 60 % RH	
Barometric pressure:	1013 hPa	
Measurement uncertainty:	± 2.9 dB	Level of confidence 95 % (k = 2)

FCC Rule: 15.207 (a)
RSS-GEN 8.8

Conducted disturbance voltage was measured with an artificial main network from 150 kHz to 30 MHz with 4.5 kHz steps and a resolution bandwidth of 9 kHz. Measurements were carried out with peak and average detectors.

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

*Decreases with the logarithm of the frequency.

Final measurements from the worst frequencies

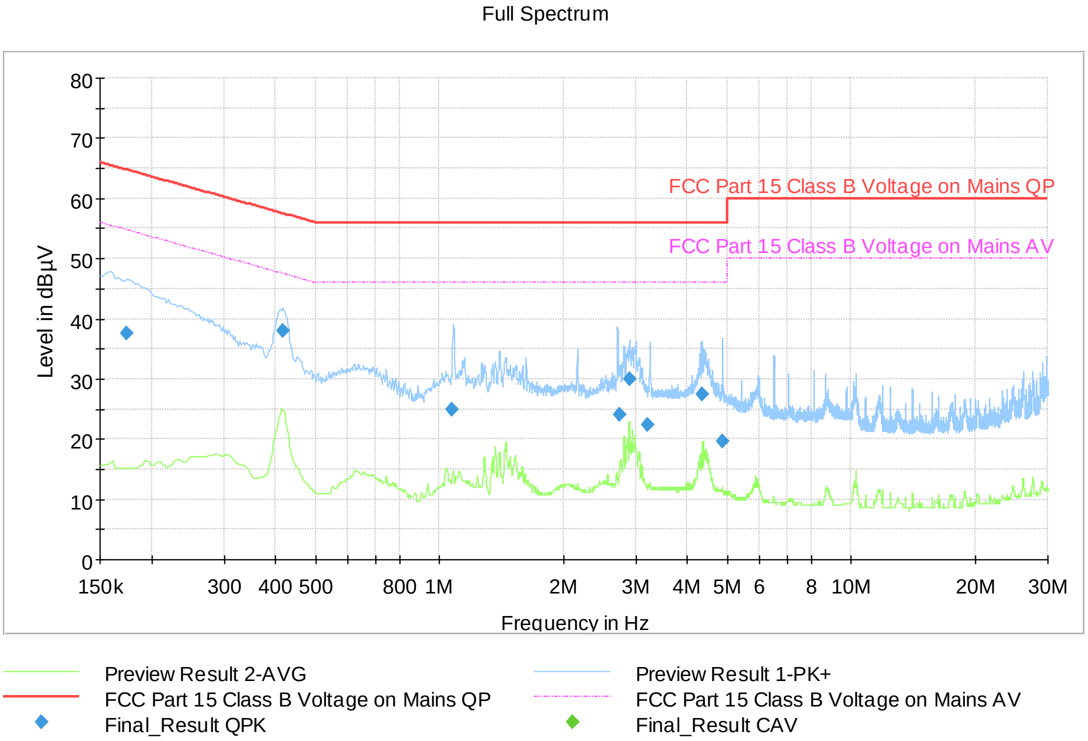


Figure 2: The measured curves with peak- and average detectors

Table 2: Final measurements from the worst frequencies

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.174000	37.66	---	64.77	27.11	1000.0	9.000	N	ON	9.6
0.416750	37.95	---	57.51	19.56	1000.0	9.000	N	ON	9.7
1.076000	24.97	---	56.00	31.03	1000.0	9.000	N	ON	9.8
2.748250	24.16	---	56.00	31.84	1000.0	9.000	N	ON	9.9
2.891250	29.92	---	56.00	26.08	1000.0	9.000	L1	ON	9.9
3.210250	22.45	---	56.00	33.55	1000.0	9.000	N	ON	9.9
4.343750	27.38	---	56.00	28.62	1000.0	9.000	L1	ON	10.0
4.862000	19.56	---	56.00	36.44	1000.0	9.000	L1	ON	10.0

The correction factor in the final result table contains the sum of the transducers (transient limiter + cables). The result value is the measured value corrected with the correction factor.

Maximum Peak Conducted Output Power

Standard:	ANSI C63.10	(2013)
Tested by:	RRE	
Date:	17 September 2019	
Temperature:	23 ± 3 °C	
Humidity:	20 - 60 % RH	
Measurement uncertainty:	± 2.87dB	Level of confidence 95 % (k = 2)

FCC Rule: 15.247(b)(3)
RSS-247 5.4(d)

For systems using digital modulation in the 902-928 MHz bands the limit is 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power.

Measured values are peak values.

Results:

Table 3: Maximum conducted output power

Channel Bandwidth [kHz]	Channel	Conducted Power [dBm]	Limit [dBm]	Margin [dBm]	Result
125	0 Low	11.24	30	18.76	PASS
	31 Mid	11.15	30	18.85	PASS
	63 High	10.94	30	19.06	PASS
500	64 Low	11.24	30	18.76	PASS
	67 Mid	11.16	30	18.84	PASS
	71 High	10.96	30	19.04	PASS

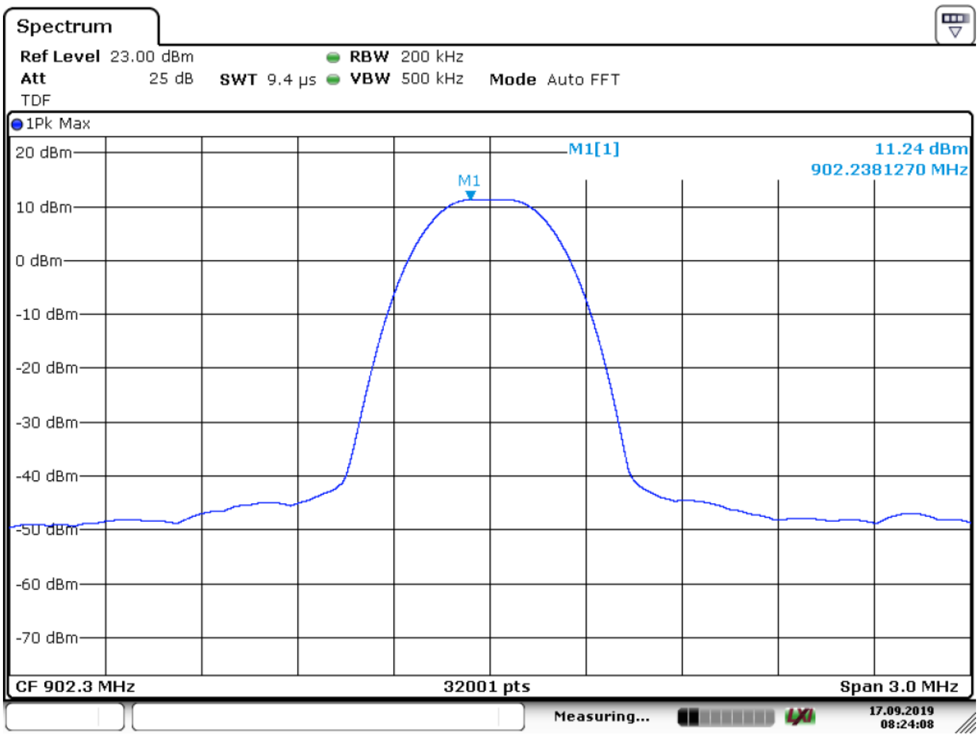


Figure 3: Conducted power, Channel 0 low (125 kHz)

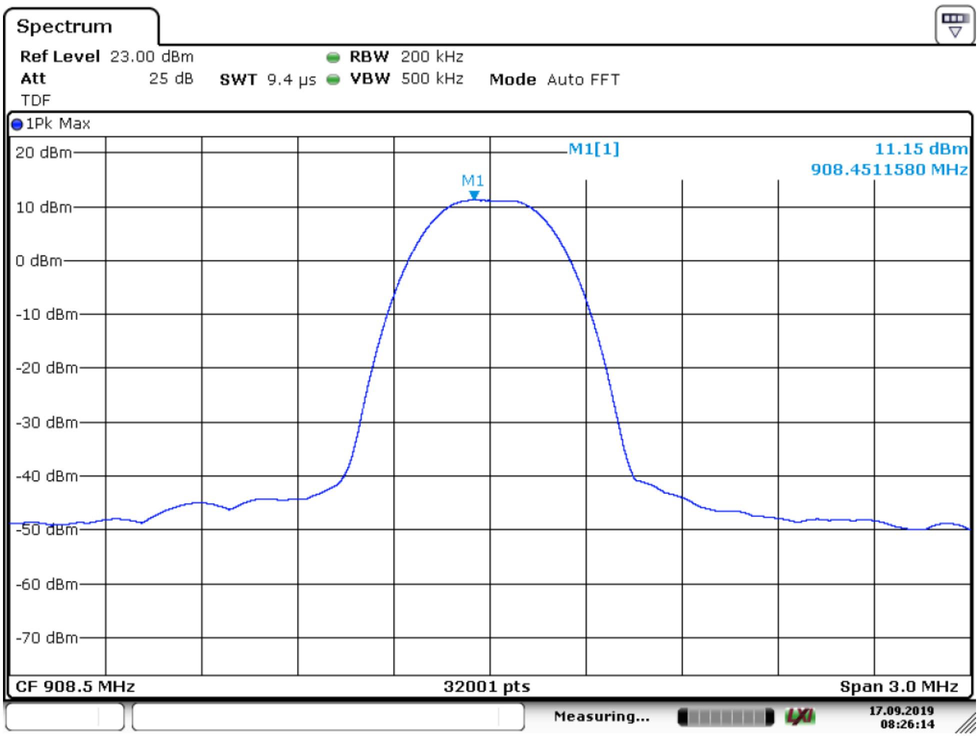


Figure 4: Conducted power, Channel 31 mid (125 kHz)

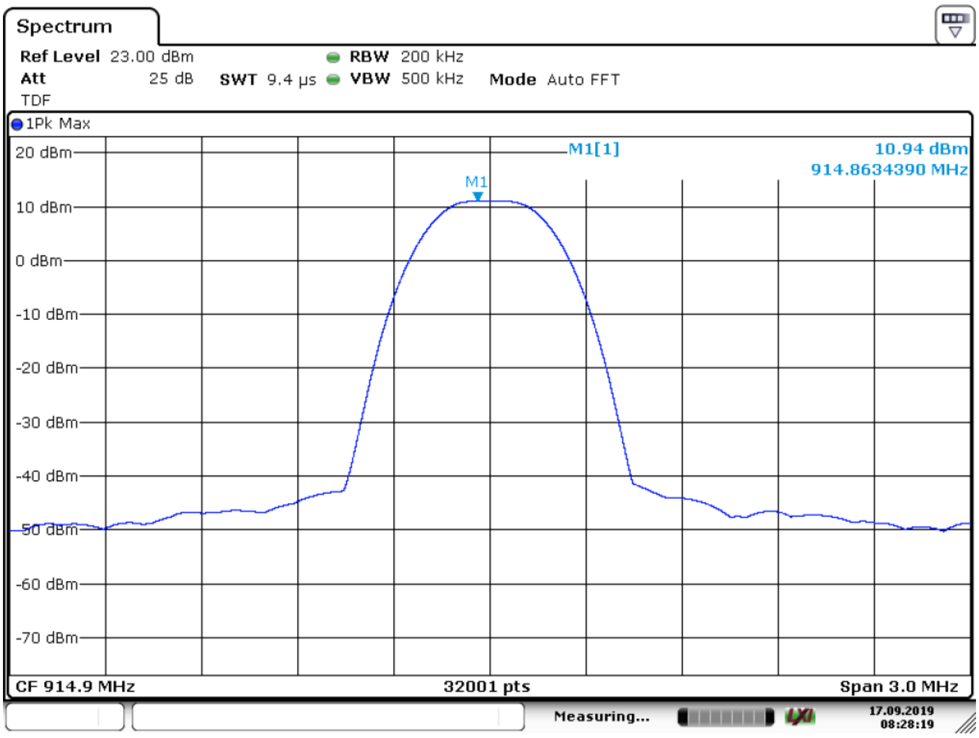


Figure 5: Conducted power, Channel 63 high (125 kHz)

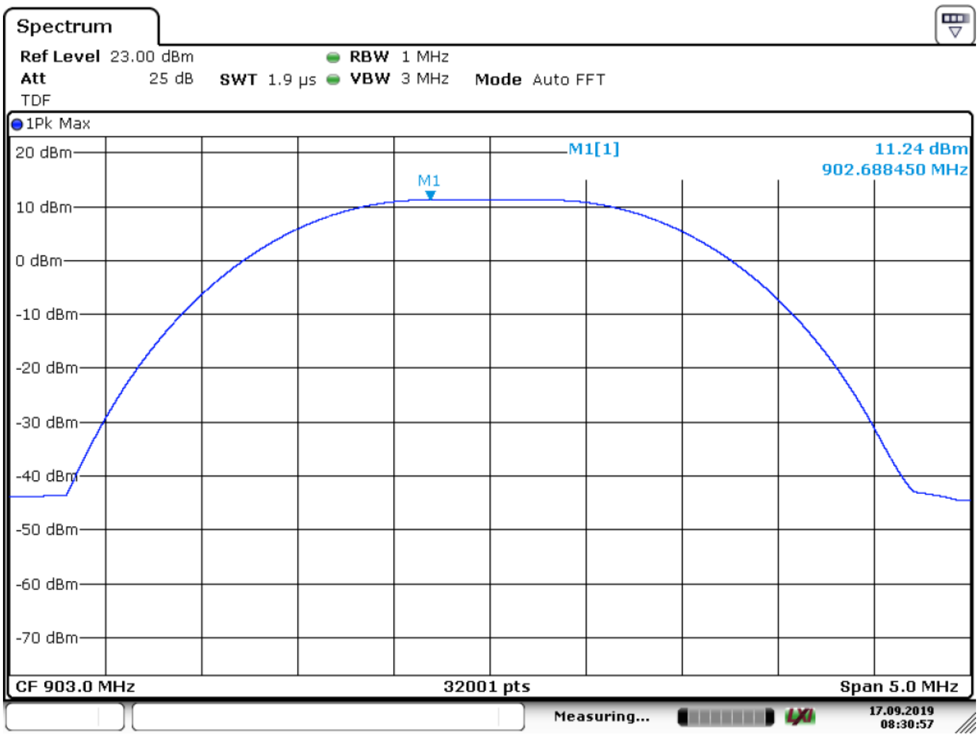


Figure 6: Conducted power, Channel 64 low (500 kHz)

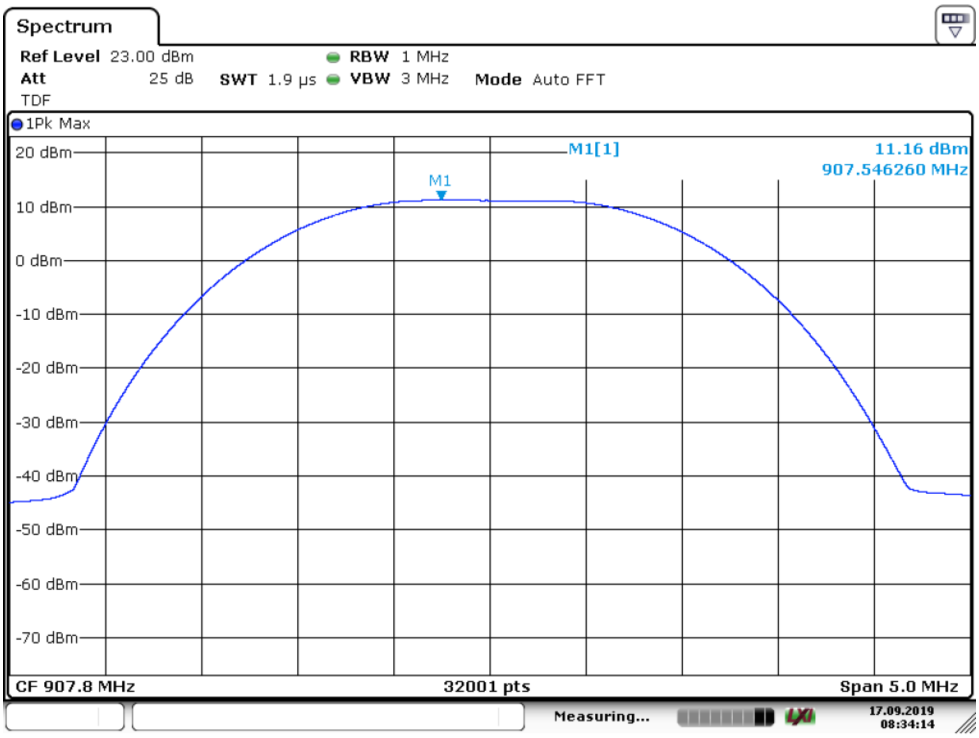


Figure 7: Conducted power, Channel 67 mid (500 kHz)

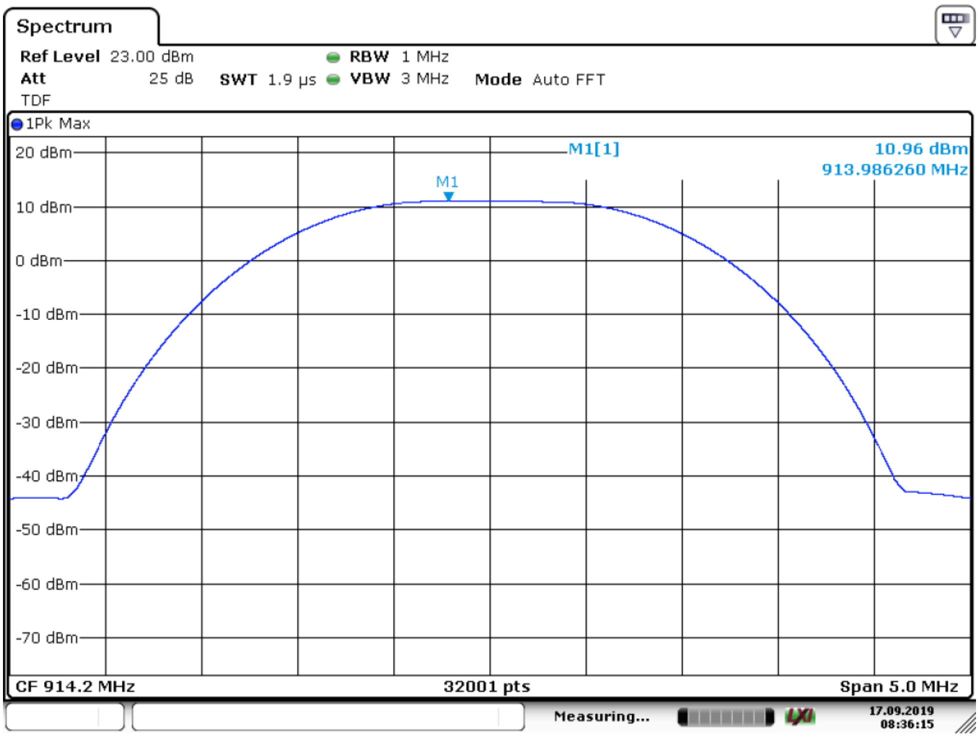


Figure 8: Conducted power, Channel 71 high (500 kHz)

Transmitter Radiated Spurious Emissions 9 kHz - 10 GHz

Standard:	ANSI C63.10	
Tested by:	HEM, PKA	
Date:	5 - 13 September 2019	
Temperature:	23 ± 3 °C	
Humidity:	20 - 60 % RH	
Measurement uncertainty:	± 4.51 dB	Level of confidence 95 % (k = 2)

FCC Rule: 15.247(d), 15.209(a)

RSS-247 5.5

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. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a)**.**

With radiated tests pretests were made with three different orthogonal positions and the worst position was selected for the tests. There were no notified differences between channels with frequency range 9 kHz – 1000 MHz. Channel 31 (125 kHz BW) and channel 67 (500 kHz BW) results are presented in this document (worst case). The measuring distance was 3 m.

The correction factor in the final result table contains the sum of the transducers (antenna + amplifier + cables).

Peak values of emissions below 1000 MHz measured for reference as well as transmitter fundamental.

Frequency range [MHz]	Limit [µV/m]	Limit [dBµV/m]	Detector
30 - 80	100	40.0	Quasi-peak
88 - 216	150	43.5	Quasi-peak
216 - 960	200	46.0	Quasi-peak
960 - 1000	500	53.9	Quasi-peak
Above 1000	500	53.9	Average
Above 1000	5000	73.9	Peak

Low channel (0) 125kHz

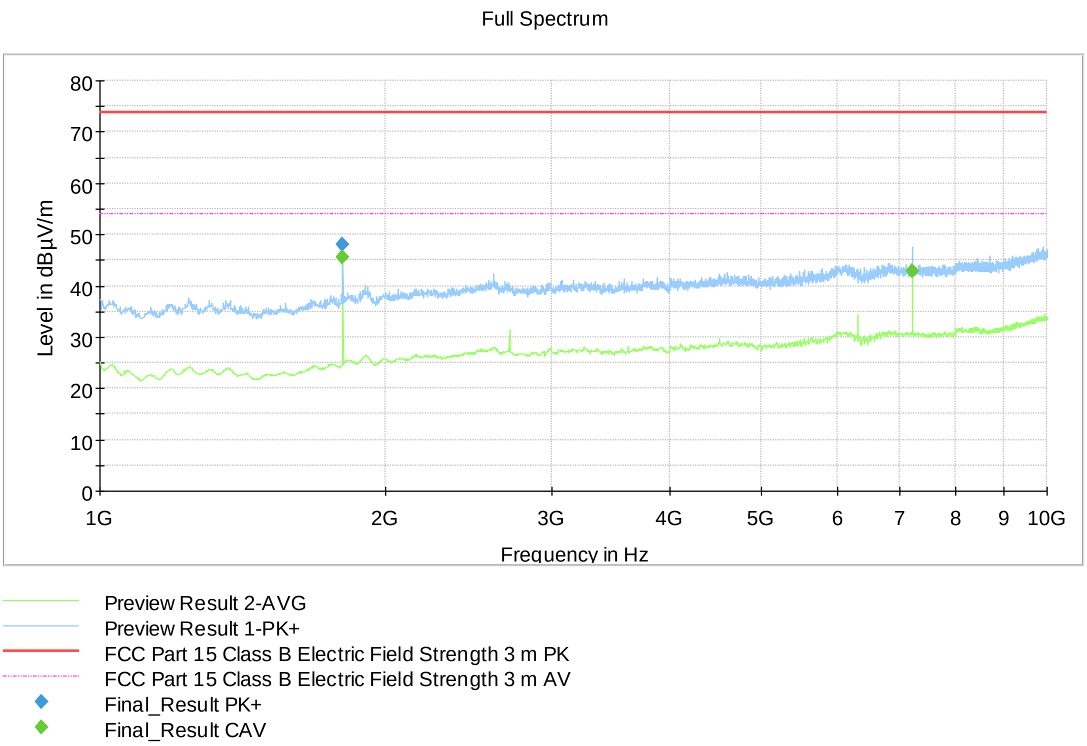


Figure 9: Channel 0 low 1 GHz – 10 GHz (125 kHz)

Table 4: Results, low channel (0), 125kHz

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/ m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1804.575000	---	45.67	53.90	8.23	15000.0	1000.0	250.0	H	242.0	2.4
1804.575000	48.11	---	73.90	25.79	15000.0	1000.0	187.0	H	239.0	2.4
7218.325000	---	42.90	53.90	11.00	15000.0	1000.0	184.0	V	228.0	10.2

Middle channel (31) 125kHz

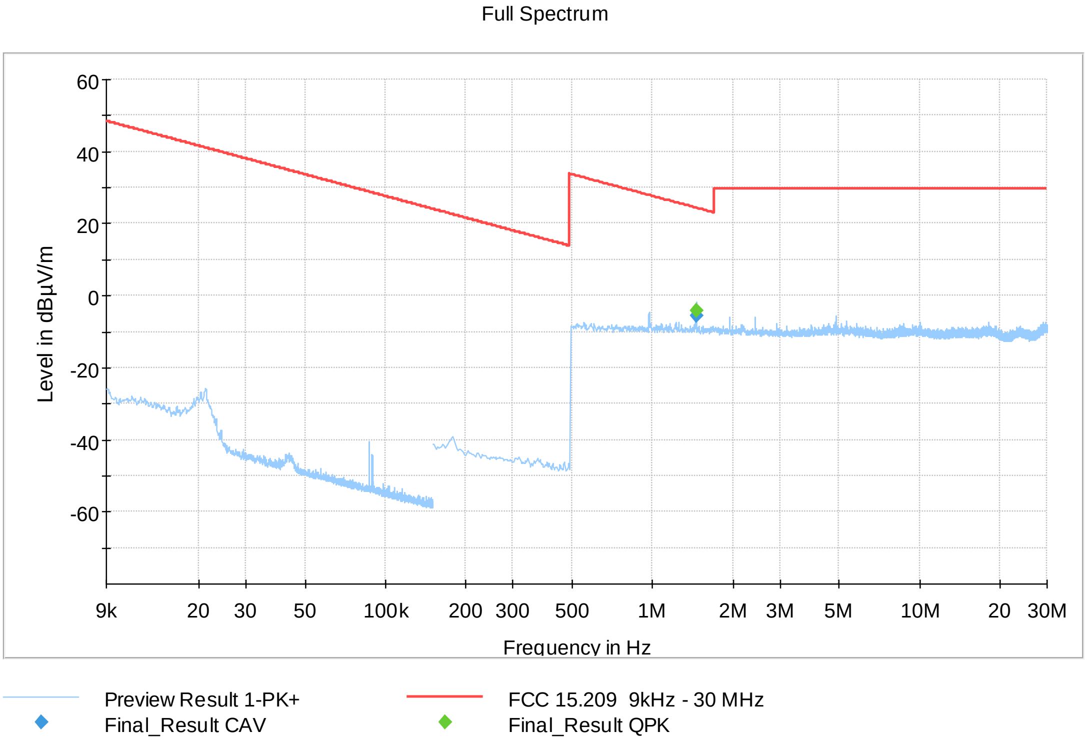


Figure 10: Channel 31 mid 9 kHz – 30 MHz (125 kHz)

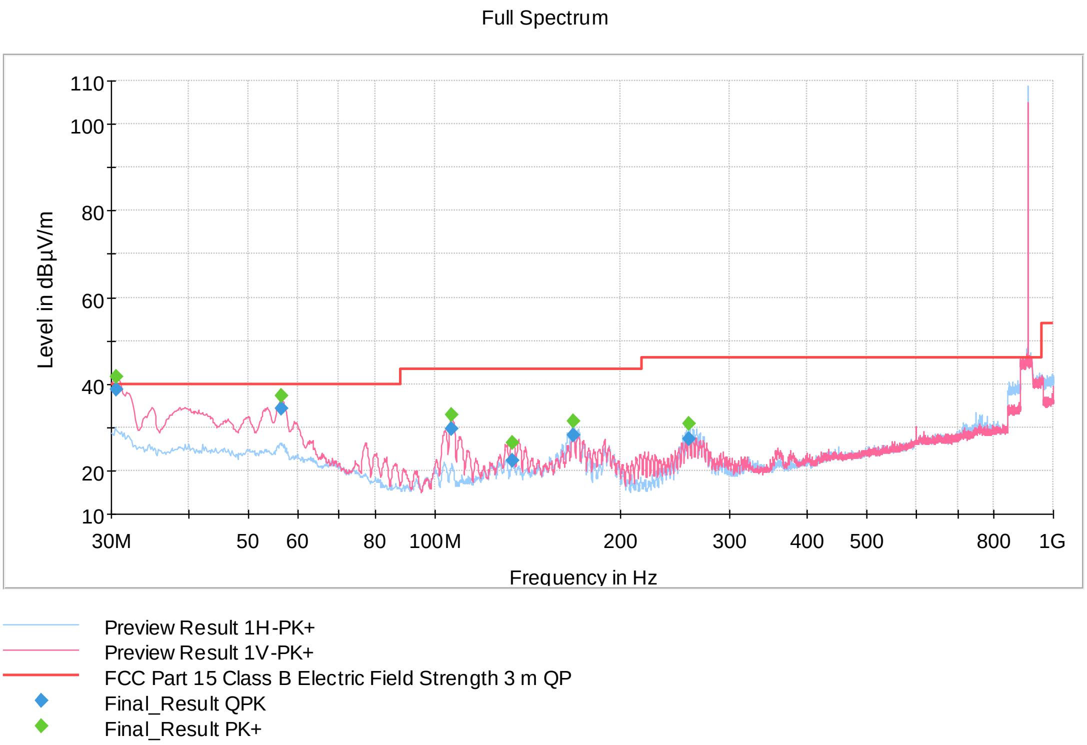


Figure 11: Channel 31 mid 30 MHz – 1000 MHz (125 kHz)

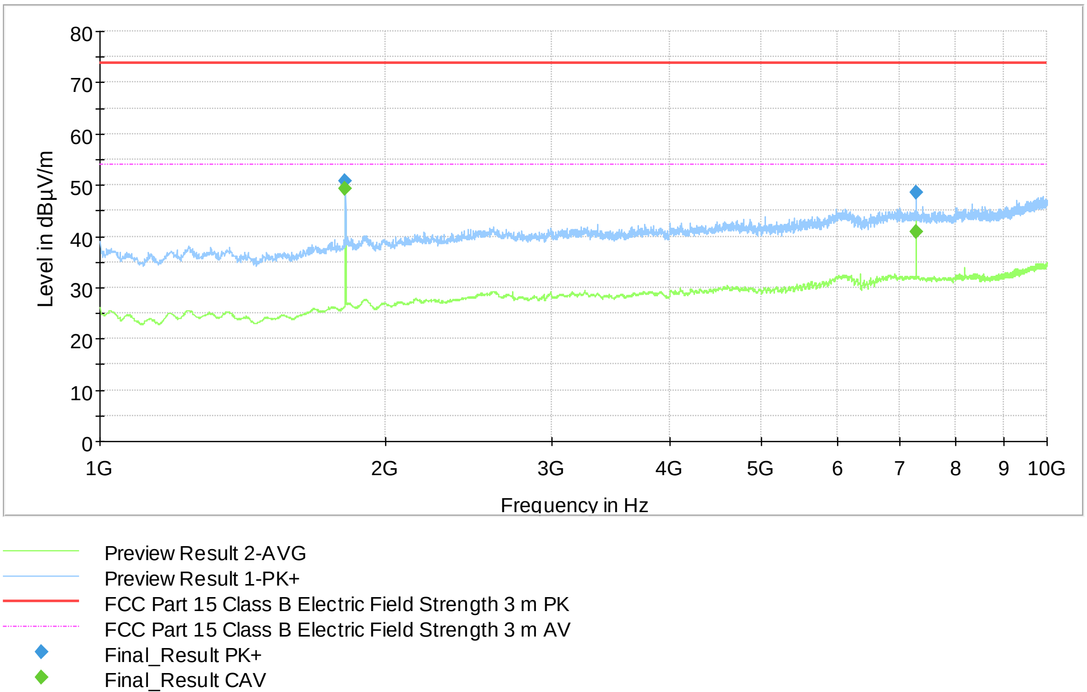


Figure 12: Channel 31 mid 1 GHz – 10 GHz (125 kHz)

Table 5: Results, mid channel (31), 125kHz

Frequency (MHz)	QuasiPeak (dBµV/m)	MaxPeak (dBµV/m)	AVG (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1.456250	-4.22	---	---	24.37	28.59	15000.0	9.000	100.0	V	221.0	-20.5
1.456250	---	---	-5.60	24.37	29.97	15000.0	9.000	100.0	V	221.0	-20.5
30.635000	38.67	---	---	40.00	1.33	15000.0	120.00	100.0	V	112.0	17.0
30.635000	---	41.61	---	---	---	15000.0	120.00	100.0	V	112.0	17.0
56.475000	34.21	---	---	40.00	5.79	15000.0	120.00	100.0	V	270.0	18.3
56.475000	---	37.28	---	---	---	15000.0	120.00	100.0	V	270.0	18.3
106.58500	29.77	---	---	43.50	13.73	15000.0	120.00	100.0	V	193.0	15.0
106.58500	---	32.77	---	---	---	15000.0	120.00	100.0	V	193.0	15.0
133.59500	---	26.43	---	---	---	15000.0	120.00	108.0	V	24.0	17.6
133.59500	22.27	---	---	43.50	21.23	15000.0	120.00	108.0	V	24.0	17.6
167.47500	28.22	---	---	43.50	15.28	15000.0	120.00	175.0	H	295.0	18.2
167.47500	---	31.52	---	---	---	15000.0	120.00	175.0	H	295.0	18.2
258.13500	---	30.94	---	---	---	15000.0	120.00	121.0	H	128.0	17.7
258.13500	27.35	---	---	46.00	18.65	15000.0	120.00	121.0	H	128.0	17.7
1816.8750	---	50.78	---	73.90	23.12	15000.0	1000.0	140.0	H	141.0	2.5
1817.0750	---	---	49.35	53.90	4.55	15000.0	1000.0	144.0	H	143.0	2.5
7267.9250	---	---	40.85	53.90	13.05	15000.0	1000.0	235.0	V	250.0	10.1
7268.1250	---	48.58	---	73.90	25.32	15000.0	1000.0	208.0	V	252.0	10.1

High channel (63) 125kHz

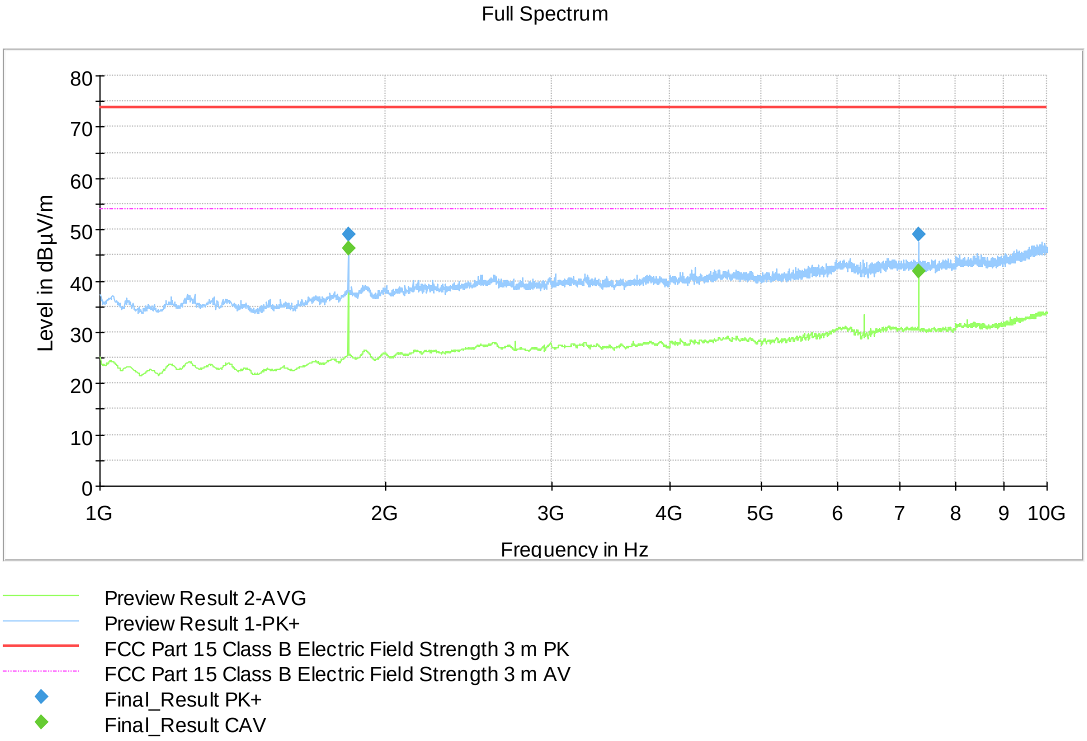


Figure 13: Channel 63 high 1 GHz – 15 GHz (125 kHz)

Table 6: Results, high channel (63), 125kHz

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1829.775000	---	46.43	53.90	7.47	15000.0	1000.0	105.0	V	120.0	2.6
1829.775000	49.16	---	73.90	24.74	15000.0	1000.0	105.0	V	120.0	2.6
7318.975000	48.98	---	73.90	24.92	15000.0	1000.0	144.0	V	261.0	10.1
7319.175000	---	41.94	53.90	11.96	15000.0	1000.0	169.0	V	261.0	10.1

Low channel (64) 500kHz

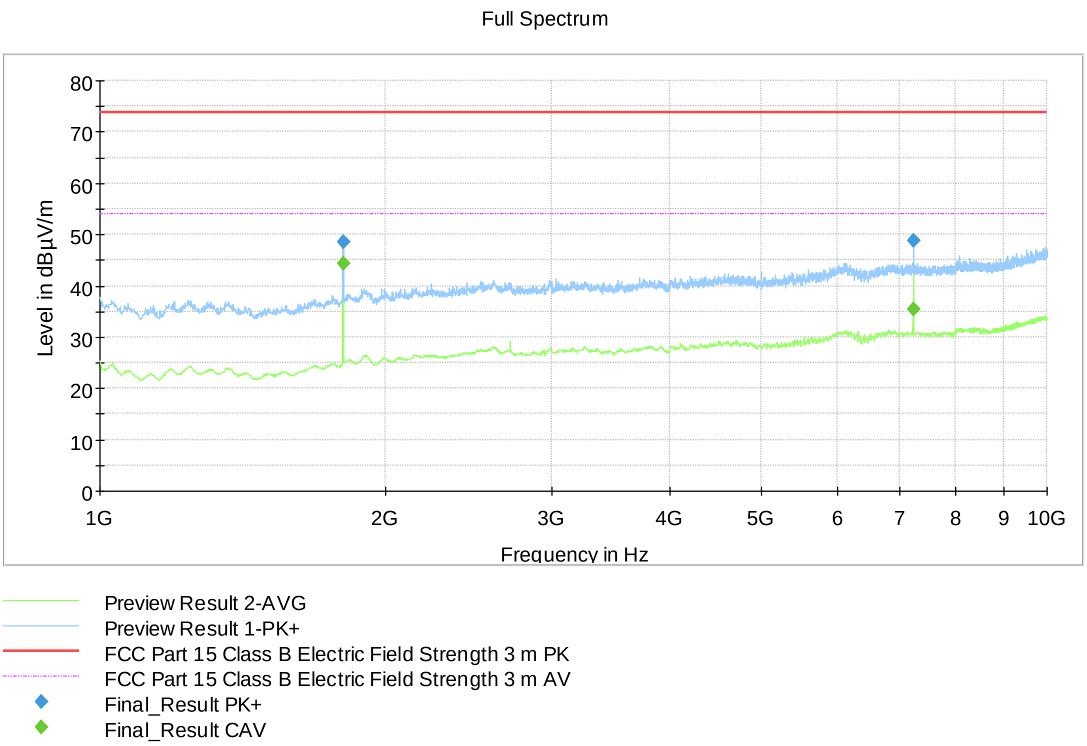


Figure 14: Channel 64 low 1 GHz – 10 GHz (500 kHz)

Table 7: Results, low channel (64), 500kHz

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1806.075000	---	44.45	53.90	9.45	15000.0	15000.	115.0	H	149.0	2.5
1806.475000	48.64	---	73.90	25.26	15000.0	15000.	120.0	H	147.0	2.5
7222.725000	48.85	---	73.90	25.05	15000.0	15000.	143.0	V	174.0	10.2
7224.775000	---	35.41	53.90	18.49	15000.0	15000.	128.0	V	172.0	10.2

Middle channel (67) 500kHz

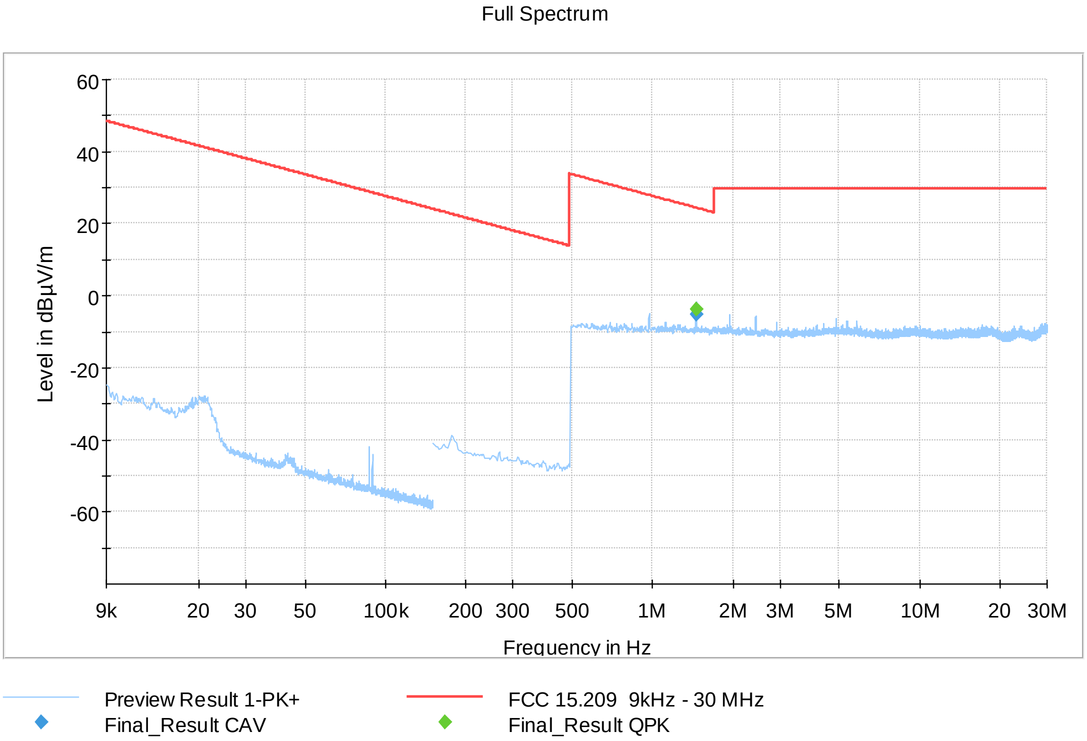


Figure 15: Channel 67 mid 9 kHz – 30 MHz (500 kHz)

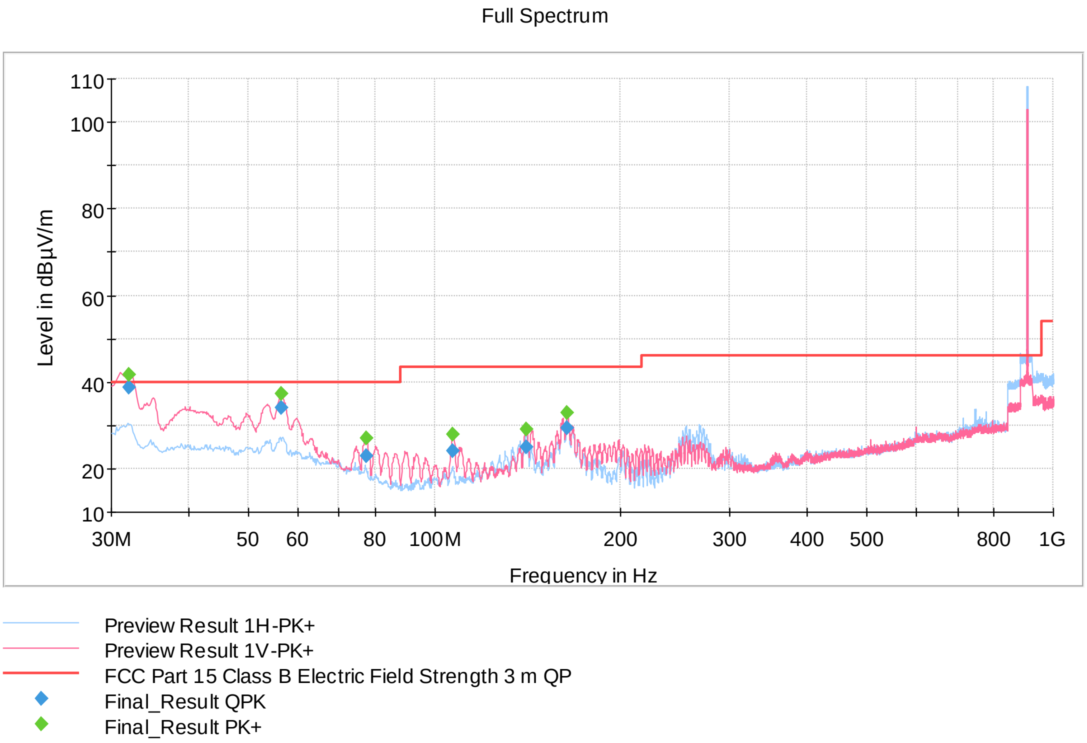


Figure 16: Channel 67 mid 30 MHz – 1000 MHz (500 kHz)

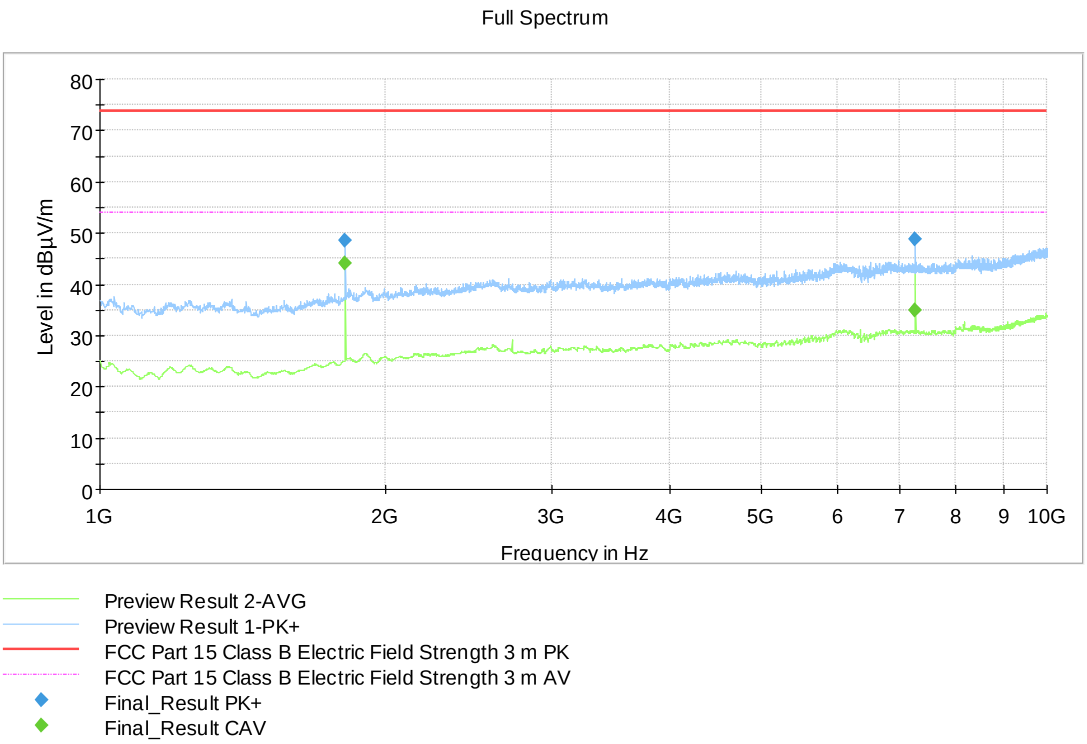


Figure 17: Channel 67 mid 1 GHz – 10 GHz (500 kHz)

Table 8: Results, middle channel (67), 500kHz

Frequency (MHz)	QuasiPeak (dBµV/m)	MaxPeak (dBµV/m)	AVG (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1.458500	-3.87	---	---	24.35	28.22	15000.0	9.000	100.0	V	233.0	-20.5
1.458500	---	---	-5.20	24.35	29.55	15000.0	9.000	100.0	V	233.0	-20.5
32.065000	38.87	---	---	40.00	1.13	15000.0	120.0	100.0	V	337.0	17.1
32.065000	---	41.63	---	---	---	15000.0	120.0	100.0	V	337.0	17.1
56.415000	33.99	---	---	40.00	6.01	15000.0	120.0	100.0	V	254.0	18.3
56.415000	---	37.33	---	---	---	15000.0	120.0	100.0	V	254.0	18.3
77.445000	23.02	---	---	40.00	16.98	15000.0	120.0	108.0	V	252.0	14.6
77.445000	---	26.91	---	---	---	15000.0	120.0	108.0	V	252.0	14.6
107.06500	---	27.75	---	---	---	15000.0	120.0	108.0	V	179.0	15.0
107.06500	24.17	---	---	43.50	19.33	15000.0	120.0	108.0	V	179.0	15.0
140.49500	---	28.93	---	---	---	15000.0	120.0	100.0	V	305.0	18.2
140.49500	25.10	---	---	43.50	18.40	15000.0	120.0	100.0	V	305.0	18.2
163.68500	29.35	---	---	43.50	14.15	15000.0	120.0	108.0	V	193.0	18.4
163.68500	---	32.80	---	---	---	15000.0	120.0	108.0	V	193.0	18.4
1815.2250	---	48.60	---	73.90	25.30	15000.0	1000.	218.0	H	239.0	2.5
1815.6250	---	---	44.21	53.90	9.69	15000.0	1000.	164.0	H	245.0	2.5
7261.8750	---	48.77	---	73.90	25.13	15000.0	1000.	169.0	V	261.0	10.1
7263.4750	---	---	34.93	53.90	18.97	15000.0	1000.	174.0	V	259.0	10.1

High channel (71) 500kHz

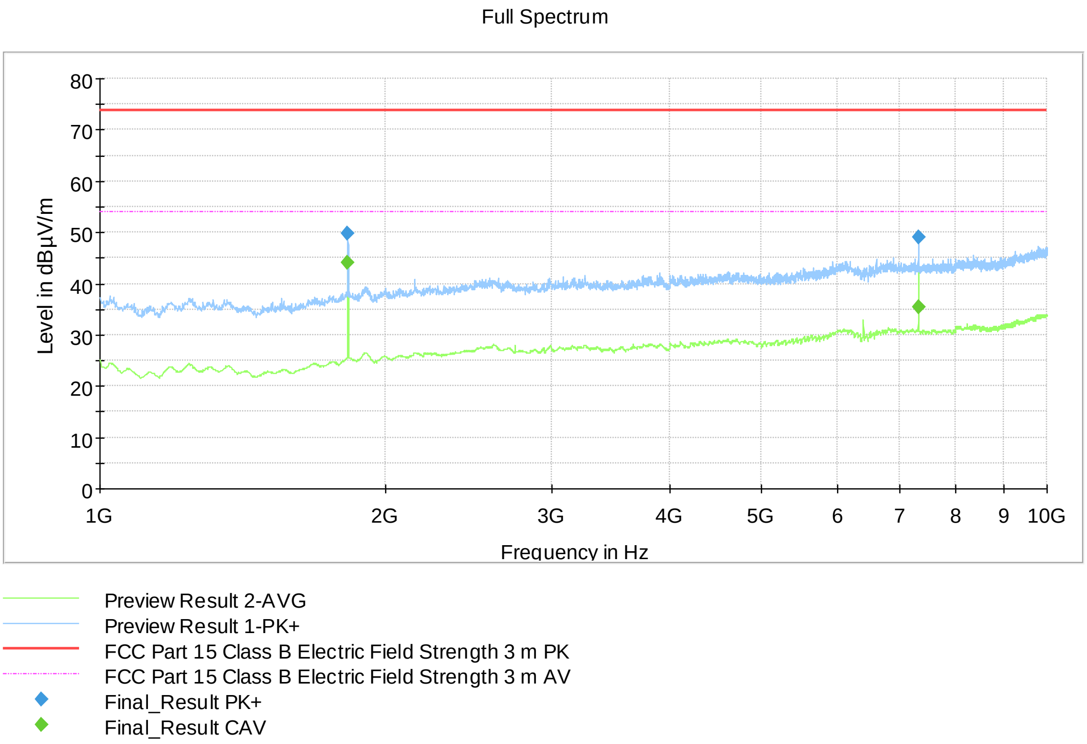


Figure 18: Channel 71 high 1 GHz – 15 GHz (500 kHz)

Table 9: Results, high channel (71), 500kHz

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1828.125000	49.68	---	73.90	24.22	15000.0	1000.	216.0	H	239.0	2.6
1828.325000	---	44.01	53.90	9.89	15000.0	1000.	149.0	V	104.0	2.6
7311.975000	48.93	---	73.90	24.97	15000.0	1000.	120.0	V	240.0	10.1
7314.175000	---	35.46	53.90	18.44	15000.0	1000.	169.0	V	239.0	10.1

Radiated Band Edge results

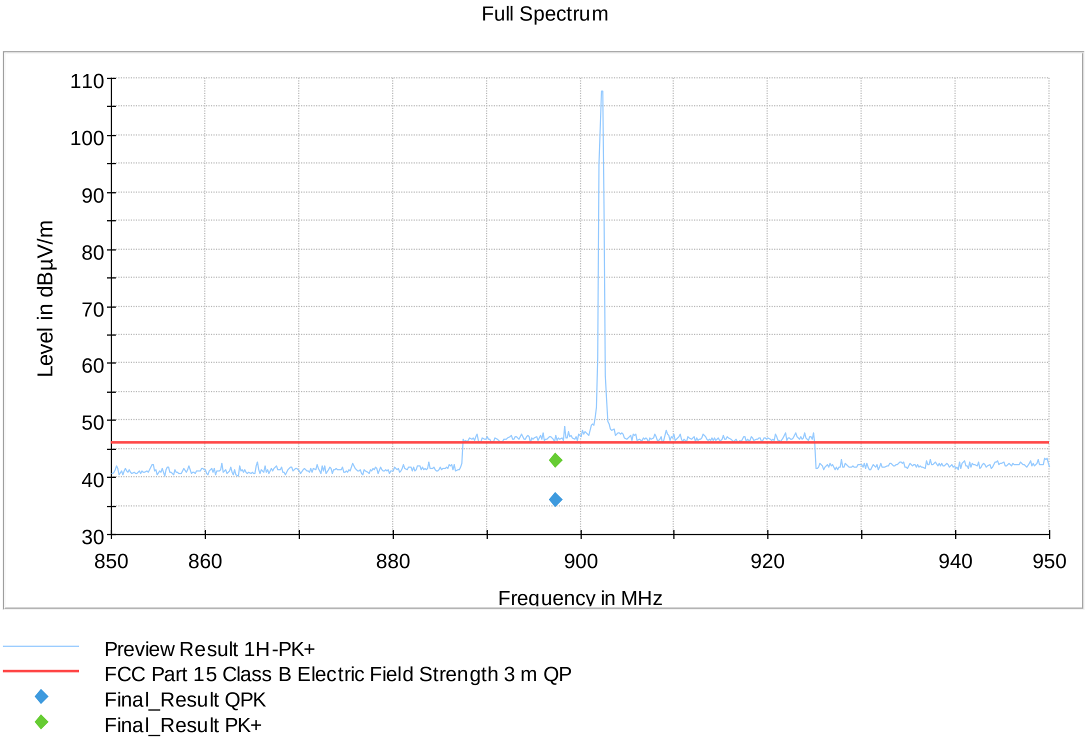


Figure 19: Radiated Band Edge measurement graph, Channel low, 125 kHz

Table 10: Channel low band edge (125 kHz)

Frequency (MHz) *	QuasiPeak (dBµV/m)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
897.30000	---	42.97	46.00	3.03	15000.0	120.000	149.0	H	211.0	27.1
897.30000	36.02	---	46.00	9.98	15000.0	120.000	149.0	H	211.0	27.1

*) worst results in the frequency range 892 – 902 MHz

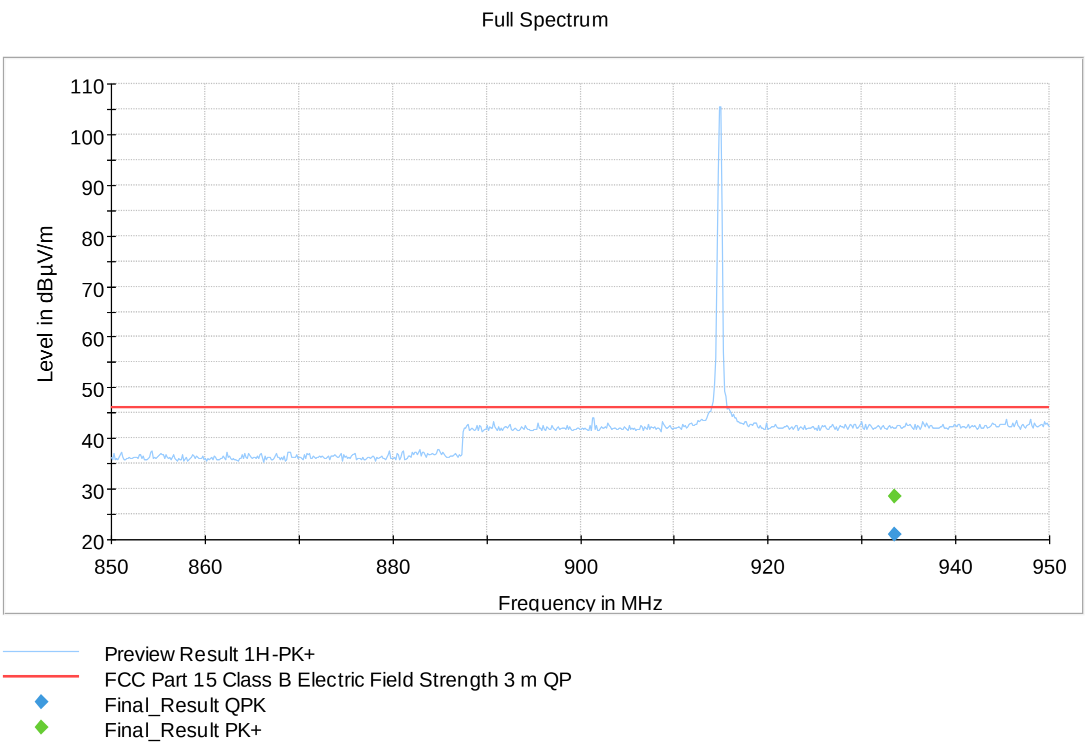


Figure 20: Radiated Band Edge measurement graph, Channel high, 125 kHz

Table 11: Channel high band edge (125 kHz)

Frequency (MHz) *	QuasiPeak (dBµV/m)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
933.52000	---	28.41	46.00	17.59	1500.0	120.0	114.0	H	62.0	27.6
933.52000	20.90	---	46.00	25.10	1500.0	120.0	114.0	H	62.0	27.6

*) worst results in the frequency range 928 – 938 MHz

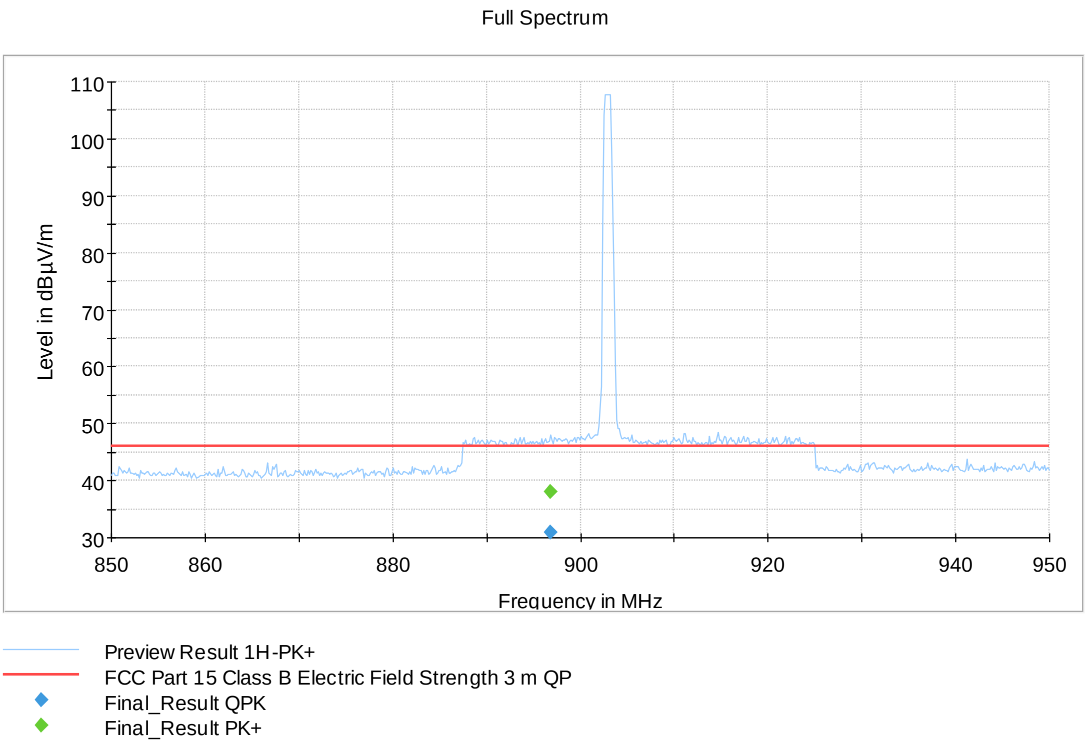


Figure 21: Radiated Band Edge measurement graph, Channel low, 500 kHz

Table 12: Channel low band edge (500 kHz)

Frequency (MHz) *	QuasiPeak (dBµV/m)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
896.880000	---	37.96	46.00	8.04	15000.0	120.0	105.0	H	173.0	27.1
896.880000	30.81	---	46.00	15.19	15000.0	120.0	105.0	H	173.0	27.1

*) worst results in the frequency range 892 – 902 MHz

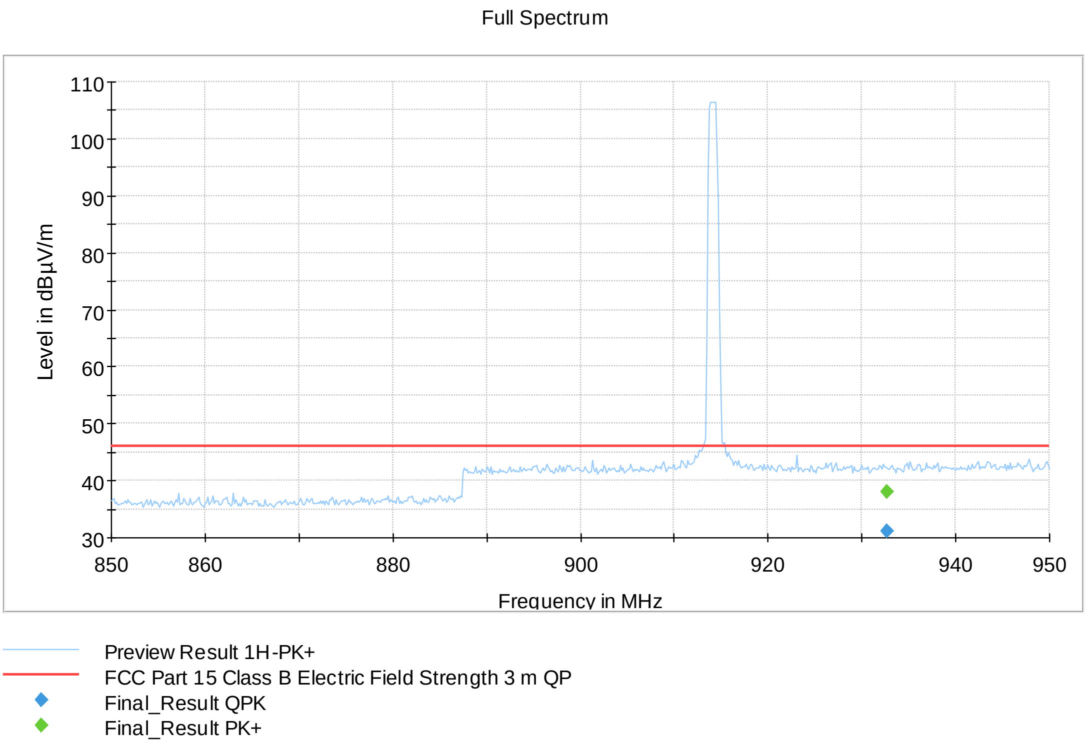


Figure 22: Radiated Band Edge measurement graph, Channel high, 500 kHz

Table 13: Channel high band edge (500 kHz)

Frequency (MHz) *	QuasiPeak (dBµV/m)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Band width (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
932.720000	---	37.92	46.00	8.08	15000.0	120.00	140.0	H	179.0	27.6
932.720000	31.13	---	46.00	14.87	15000.0	120.00	140.0	H	179.0	27.6

*) worst results in the frequency range 928 – 938 MHz

Transmitter Band Edge Measurement and Conducted Spurious Emissions

Standard:	ANSI C63.10	(2013)
Tested by:	RRE	
Date:	16 September 2019	
Temperature:	23 ± 3 °C	
Humidity:	20 - 60 % RH	
Measurement uncertainty:	± 2.87 dB	Level of confidence 95 % (k = 2)

FCC Rule: 15.247(d), 15.209(a)
RSS-247 5.5

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 Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

Table 14: Band edge attenuation 125kHz

Band Edge Attenuation	
Lower Band Edge (ch 0)	**Upper Band Edge (ch 63)**
-50.73 dBc	-78.83 dBc
Limit: -20 dBc	

Table 15: Band edge attenuation 500kHz

Band Edge Attenuation	
Lower Band Edge (ch 64)	**Upper Band Edge (ch 71)**
-61.33 dBc	-79.27 dBc
Limit: -20 dBc	

Table 16: Conducted spurious emissions, low channel, 125 kHz

Frequency [MHz]	Level [dBm]	Limit [dBm]	Margin [dB]	Result
1804.56	-52.50	-9.06	-43.44	PASS
2472.41	-37.31	-9.06	-28.26	PASS
3609.21	-61.32	-9.06	-52.26	PASS
6993.67	-60.45	-9.06	-51.39	PASS
7218.48	-46.64	-9.06	-37.58	PASS
12532.53	-58.07	-9.06	-49.01	PASS
15502.63	-56.00	-9.06	-46.95	PASS
16474.88	-54.53	-9.06	-45.48	PASS
19177.51	-55.20	-9.06	-46.15	PASS
24171.79	-55.38	-9.06	-46.33	PASS
26226.42	-55.14	-9.06	-46.09	PASS

Table 17: Conducted spurious emissions, middle channel, 125 kHz

Frequency [MHz]	Level [dBm]	Limit [dBm]	Margin [dB]	Result
1816.98	-52.01	-9.13	-42.89	PASS
2415.44	-37.15	-9.13	-28.03	PASS
3634.04	-61.16	-9.13	-52.03	PASS
6589.15	-60.50	-9.13	-51.38	PASS
7268.16	-47.15	-9.13	-38.03	PASS
12895.99	-57.15	-9.13	-48.02	PASS
15793.52	-55.31	-9.13	-46.19	PASS
16123.98	-54.04	-9.13	-44.91	PASS
19498.88	-56.40	-9.13	-47.27	PASS
24447.13	-54.07	-9.13	-44.95	PASS
26180.35	-55.31	-9.13	-46.19	PASS

Table 18: Conducted spurious emissions, high channel, 125 kHz

Frequency [MHz]	Level [dBm]	Limit [dBm]	Margin [dB]	Result
1829.72	-51.41	-9.33	-42.08	PASS
2418.86	-37.42	-9.33	-28.09	PASS
3659.39	-60.02	-9.33	-50.68	PASS
6973.52	-61.20	-9.33	-51.87	PASS
7318.88	-48.51	-9.33	-39.18	PASS
12506.28	-58.30	-9.33	-48.97	PASS
15841.15	-56.32	-9.33	-46.99	PASS
16155.86	-53.39	-9.33	-44.06	PASS
21865.05	-56.10	-9.33	-46.77	PASS
24840.30	-55.33	-9.33	-46.00	PASS
25586.88	-53.82	-9.33	-44.49	PASS

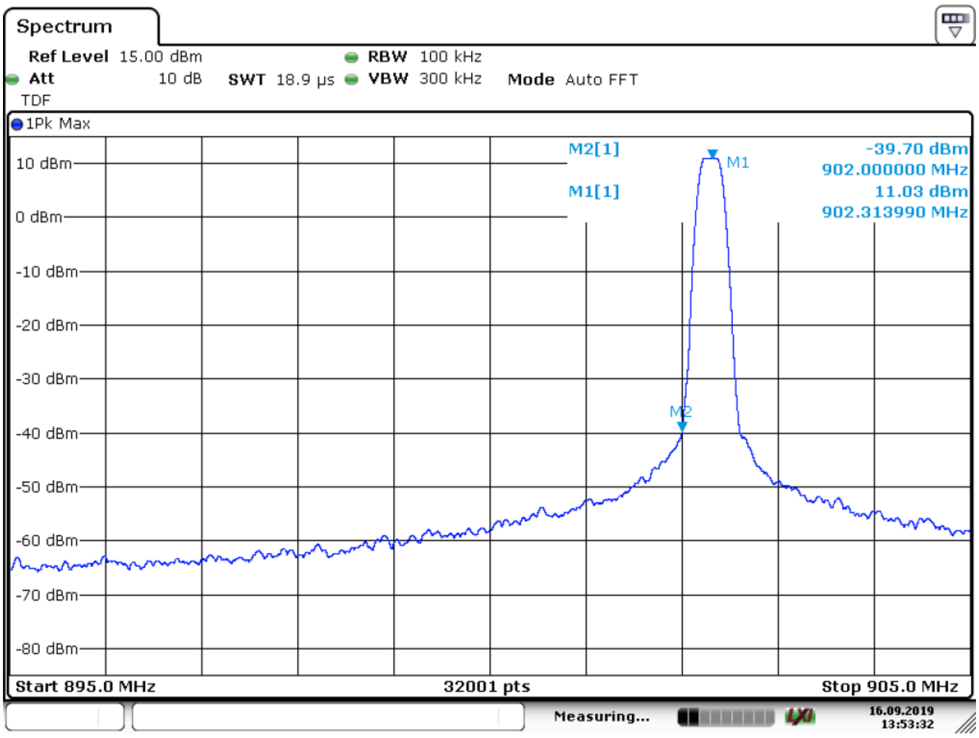


Figure 23: Lower Band Edge, channel 0 low, 125 kHz

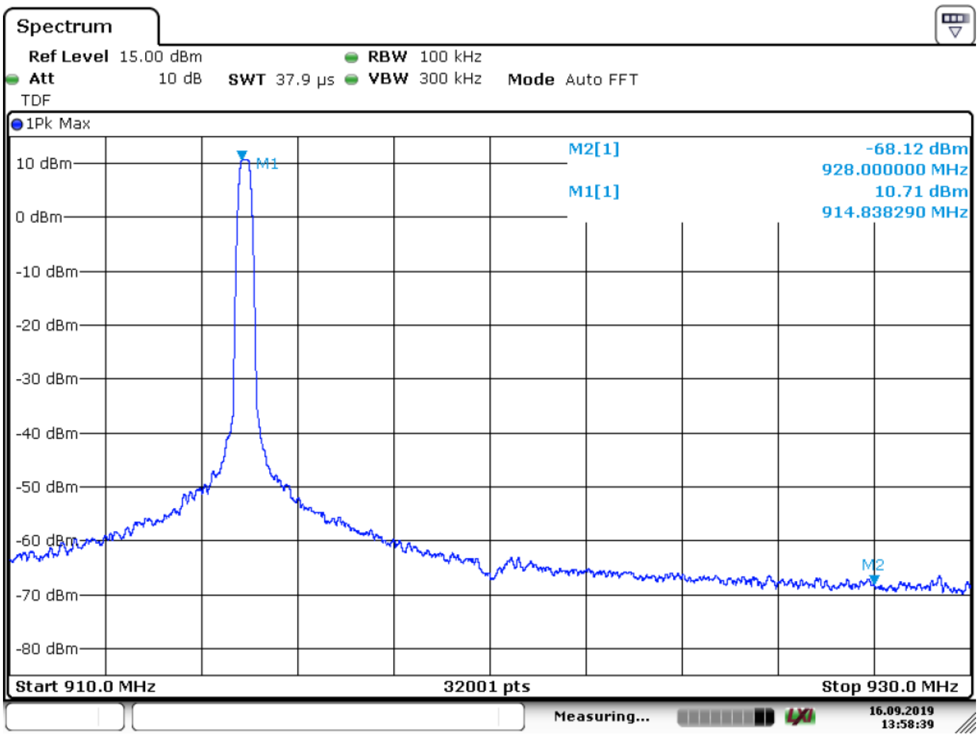


Figure 24: Upper Band Edge, channel 63, 125 kHz

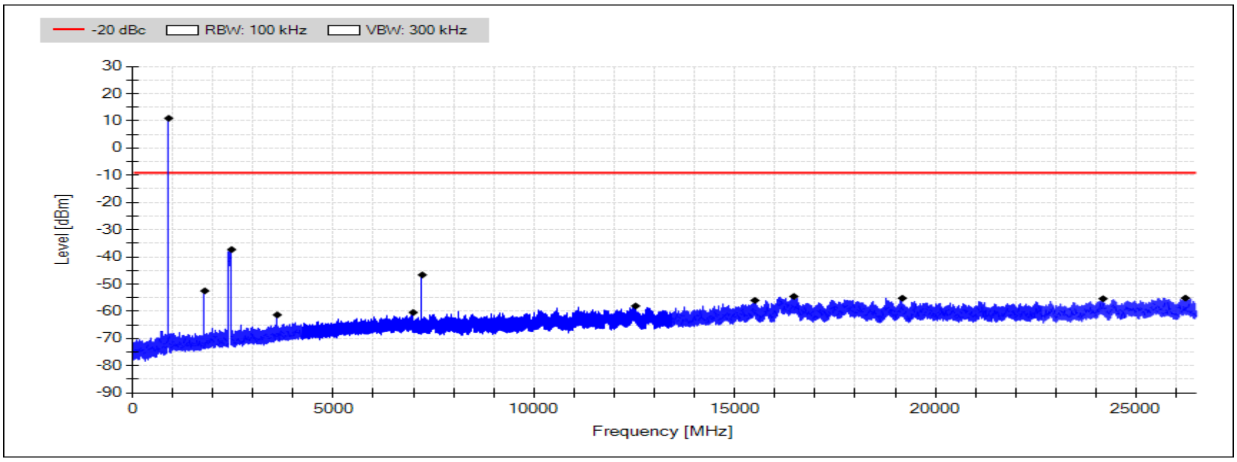


Figure 25: Conducted spurious emissions 30 - 26500 MHz channel 0 low, 125 kHz

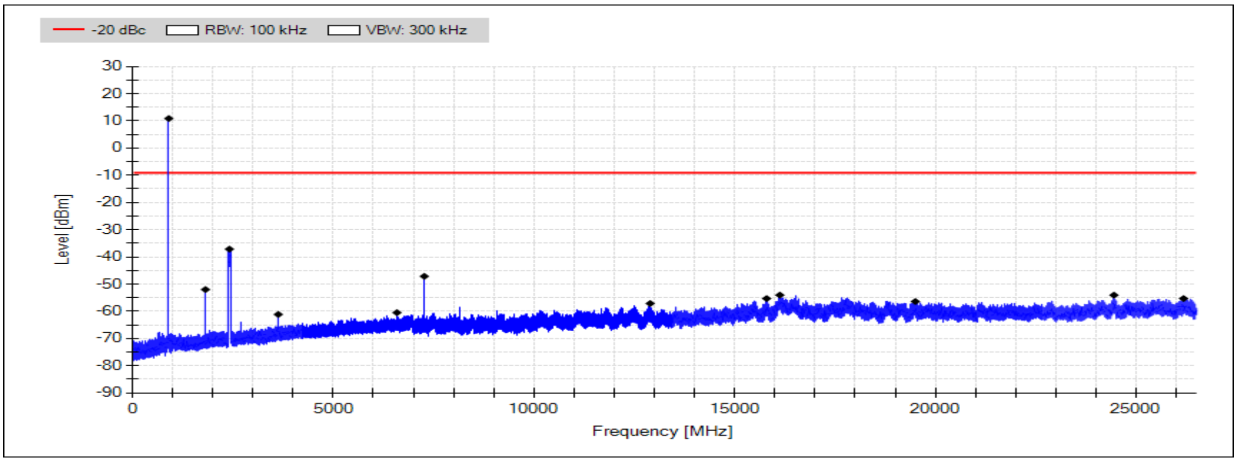


Figure 26: Conducted spurious emissions 30 - 26500 MHz channel 31 mid, 125 kHz

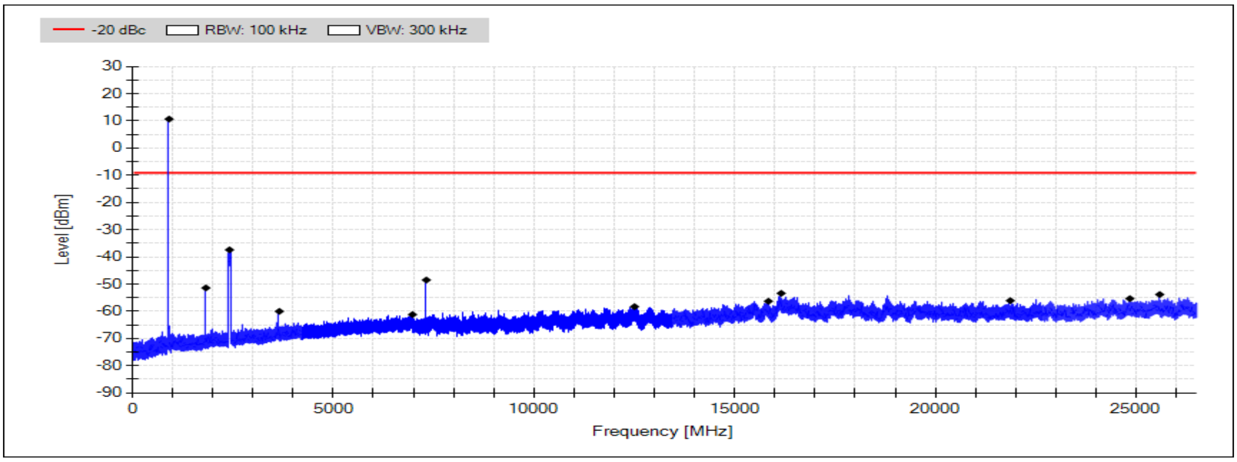


Figure 27: Conducted spurious emissions 30 - 26500 MHz channel 63 high, 125 kHz

Table 19: Conducted spurious emissions, low channel, 500 kHz

Frequency [MHz]	Level [dBm]	Limit [dBm]	Margin [dB]	Result
1805.65	-52.52	-9.06	-43.46	PASS
2474.49	-37.51	-9.06	-28.45	PASS
3611.05	-61.35	-9.06	-52.28	PASS
6560.28	-60.51	-9.06	-51.45	PASS
7225.98	-46.68	-9.06	-37.62	PASS
12491.84	-57.93	-9.06	-48.86	PASS
14817.90	-55.94	-9.06	-46.87	PASS
16155.48	-54.18	-9.06	-45.11	PASS
19500.09	-55.68	-9.06	-46.61	PASS
24153.42	-54.89	-9.06	-45.83	PASS
25599.68	-54.88	-9.06	-45.82	PASS

Table 20: Conducted spurious emissions, middle channel, 500 kHz

Frequency [MHz]	Level [dBm]	Limit [dBm]	Margin [dB]	Result
1816.02	-52.04	-9.17	-42.87	PASS
2475.06	-37.20	-9.17	-28.03	PASS
3630.72	-61.40	-9.17	-52.22	PASS
6520.91	-61.30	-9.17	-52.13	PASS
7262.91	-47.25	-9.17	-38.08	PASS
12494.66	-57.67	-9.17	-48.50	PASS
15537.41	-56.22	-9.17	-47.04	PASS
16128.01	-54.29	-9.17	-45.12	PASS
21107.95	-55.59	-9.17	-46.41	PASS
24448.91	-55.31	-9.17	-46.13	PASS
25484.65	-55.14	-9.17	-45.97	PASS

Table 21: Conducted spurious emissions, high channel, 500 kHz

Frequency [MHz]	Level [dBm]	Limit [dBm]	Margin [dB]	Result
1827.97	-51.68	-9.33	-42.34	PASS
2477.15	-37.09	-9.33	-27.76	PASS
3656.36	-61.14	-9.33	-51.81	PASS
6967.61	-60.99	-9.33	-51.66	PASS
7313.73	-48.40	-9.33	-39.06	PASS
12502.06	-57.80	-9.33	-48.46	PASS
15480.88	-55.92	-9.33	-46.58	PASS
16125.95	-54.40	-9.33	-45.06	PASS
19506.47	-55.42	-9.33	-46.09	PASS
24412.91	-55.30	-9.33	-45.97	PASS
26259.75	-54.89	-9.33	-45.55	PASS

Transmitter Band Edge Measurement and Conducted Spurious Emissions 9 kHz – 26.5 GHz

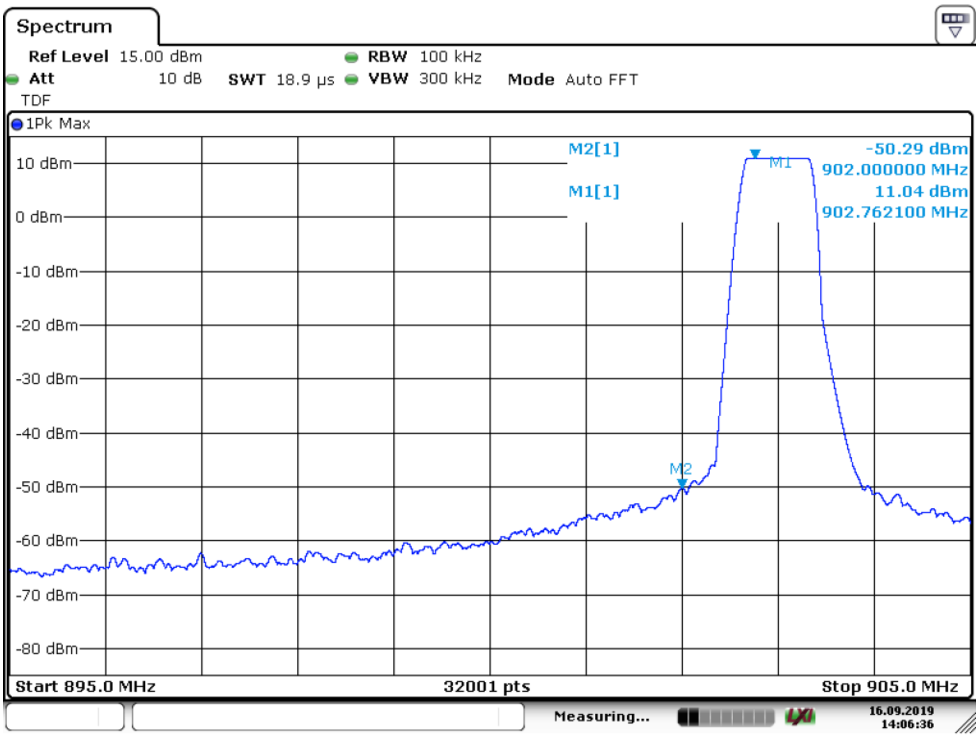


Figure 28: Lower Band Edge, channel 64 low, 500 kHz

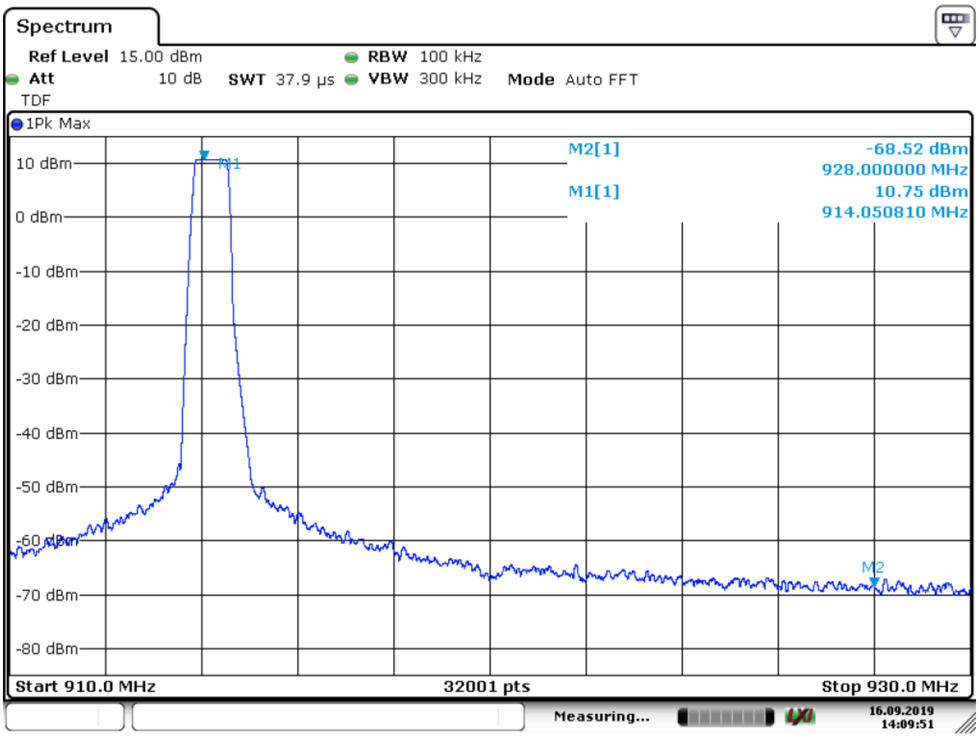


Figure 29: Upper Band Edge, channel 71, 500 kHz

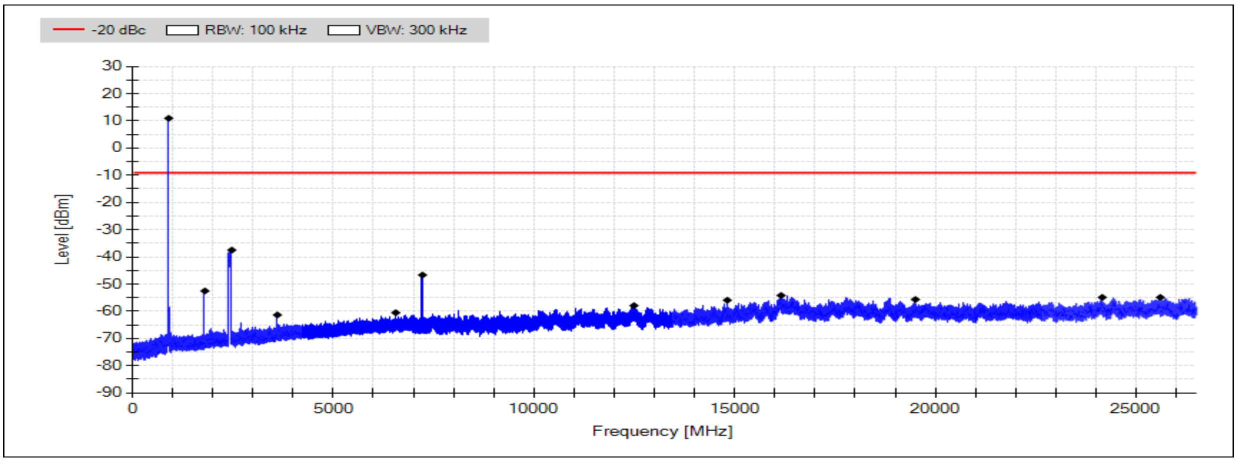


Figure 30: Conducted spurious emissions 30 - 26500 MHz channel 64 low, 500 kHz

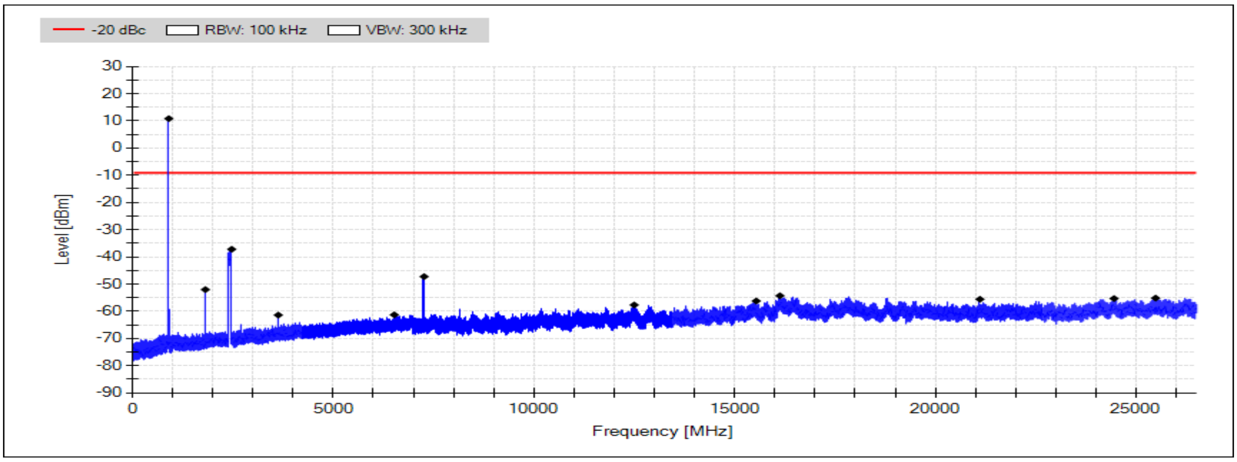


Figure 31: Conducted spurious emissions 30 - 26500 MHz channel 67 mid, 500 kHz

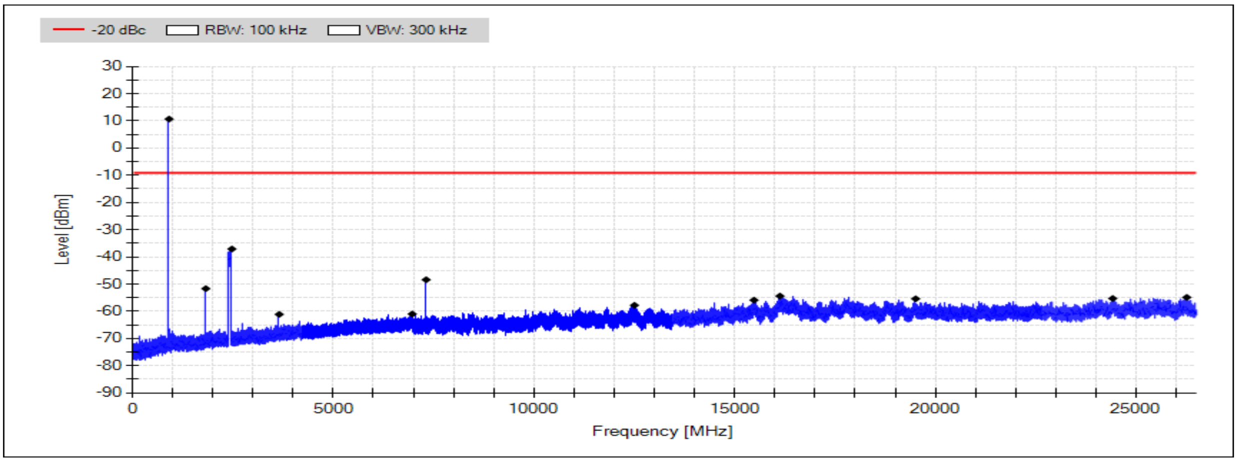


Figure 32: Conducted spurious emissions 30 - 26500 MHz channel 71 high, 500 kHz

Occupied/DTS Bandwidth of the Channel

Standard:	ANSI C63.10	(2013)
Tested by:	RRE	
Date:	16 September 2019	
Temperature:	23 ± 3 °C	
Humidity:	20 - 60 % RH	

FCC Rule: 15.247(a)(2)
RSS-247 5.2(a)

Results:

Table 22: 20 dB bandwidth test results for 125 kHz channel

Channel	20 dB BW [kHz]	Minimum limit [kHz]	Result
0 Low	138.074	-	PASS
31 Mid	138.574		PASS
63 High	138.464		PASS

Table 23: 6 dB bandwidth test results for 500 kHz channel

Channel	6 dB BW [kHz]	Minimum limit [kHz]	Result
64 Low	840.442	500	PASS
67 Mid	783.444		PASS
71 High	772.851		PASS

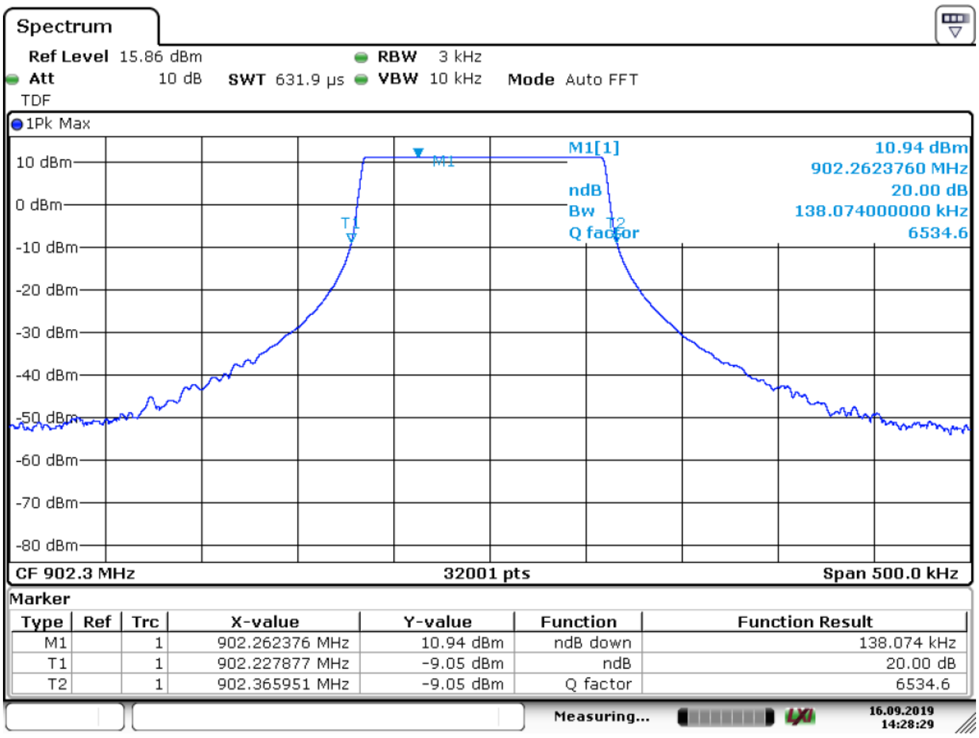


Figure 33: 20 dB bandwidth, channel 0 low, 125 kHz

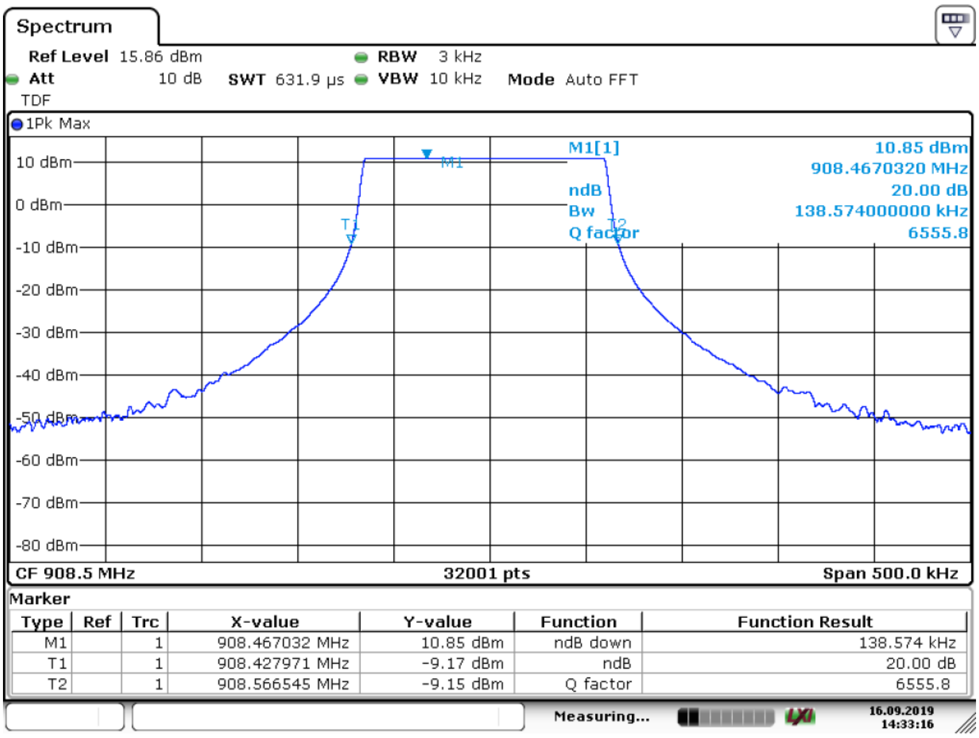


Figure 34: 20 dB bandwidth, channel 31 mid, 125 kHz

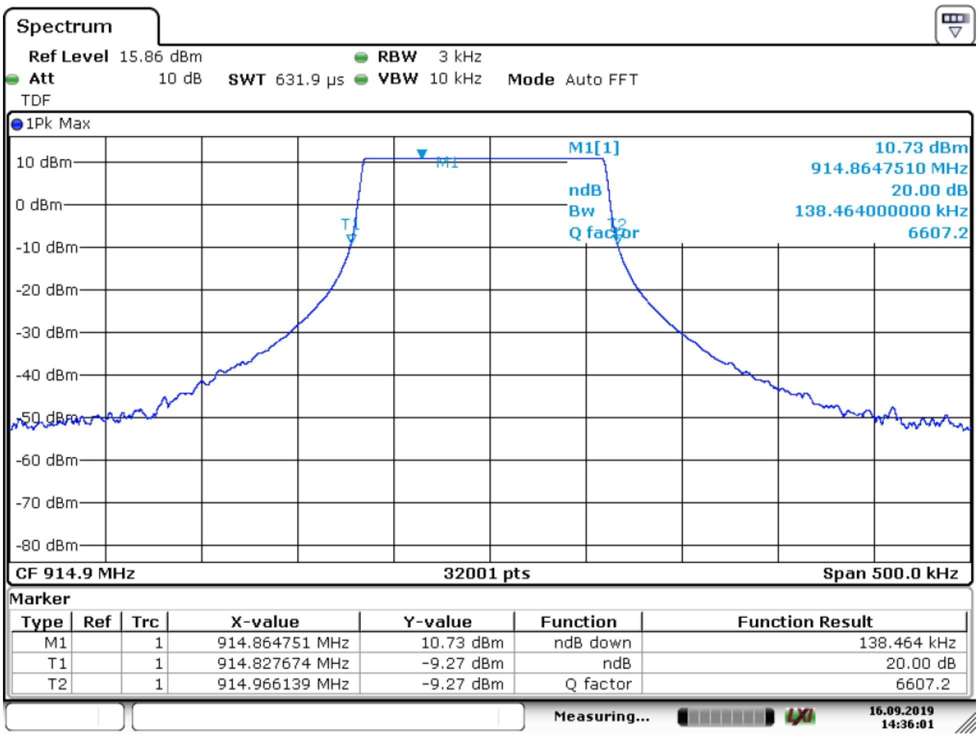
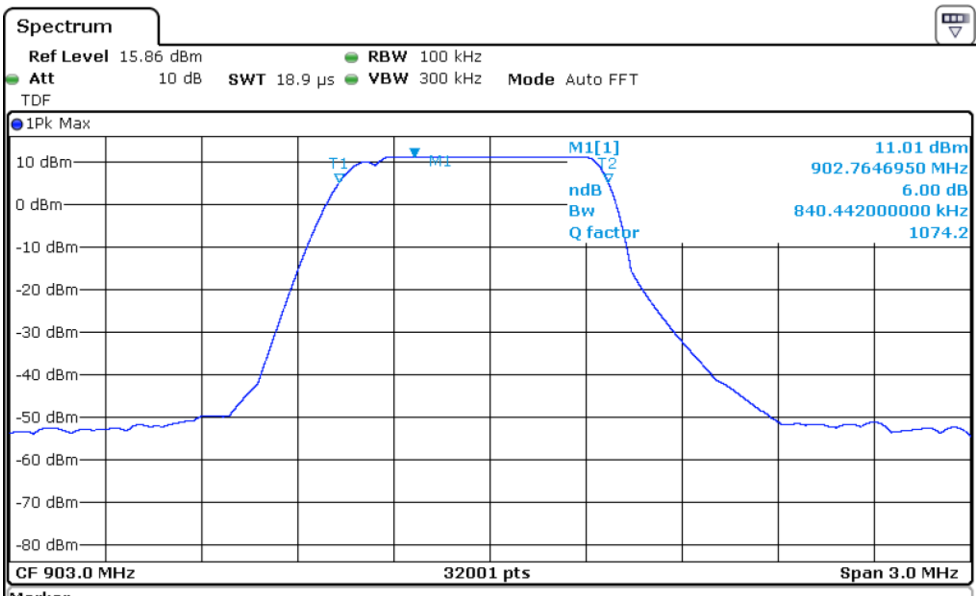
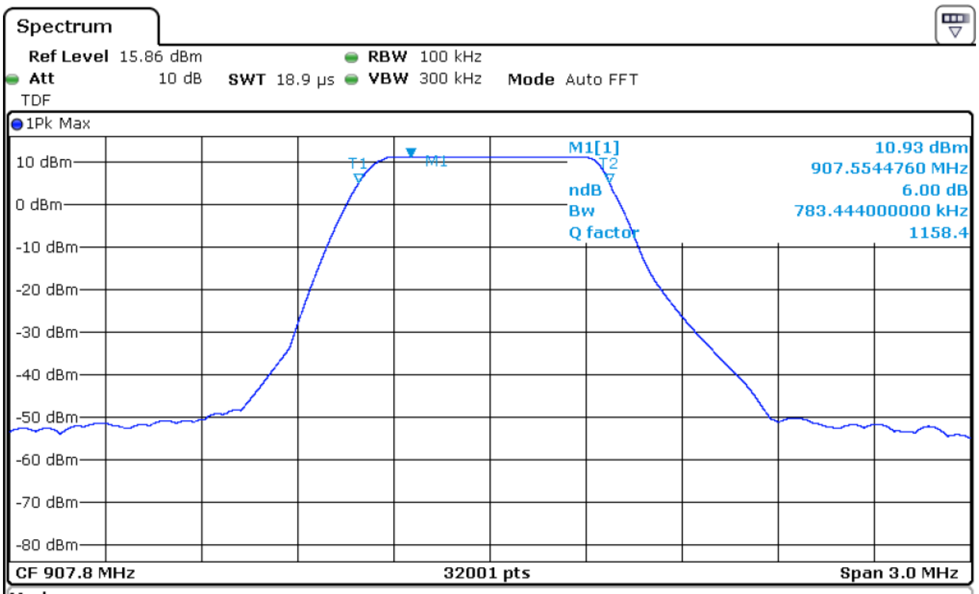


Figure 35: 20 dB bandwidth, channel 63 high, 125 kHz



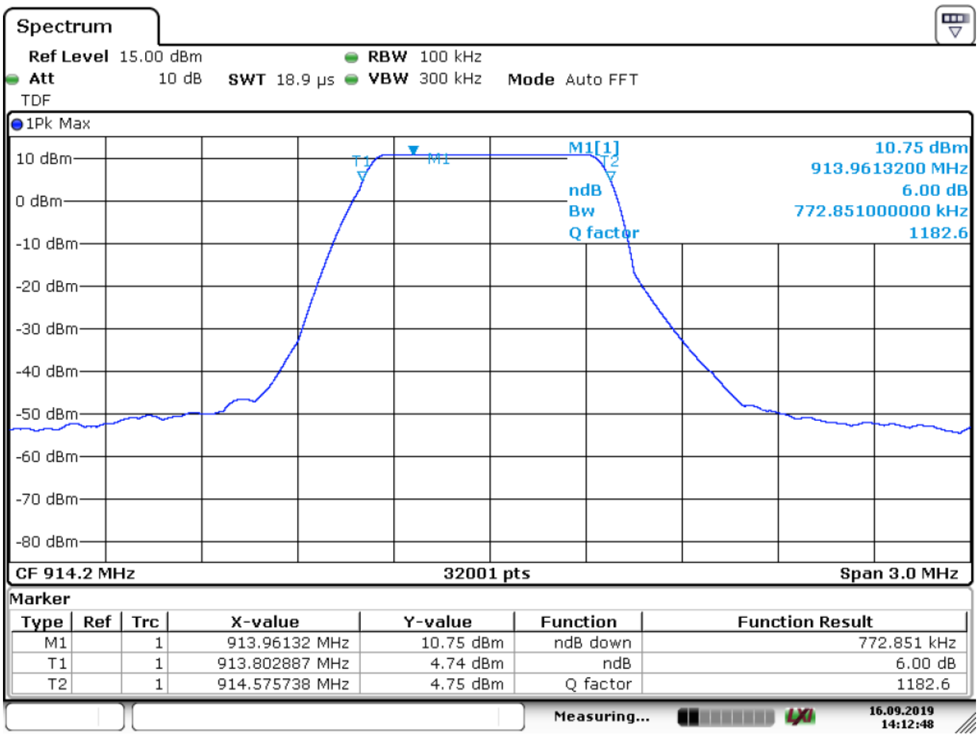
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	902.764695 MHz	11.01 dBm	ndB down	840.442 kHz
T1		1	902.52864 MHz	5.02 dBm	ndB	6.00 dB
T2		1	903.369082 MHz	5.02 dBm	Q factor	1074.2

Figure 36: 6 dB bandwidth, channel 64 low, 500 kHz



Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	907.554476 MHz	10.93 dBm	ndB down	783.444 kHz
T1		1	907.389763 MHz	4.93 dBm	ndB	6.00 dB
T2		1	908.173207 MHz	4.93 dBm	Q factor	1158.4

Figure 37: 6 dB bandwidth, channel 67 mid, 500 kHz



Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	913.96132 MHz	10.75 dBm	ndB down	772.851 kHz
T1		1	913.802887 MHz	4.74 dBm	ndB	6.00 dB
T2		1	914.575738 MHz	4.75 dBm	Q factor	1182.6

Figure 38: 6 dB bandwidth, channel 71 high, 500 kHz

Power Spectral Density

Standard: ANSI C63.10 (2013)
Tested by: RRE
Date: 16 September 2019
Temperature: 23 ± 3 °C
Humidity: 20 - 60 % RH

FCC Rule: 15.247(e)
RSS-247 5.2(b)

Results:

Table 24: Power spectral density test results

Channel Bandwidht [kHz]	Channel	PSD dBm/3 kHz	Maximum limit [dBm/3kHz]	Result
500	Low	6.76	+8.00	PASS
	Mid	6.74		PASS
	High	6.73		PASS

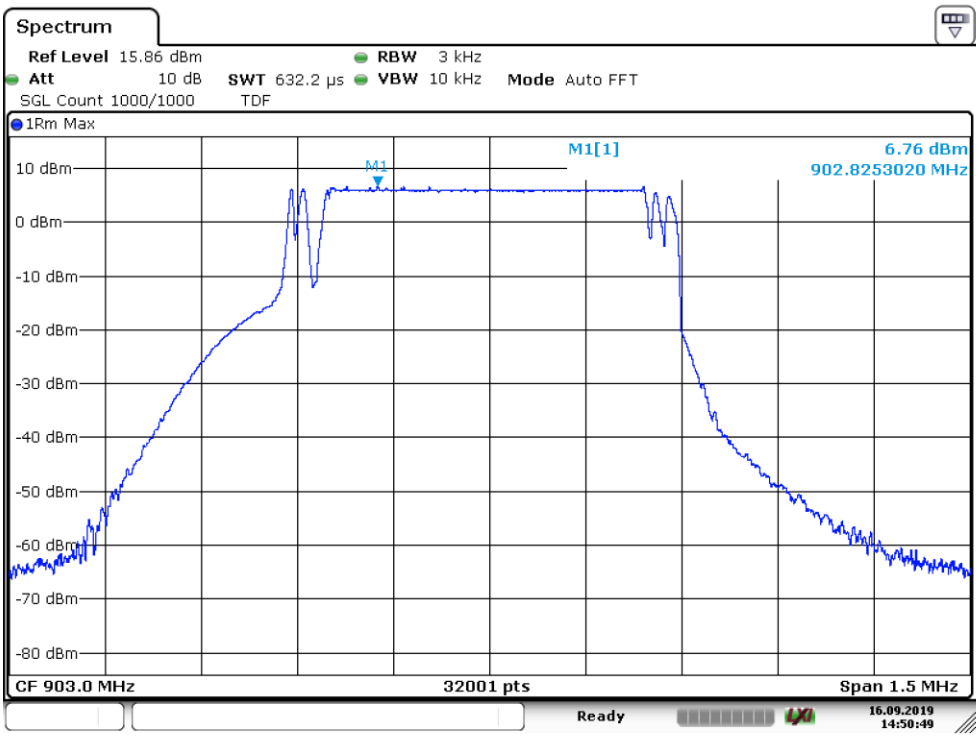


Figure 39: Power spectral density, channel 64 low, 500 kHz

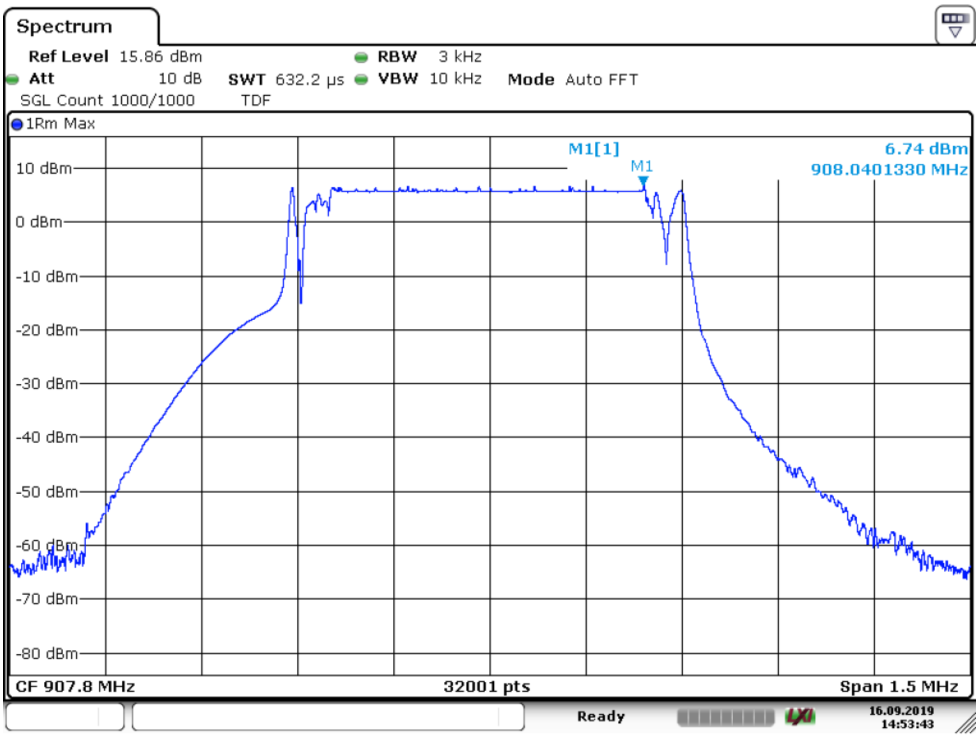


Figure 40: Power spectral density, channel 67 mid, 500 kHz

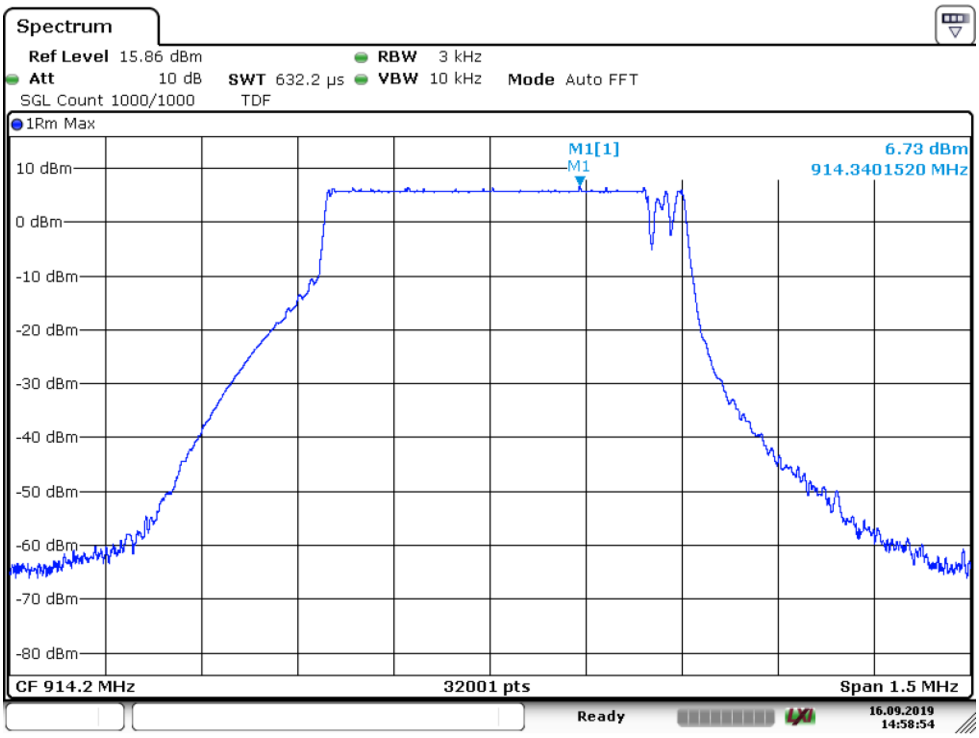


Figure 41: Power spectral density, channel 71 high, 500 kHz

Time of Occupancy (Dwell Time)

Standard: ANSI C63.10 (2013)
Tested by: HEM
Date: 28 – 29 October 2019
Temperature: 23 ± 3 °C
Humidity: 20 - 60 % RH

FCC Rule: 15.247(a)
RSS-247 5.1(c)

Results:

Table 25: Dwell Time, LORA (FHSS)

Channel Bandwidht [kHz]	Channel	Time of single pulse [ms]	Number of pulses in 20 seconds	Limit within 20 seconds [ms]	Result
125	Low	363	1	400	PASS
	Mid	365	1		PASS
	High	366	1		PASS

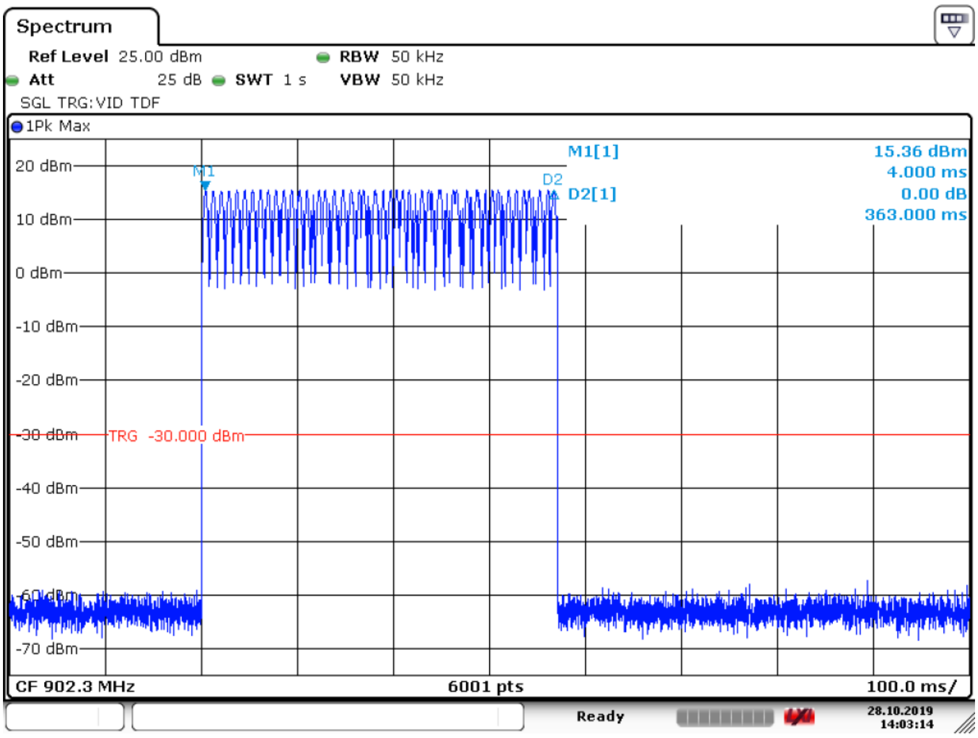


Figure 42: Time of single pulse, channel 0 low, 125kHz hopping enabled

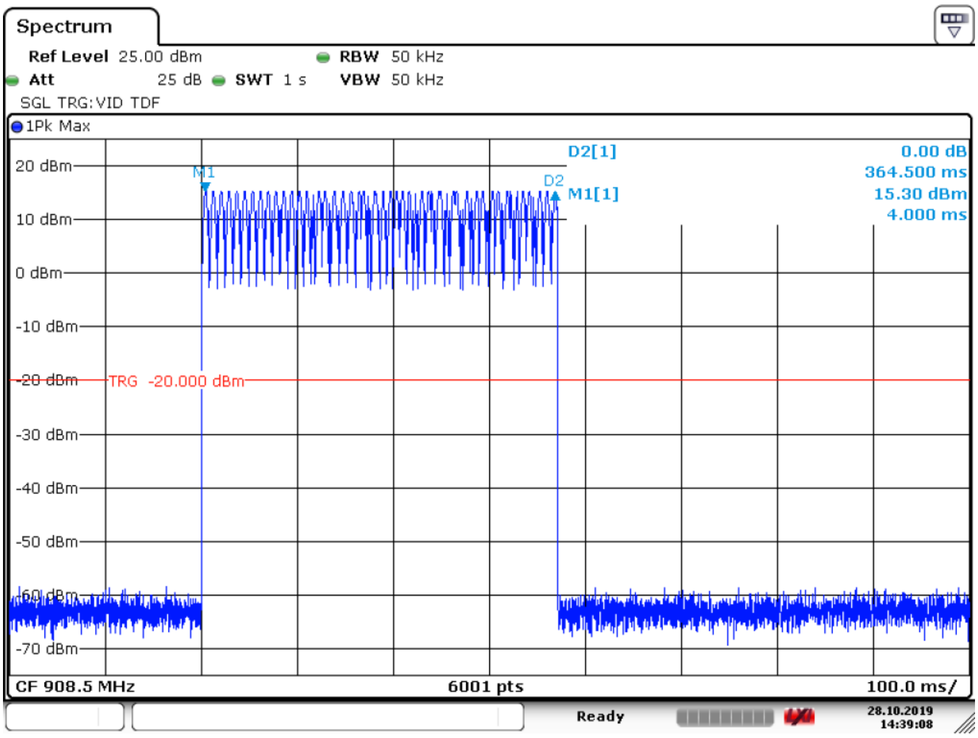


Figure 43: Time of single pulse, channel 31 middle, 125kHz hopping enabled

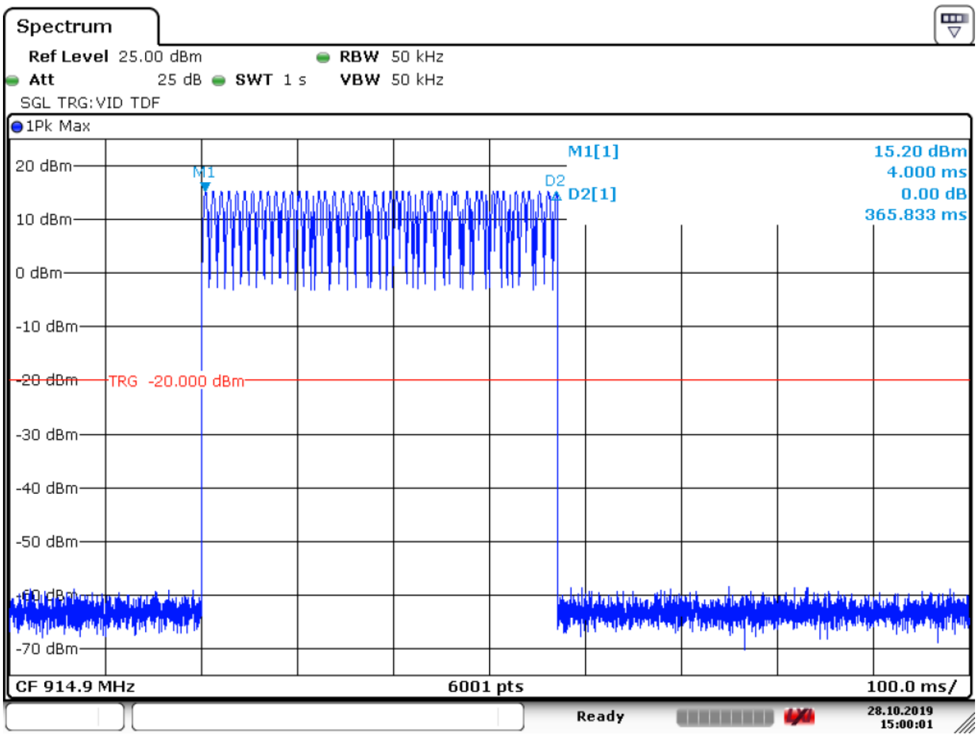


Figure 44: Time of single pulse, channel 63 high, 125kHz hopping enabled

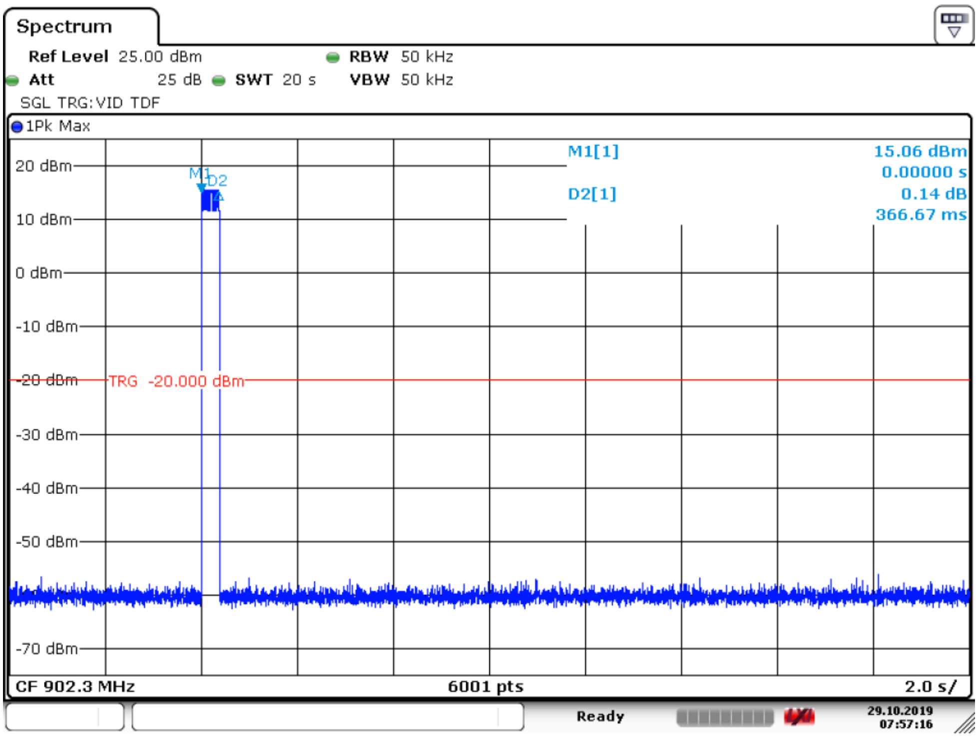


Figure 45: Number of pulses in 20 seconds, channel 0 low, 125kHz hopping enabled

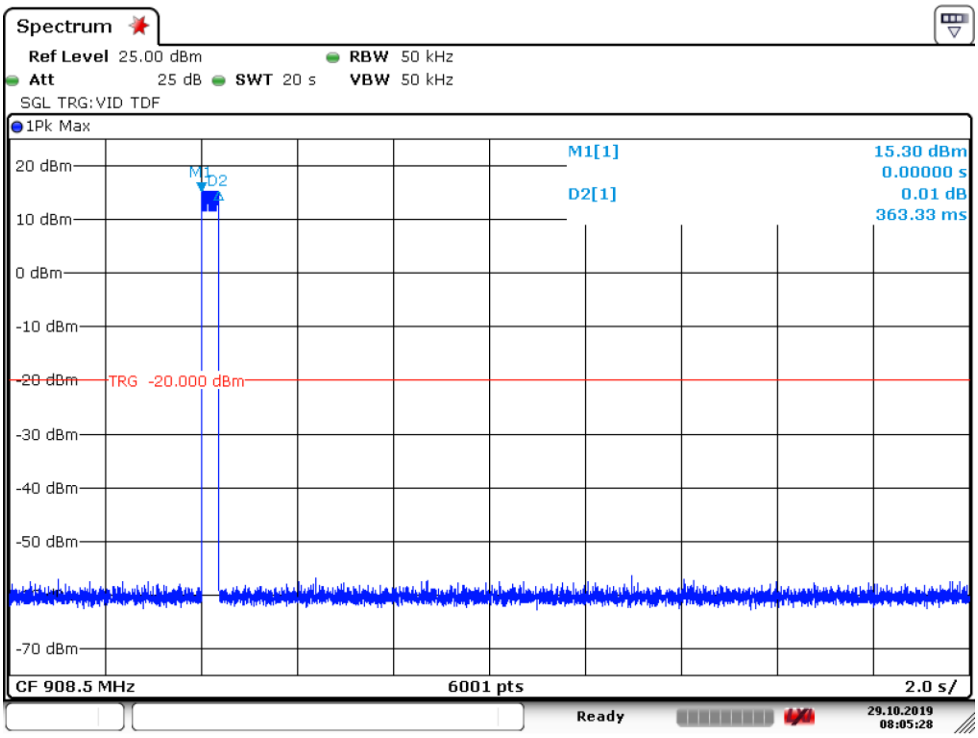


Figure 46: Number of pulses in 20 seconds, channel 31 middle, 125kHz hopping enabled

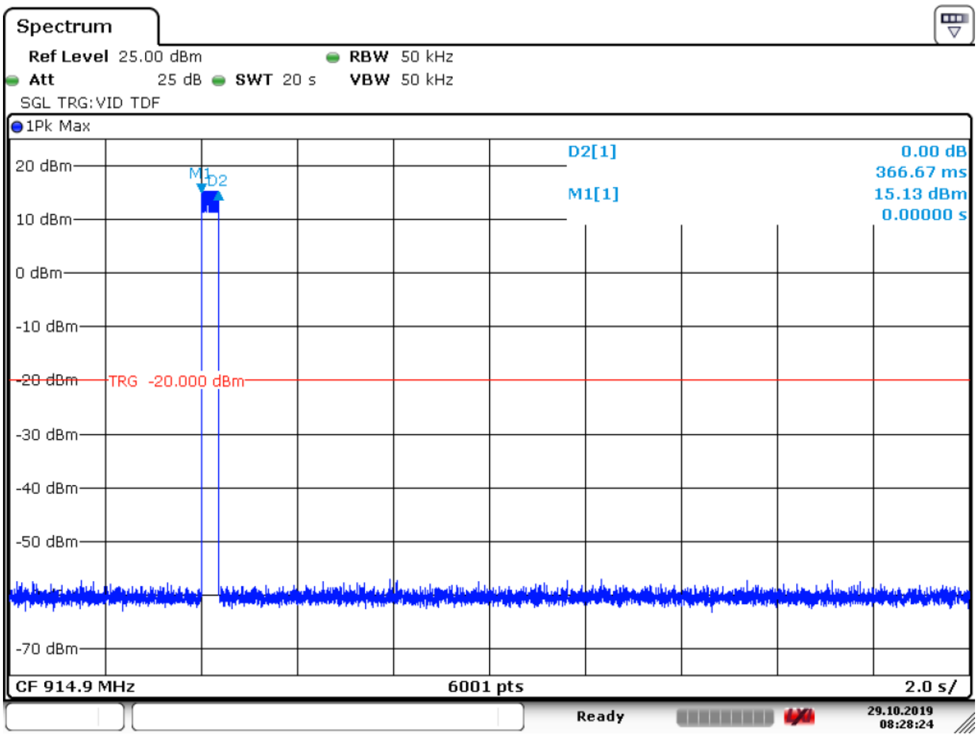


Figure 47: Number of pulses in 20 seconds, channel 63 high, 125kHz hopping enabled

Number of Hopping Frequencies

Standard: ANSI C63.10 (2013)
Tested by: HEM
Date: 26 November 2019
Temperature: 23 ± 3 °C
Humidity: 20 - 60 % RH

FCC Rule: 15.247(a)
RSS-247 5.1(c)

Results:

Table 26: Number of Hopping Frequencies, LORA (FHSS)

Operating frequency [MHz]	Number of channels	Total Number of channels	Minimum Limit	Result
902.3 - 914.9	64	64	50	PASS

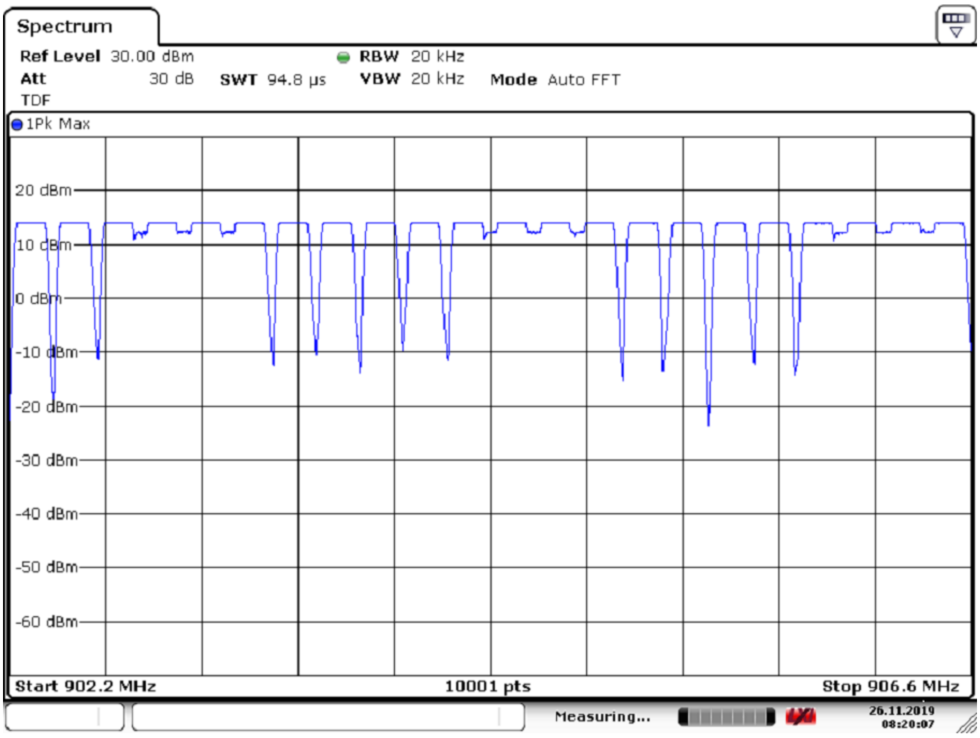


Figure 48: Number of hopping frequencies, 125kHz hopping enabled, channels 0-21

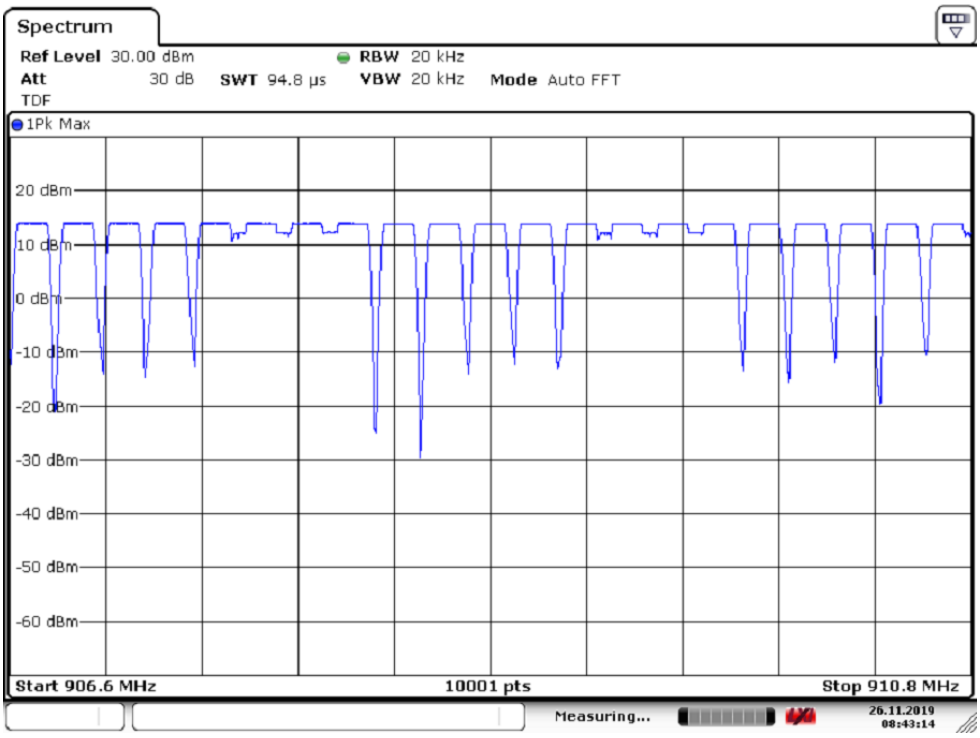


Figure 49: Number of hopping frequencies, 125kHz hopping enabled, channels 22-42

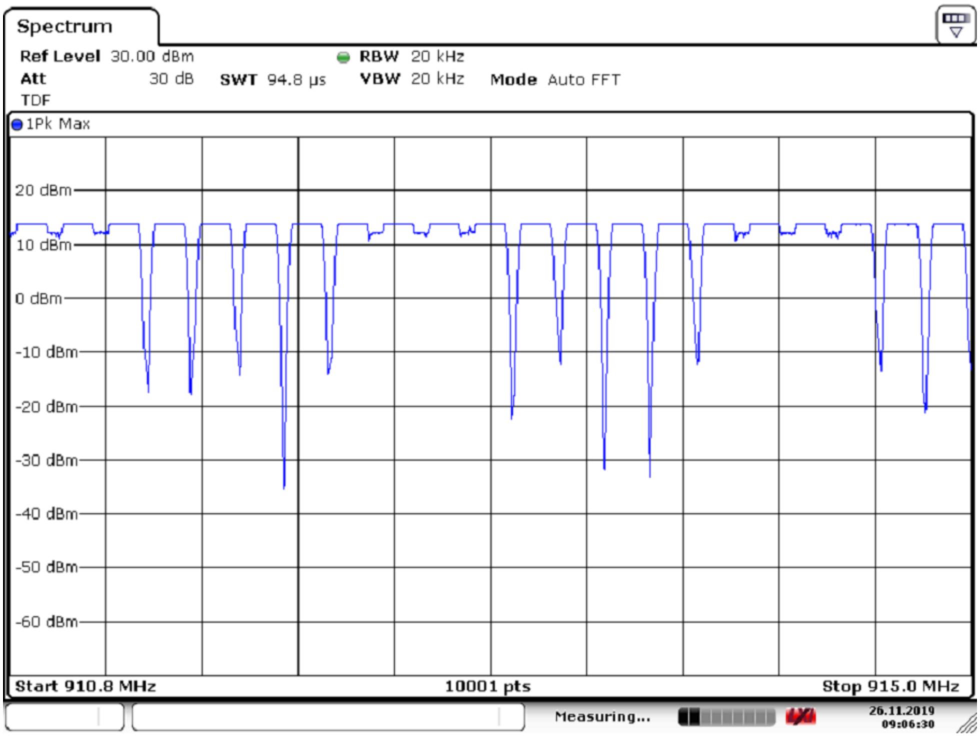


Figure 50: Number of hopping frequencies, 125kHz hopping enabled, channels 43-63

Carrier Frequency Separation

Standard: ANSI C63.10 (2013)
Tested by: HEM
Date: 26 November 2019
Temperature: 23 ± 3 °C
Humidity: 20 - 60 % RH

FCC Rule: 15.247(a)
RSS-247 5.1(b)

Results:

Table 27: Carrier Frequency Separation, LORA (FHSS)

Channel Bandwidht [kHz]	Channel Separation [kHz]	Minimum limit 20dB BW [kHz]	Result
125	200	138.574	PASS

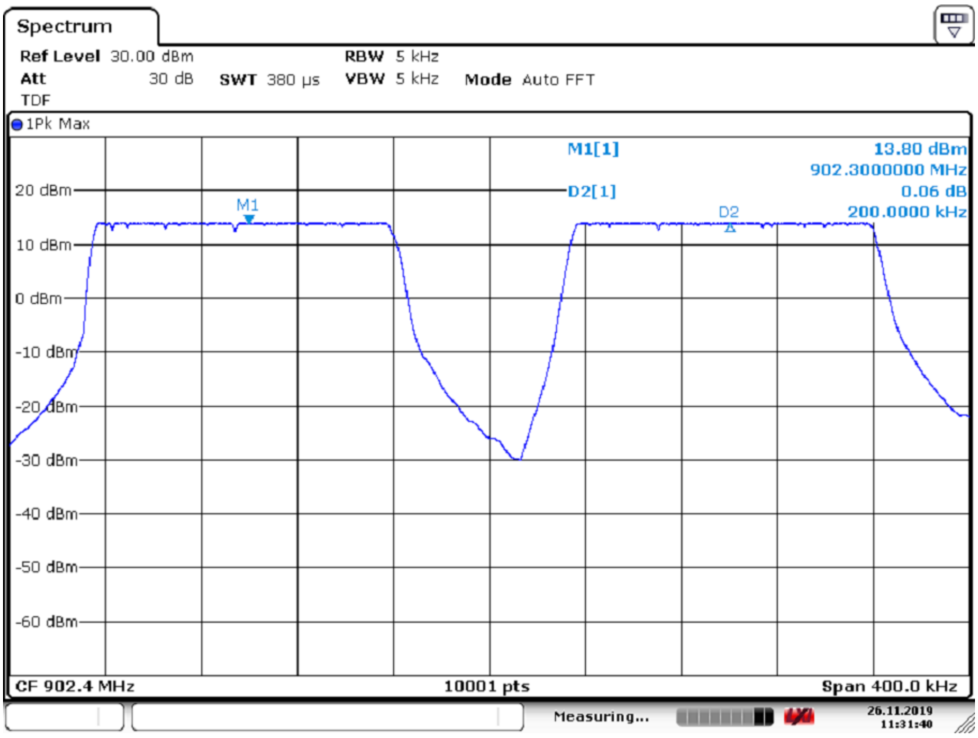


Figure 51: Carrier frequency separation, 125kHz hopping enabled, channels 0-1

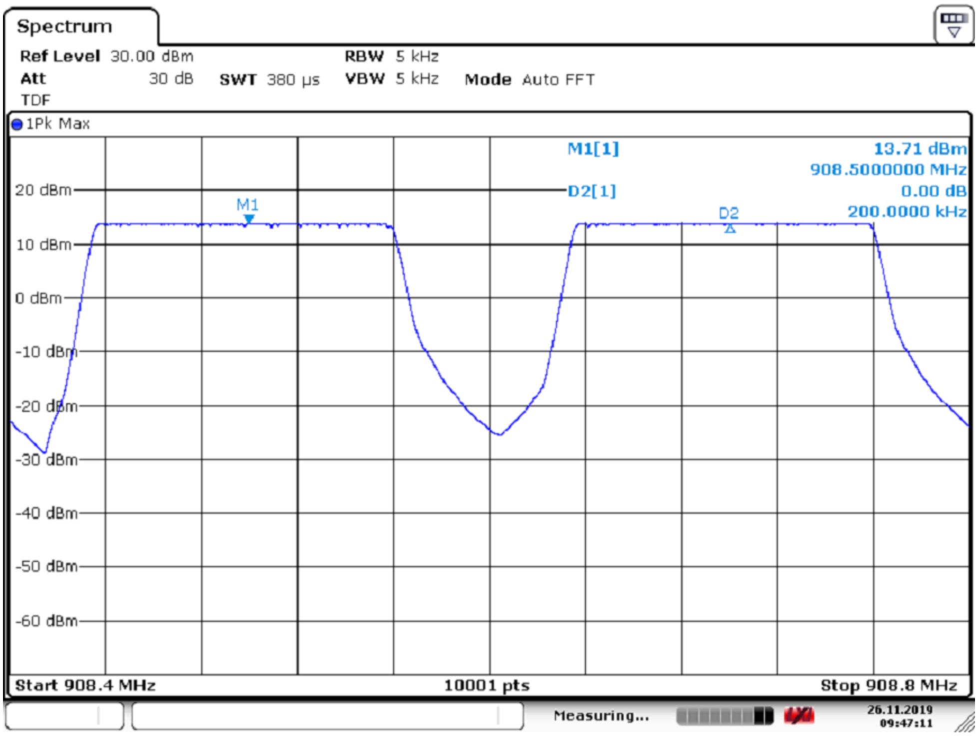


Figure 52: Carrier frequency separation, 125kHz hopping enabled, channels 31-32

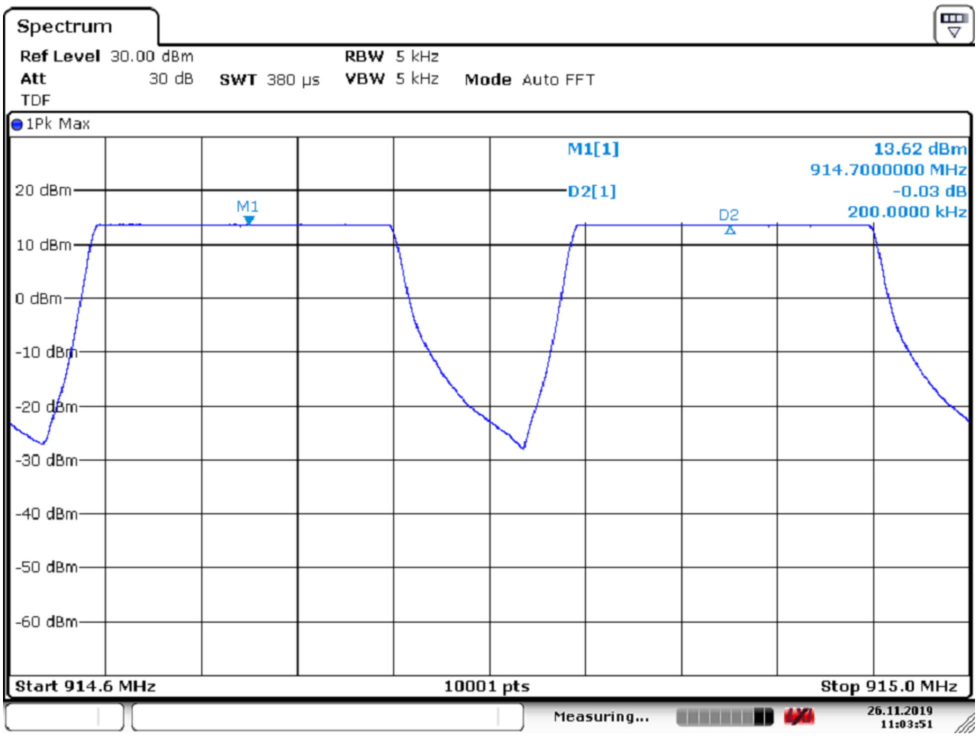


Figure 53: Carrier frequency separation, 125kHz hopping enabled, channels 62-63

99% Occupied Bandwidth

Standard:	RSS-GEN	(2014)
Tested by:	RRE	
Date:	17 September 2019	
Temperature:	23 ± 3 °C	
Humidity:	20 - 60 % RH	

RSS-GEN 6.7

Results:

Table 28: 99% occupied bandwidth test results

Channel bandwidth [kHz]	Channel	Limit	99 % BW [kHz]	Result
125	0 Low	-	127.48	PASS
	31 Mid	-	127.51	PASS
	63 High	-	127.20	PASS
500	64 Low	-	872.32	PASS
	67 Mid	-	883.10	PASS
	71 High	-	836.69	PASS

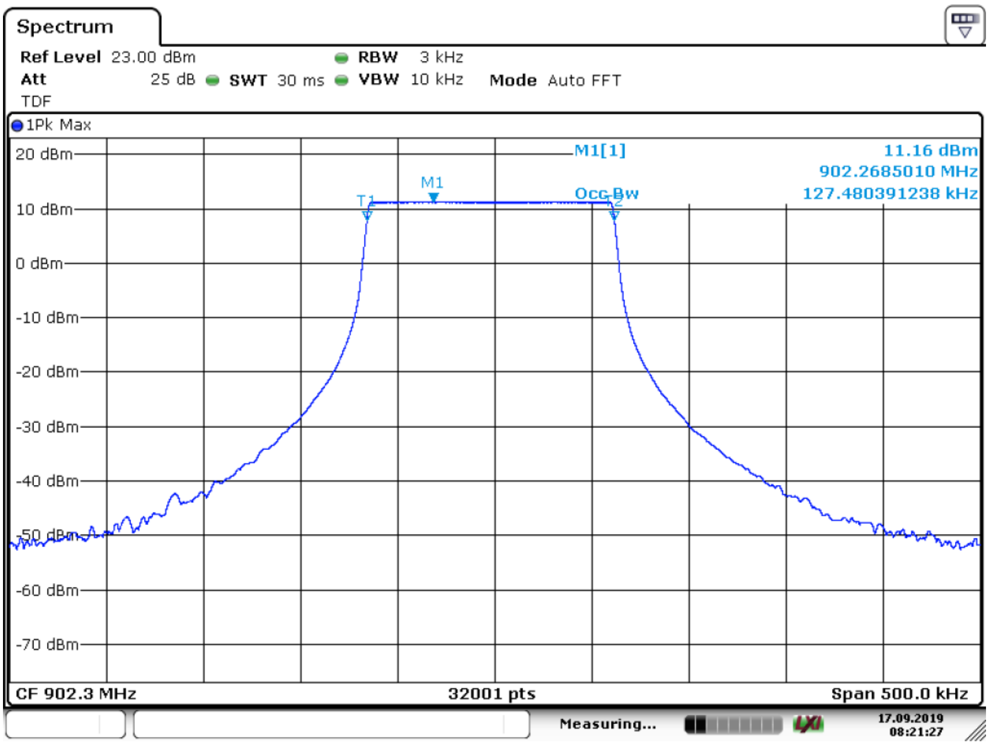


Figure 54: 99% OBW, Channel 0 low, 125 kHz

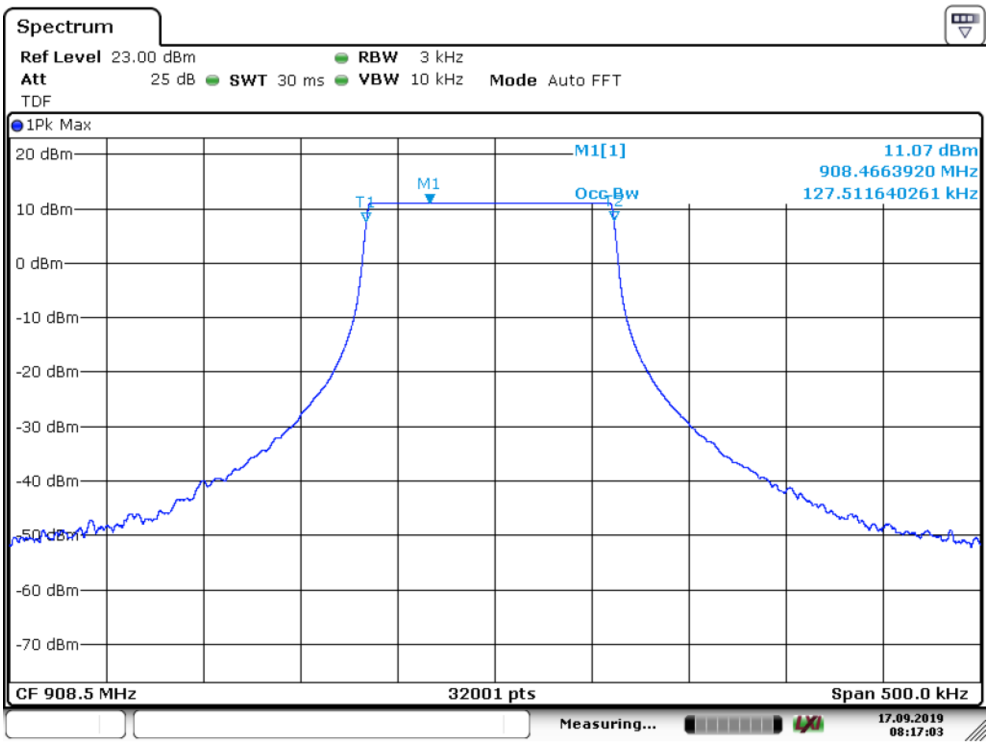


Figure 55: 99% OBW, Channel 31 mid, 125 kHz

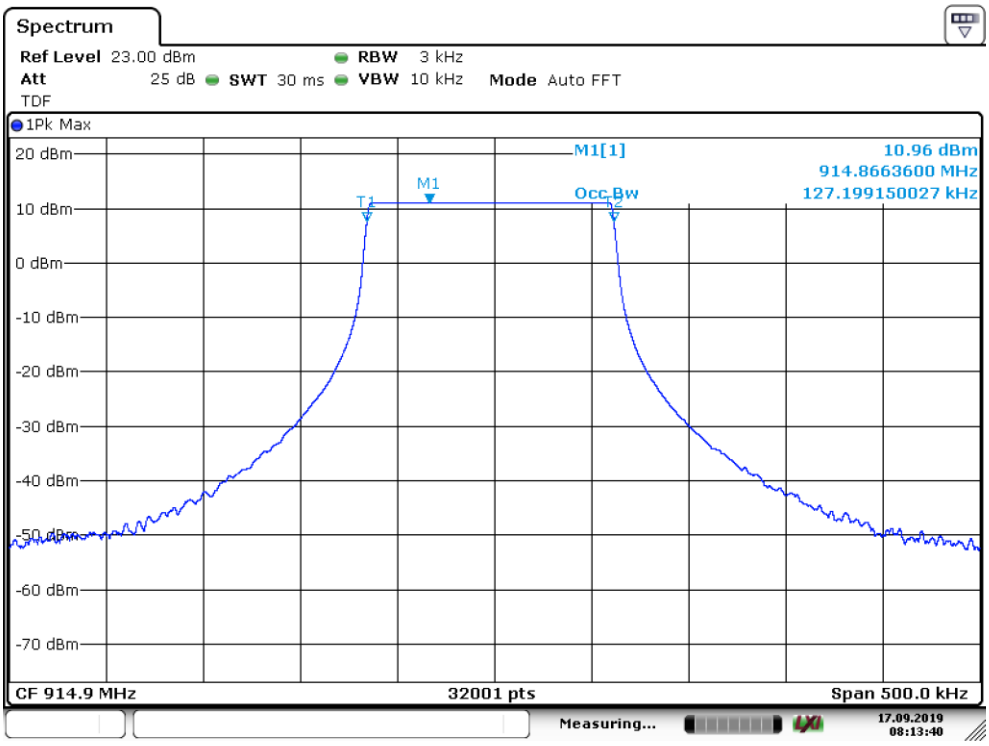


Figure 56: 99% OBW, Channel 63 high, 125 kHz

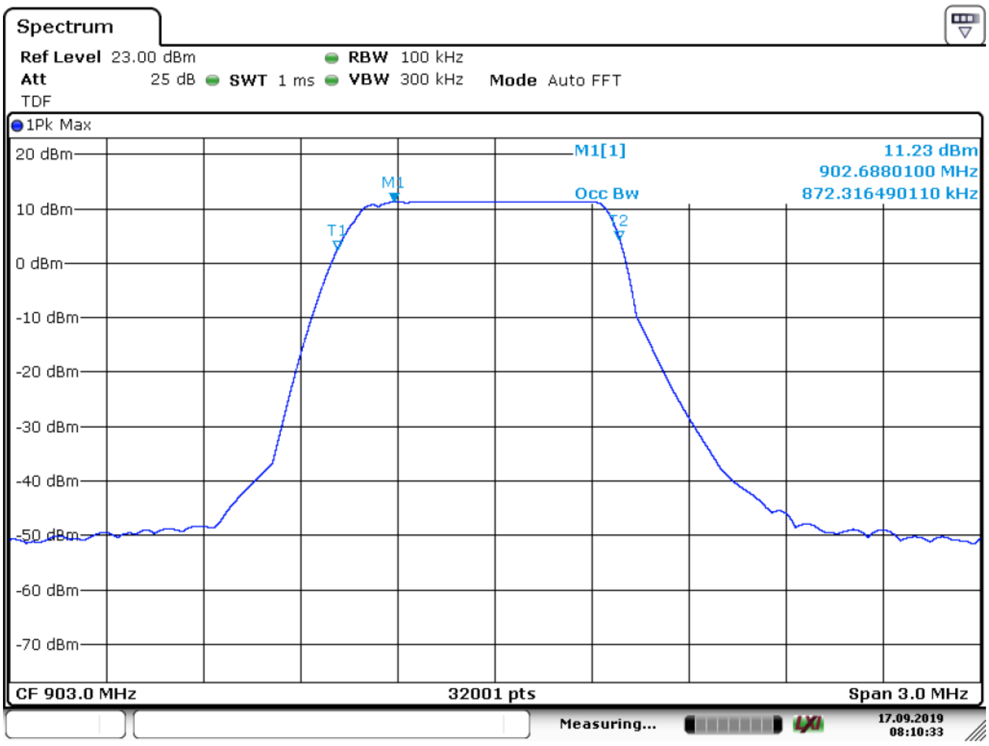


Figure 57: 99% OBW, Channel 64 low, 500k Hz

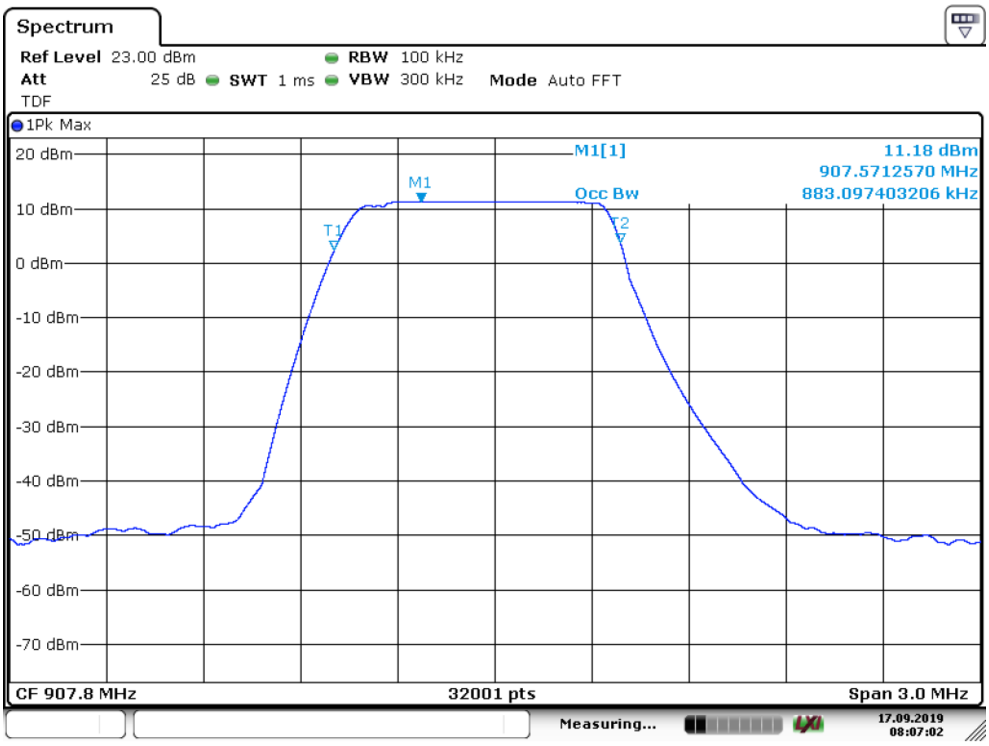


Figure 58: 99% OBW, Channel 67 mid, 500 kHz

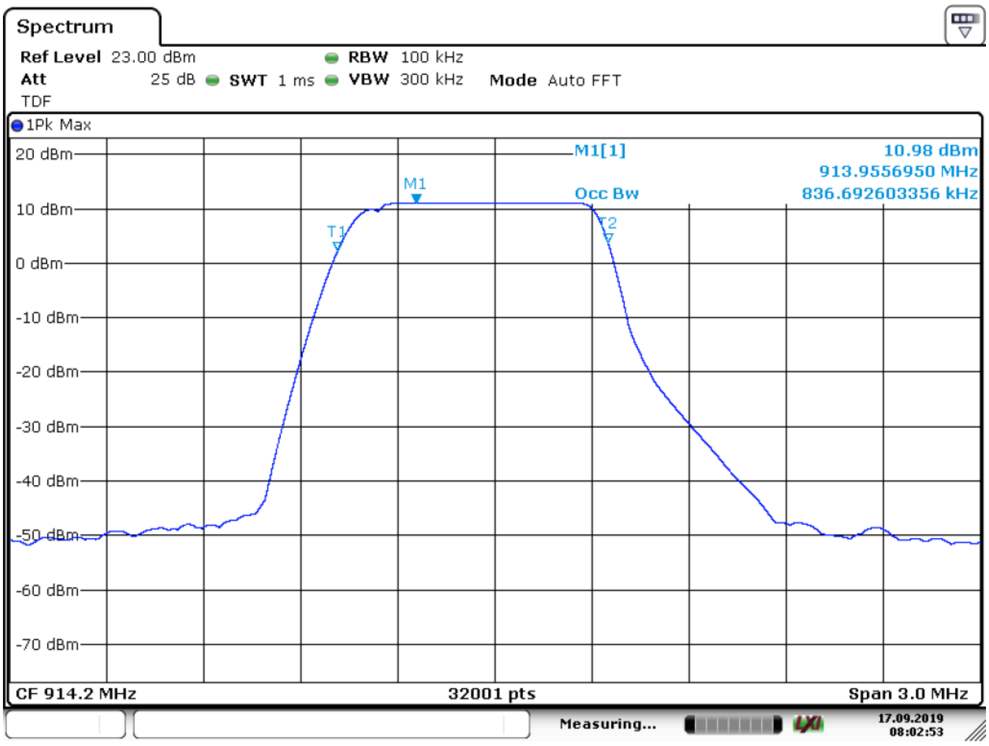


Figure 59: 99% OBW, Channel 71 high, 500 kHz

TEST EQUIPMENT

RF-Test Equipment

Equipment	Manufacturer	Type	Inv or serial	Prev Calib	Next Calib
ANTENNA	A.H. SYSTEMS	SAS-200/518	inv:7873	-	-
SPECTRUM ANALYZER	AGILENT	E7405A	inv:9746	2018-01-08	2020-01-08
PREAMPLIFIER	CIAO	CA118-3123	inv:10278	2019-10-09	2020-10-09
POWER SUPPLY	DELTA	SM 130-25D	inv:10406	-	-
ANTENNA	EMCO	3117	inv:7293	2018-03-14	2020-03-04
ANTENNA	ROHDE & SCHWARZ	HFH2-Z2, 335.4711.52	inv:8013	2018-10-30	2020-10-30
TURNTABLE	MATURO	DS430 UPGRADED	inv:10182	-	-
MAST & TURNTABLE CONTROLLER	MATURO	NCD	inv:10183	-	-
ANTENNA MAST	MATURO	TAM 4.0E	inv:10181	-	-
ATTENUATOR	PASTERNACK	PE 7004-4	inv:10126	2019-04-01	2021-04-01
TEST SOFTWARE	ROHDE & SCHWARZ	EMC-32	-	-	-
EMI TEST RECEIVER	ROHDE & SCHWARZ	ESW26	inv:10679	2019-06-28	2020-06-27
SIGNAL ANALYZER	ROHDE & SCHWARZ	FSV40	inv:9093	2018-06-28	2020-06-28
ANTENNA	SCHWARZBECK	VULB 9168	inv:8911	2018-10-25	2020-10-25
TEMPERATURE/ HUMIDITY METER	VAISALA	HMT 333	inv:8638	2019-04-10	2020-04-10
HIGH PASS FILTER	WAINWRIGHT	HP, WHKX1.0/15G-10SS	inv:8267	2019-04-11	2021-04-01
LISN	ROHDE & SCHWARZ	ENV216	inv:9611	2019-03-01	2020-03-01