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RADIO TEST REPORT – 393579-1TRFWL

Type of assessment:

Final product testing

Applicant:

Summation Research Inc.

Product name (type):

STR-1800 Land Mobile Data Radio

Series:

STR-1800

Model:

STR-1820A

Model variant:

STR-1821A

FCC ID:

OQW-STR1800

IC Registration number:

9110A-STR1800

Specifications:

- FCC 47 CFR Part 90, Subpart I
- RSS-119, Issue 12, May 2015

Date of issue: June 5, 2020

Andrey Adelberg, Senior EMC/RF Specialist	
Tested by	Signature
Kevin Rose, EMC/RF Lab Manager	
Reviewed by	Signature

Lab locations

Company name	Nemko Canada Inc.			
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Test site registration	**Organization**	**Recognition numbers and location**		
	FCC/ISED	FCC: CA2040; IC: 2040A-4 (Ottawa/Almonte); FCC: CA2041; IC: 2040G-5 (Montreal); CA0101 (Cambridge)		
Website	www.nemko.com			

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 contained in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

Copyright notification

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Section 1 Report summary

1.1 Test specifications

FCC 47 CFR Part 90, Subpart I	Private land mobile radio services. General technical standards
RSS-119 Issue 12, May 2015	Land Mobile and Fixed Equipment Operating in the Frequency Range 27.41–960 MHz

1.2 Test methods

ANSI C63.26-2015	American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services
RSS-102, Issue 5, March 19, 2015	Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)
SRSP-501, Issue 5, October 2004	Technical Requirements for Land Mobile and Fixed Radio Services Operating in the Bands 406.1–430 MHz and 450–470 MHz
FCC 47 CFR Part 2, Subpart J	Equipment authorization procedures
RSS-Gen Issue 5, March 2019	General Requirements for Compliance of Radio Apparatus

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
TRF	June 5, 2020	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

Model variant SRT-1821A is available supporting two independently tunable receiver paths.

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.

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

UKAS Lab 34 and TIA-603-B have been used as guidance for measurement uncertainty reasonable estimations with regards to previous experience and validation of data. Nemko Canada, Inc. follows these test methods in order to satisfy ISO/IEC 17025 requirements for estimation of uncertainty of measurement for wireless products.

Measurement uncertainty budgets for the tests are detailed below. Measurement uncertainty calculations assume a coverage factor of K = 2 with 95% certainty.

Table 4.1-1: *Measurement uncertainty calculations*

Test name	Measurement uncertainty, ±dB
All antenna port measurements	0.55
Occupied bandwidth	4.45
Conducted spurious emissions	1.13
Radiated spurious emissions	3.78
AC power line conducted emissions	3.55

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 and manufacturer

Company name	Summation Research Inc.
Address	305 East Dr. Suite D, Melbourne FL, 32904, USA

5.3 EUT information

Product name	STR-1800 Land Mobile Data Radio
Series	STR-1800
Model	STR-1820A
Model variant	STR-1821A
Serial number	4500204
Part number	70-1820-01
WABTEC Part number	1003144-224 (STR-1820A), 1003144-214 (STR-1821A)
Operating conditions	The EUT is running firmware that allows it to be commanded via RS-422 interface to the following settings: Frequency: Pre-programmed frequencies between 400 and 470 MHz Power: 5, 8 or 30 watts Modulation: 1200 bps, 12.5 kHz modulation width, FFSK or FSK modulation 4800 bps, 6.25 kHz modulation width, SOQPSK modulation Unique RS-422 commands contain data to be transmitted over the air or recovered data from over the air. Special test firmware is used to allow the radio to be keyed for longer than 15 seconds.
Product description and theory of operation	UHF Land Mobile Data Radio, simplex operation, modulates user analog and digital data to and from a 12.5 KHz or 6.25 KHz carrier between the frequencies of 400 MHz and 470 MHz, approved for operation with external antenna with a gain of up to 0 dBd, with an output power up to 30 W maximum measured at the output of the transceiver.

5.4 Technical information

System type	☒ Mobile system
	☐ Base/Fixed point-to-point system
Frequency band	450–470 MHz
Frequency Min (MHz)	452.925
Frequency Max (MHz)	457.950
RF power Max (W), Conducted	31.55 (44.99 dBm)
Measured BW (kHz), 99% OBW	7691 (12.5 kHz channel); 3686 (6.25 kHz channel)
Type of modulation	SOQPSK, FSK and FFSK
Emission classification	11K2F2D, 11K2F1D, 4K00F1D
Transmitter spurious, dBµV/m @ 3 m	64.43 (peak) at 2747 MHz (based on EIRP measurement)
Power supply requirements	13.6 V_{DC} (Tx: max 9 A, Rx: 0.7 A)
Antenna information	Sinclair, MN: ST321-SF9SNF, Gain: 0 dBd (2.15 dBi) Kathrein, MN: K 70 20 21, Gain: 0 dBd (2.15 dBi)

5.5 EUT setup details

5.5.1 EUT exercise and monitoring

Methods used to exercise the EUT and all relevant ports:

- EUT was connected to a laptop with executable test software that exercised radio with ability to select transmitting channel, modulation, bandwidth, power and transmission duration.

Configuration details:

- The EUT setup in a configuration that was expected to produce the highest amplitude emissions relative to the limit and that satisfy normal operation/installation practice by the end user.
- The type and construction of cables used in the measurement set-up were consistent with normal or typical use. Cables with mitigation features (for example, screening, tighter/more twists per length, ferrite beads) have been noted below:
  - The following deviations were:
  - None
- The EUT was setup in a manner that was consistent with its typical arrangement and use. The measurement arrangement of the EUT, local AE and associated cabling was representative of normal practice. Any deviations from typical arrangements have been noted below:
  - The following deviations were:
  - EUT was specially programmed for testing to transmit for extended period: 70 seconds.

5.5.2 EUT setup configuration

Table 5.5-1: *EUT interface ports*

Description	Qty.
Primary power connector	1
DB-9 Front panel connector	1
DB-25 Front panel connector	1
UHF PL-259 Type (F) RF 50 Ω antenna connector	1

Table 5.5-2: *Support equipment*

Description	Brand name	Model, Part number, Serial number, Revision level
Laptop	Dell	Asset number: FA002852
Front panel	Summation	MN: No Model Number, PN: 30-STR1800-01, SN: NSN, Rev. NRN

Table 5.5-3: *Inter-connection cables*

Cable description	From	To	Length (m)
Power	Nemko DC power supply	STR-1800 Radio	1.5
Front panel data	STR-1800 Radio	Front panel	0.3

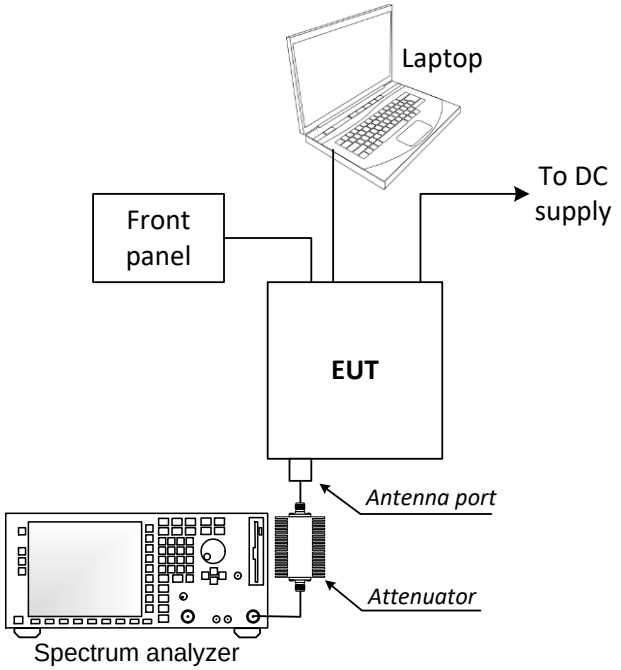

Figure 5.5-1: *Antenna port testing block diagram*

EUT setup configuration, continued

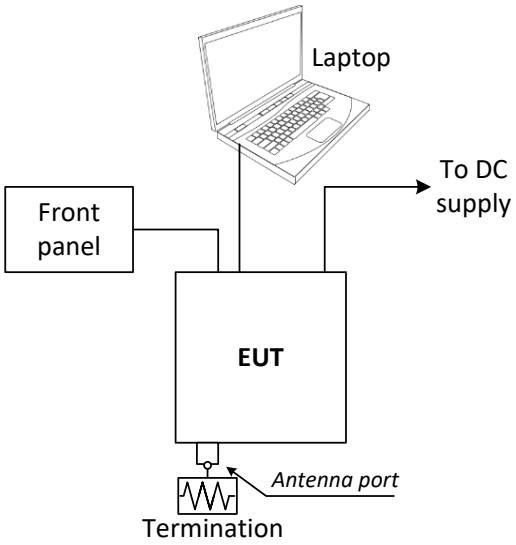

Figure 5.5-2: *Radiated testing block diagram*

Section 6 Summary of test results

6.1 Testing location

Test location (s)	Ottawa

6.2 Testing period

Test start date	March 24, 2020	Test end date	April 14, 2020

6.3 Sample information

Receipt date	March 9, 2020	Nemko sample ID number(s)	1, 2

6.4 FCC Part 2 Subpart J and Part 90 Subpart I test results

Table 6.4-1: *FCC requirements results*

Part	Test description	Verdict
§2.1047	Modulation characteristics	Not applicable[1]
§90.205(h)	Transmitter output power	Pass
§90.209(b)	Bandwidth limitations	Pass
§90.210	Spectrum mask and spurious emissions	Pass
§90.214	Transient frequency behavior	Pass
§90.213(a)	Transmitter frequency stability	Pass

Note: This equipment is not used for voice communications therefore the Modulation characteristics are not required

6.5 ISED RSS-119, Issue 12 test results

Table 6.5-1: *Canada requirements results*

Section	Test description	Verdict
5.4	Transmitter output power	Pass
5.5	Bandwidth limitations	Pass
5.5	Spectrum mask and spurious emissions	Pass
5.9	Transient frequency behavior	Pass
5.3	Transmitter frequency stability	Pass
RSS-Gen, 6.9	Number of frequencies	Pass

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.
3 m EMI test chamber	TDK	SAC-3	FA002047	1 year	January 24, 2021
Flush mount turntable	Sunol	FM2022	FA002082	—	NCR
Controller	Sunol	SC104V	FA002060	—	NCR
Antenna mast	Sunol	TLT2	FA002061	—	NCR
DC Power source	Ametek	SGA80X125C-0AAA	FA002737	—	VOU
Receiver/spectrum analyzer	Rohde & Schwarz	ESU 26	FA002043	1 year	May 8, 2020
Spectrum analyzer	Rohde & Schwarz	FSU	FA001877	1 year	October 31, 2020
Horn (1–18 GHz)	ETS Lindgren	3117	FA002840	1 year	January 25, 2021
Preamp (1–18 GHz)	ETS Lindgren	124334	FA002873	1 year	November 4, 2020
Bilog antenna (20–3000 MHz)	Sunol	JB3	FA002108	1 year	January 14, 2021
Temperature chamber	Espec	EPX-4H	FA002735	1 year	September 11, 2020
WR28 20 dB attenuator	Dorado Company	FA-28-20	99001	—	VOU

Note: NCR - no calibration required, VOU - verify on use

Section 8 Testing data

8.1 ANSI C63.26, Clause 5.1.2 and RSS-Gen, Clause 6.9 Number of frequencies

8.1.1 References, definitions and limits

ANSI:
Measurements of transmitters shall be performed and, if required, reported for each frequency band in which the EUT can be operated with the device transmitting at the number of frequencies in each band specified in table below.

ISED:
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 8.1-1: *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

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

8.1.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	April 14, 2020

8.1.3 Observations, settings and special notes

Per ANSI C63.10 Subclause 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.

Per ANSI C63.10 Subclause 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.

8.1.4 Test data

Table 8.1-2: *Test channels selection – FSK modulation*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	High channel, MHz
450	470	20*	452.925	457.950

Note: *EUT operates only within a part of the band which is less than 10 MHz wide: from ~453 MHz up to ~458 MHz, hence only high and low operating frequencies were measured.

Table 8.1-3: *Test channels selection – SOQPSK modulation*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	High channel, MHz
450	470	20*	452.925	457.950

Note: *EUT operates only within a part of the band which is less than 10 MHz wide: from ~453 MHz up to ~458 MHz, hence only high and low operating frequencies were measured.

Table 8.1-4: *Test channels selection – FFSK modulation*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	High channel, MHz
450	470	20*	452.9375	457.9375

Note: *EUT operates only within a part of the band which is less than 10 MHz wide: from ~453 MHz up to ~458 MHz, hence only high and low operating frequencies were measured.

8.2 FCC 90.205(h) and RSS-119, Clause 5.4 Transmitter Output Power

8.2.1 References, definitions and limits

FCC:

(1) The maximum allowable station effective radiated power (ERP) is dependent upon the station's antenna HAAT and required service area and will be authorized in accordance with table below. Applicants requesting an ERP in excess of that listed in table below must submit an engineering analysis based upon generally accepted engineering practices and standards that includes coverage contours to demonstrate that the requested station parameters will not produce coverage in excess of that which the applicant requires.

(2) Applications for stations where special circumstances exist that make it necessary to deviate from the ERP and antenna heights in Table below will be submitted to the frequency coordinator accompanied by a technical analysis, based upon generally accepted engineering practices and standards, that demonstrates that the requested station parameters will not produce a signal strength in excess of 39 dBu at any point along the edge of the requested service area. The coordinator may then recommend any ERP appropriate to meet this condition.

(3) An applicant for a station with a service area radius greater than 32 km (20 mi) must justify the requested service area radius, which may be authorized only in accordance with table below, note 4. For base stations with service areas greater than 80 km, all operations 80 km or less from the base station will be on a primary basis and all operations outside of 80 km from the base station will be on a secondary basis and will be entitled to no protection from primary operations.

Table 8.2-1: *Maximum ERP/Reference HAAT for a Specific Service Area Radius (FCC)*

Service area radius (km):	**3**	**8**	**13**	**16**	**24**	**32**	**40[4]**	**48[4]**	**64[4]**	**80[4]**
Maximum ERP (W)[1]:	2	100	[2]500	[2]500	[2]500	[2]500	[2]500	[2]500	[2]500	[2]500
Up to reference HAAT (m)[3]:	15	15	15	27	63	125	250	410	950	2700

[1]Maximum ERP indicated provides for a 39 dBu signal strength at the edge of the service area per FCC Report R-6602, Fig. 29 (See §73.699, Fig. 10 b).

[2]Maximum ERP of 500 watts allowed. Signal strength at the service area contour may be less than 39 dBu.

[3]When the actual antenna HAAT is greater than the reference HAAT, the allowable ERP will be reduced in accordance with the following equation:

$$ERP_{allow} = ERP_{max} \times (HAAT_{ref} / HAAT_{actual})^2.$$

[4]Applications for this service area radius may be granted upon specific request with justification and must include a technical demonstration that the signal strength at the edge of the service area does not exceed 39 dBu.

(s) The output power shall not exceed by more than 20 percent either the output power shown in the Radio Equipment List for transmitters included in this list or when not so listed, the manufacturer's rated output power for the particular transmitter specifically listed on the authorization.

ISED:

The output power shall be within ±1 dB of the manufacturer's rated power listed in the equipment specifications.
The transmitter output power limits set forth in Table below will come into force upon the publication of Issue 12 of this standard and will apply to newly certified equipment.

Table 8.2-2: *Transmitter Output Power (ISED)*

Frequency Band (MHz)	**Transmitter Output Power for Base/Fixed Equipment**	**Transmitter Output Power for Mobile Equipment**
450–470	110 W (50.41 dBm)	60 W (47.78 dBm)

8.2.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	April 14, 2020

8.2.3 Observations, settings and special notes

Manufacturer's rated output power is 25 W or 44 dBm. 20% or 10 × Log_{10} (0.2) = −6.99 dB.
Measurement of peak power was performed per ANSI C63.26 subclause 5.2.3.3. Spectrum analyser settings:

Resolution bandwidth	≥ OBW
Video bandwidth	≥ 3 × RBW
Frequency span	≥ 2 × OBW
Detector mode	Peak
Trace mode	Max Hold
Sweep time	≥ 10 × (number of points in sweep) × (transmission symbol period)

8.2.4 Test data

Table 8.2-3: *Transmitter power results for FCC*

Modulation	Frequency, MHz	Output power, dBm	Antenna gain, dBd	ERP, dBm	ERP limit, dBm	Margin, dB
FFSK	452.9375	44.41	0.00	44.41	50.00	5.59
	457.9375	44.52	0.00	44.52	50.00	5.48
FSK	452.9250	44.99	0.00	44.99	50.00	5.01
	457.9500	44.49	0.00	44.49	50.00	5.51
SOQPSK	452.9250	44.83	0.00	44.83	50.00	5.17
	457.9500	44.93	0.00	44.93	50.00	5.07

Note: ERP limit of 100 W (50 dBm) was selected as a most stringent limit.

Table 8.2-4: *Transmitter power results for ISED*

Modulation	Frequency, MHz	Output power, dBm	Output power limit, dBm	Margin, dB
FFSK	452.9375	44.41	47.78	3.37
	457.9375	44.52	47.78	3.26
FSK	452.9250	44.99	47.78	2.79
	457.9500	44.49	47.78	3.29
SOQPSK	452.9250	44.83	47.78	2.95
	457.9500	44.93	47.78	2.85

Table 8.2-5: *Rated vs measured power for ISED*

Modulation	Frequency, MHz	Rated power, dBm	Measured power, dBm	Difference, dB	Difference limit, ±dB	Margin, dB
FFSK	452.9375	44.00	44.41	0.41	1.00	0.59
	457.9375	44.00	44.52	0.52	1.00	0.48
FSK	452.9250	44.00	44.99	0.99	1.00	0.01
	457.9500	44.00	44.49	0.49	1.00	0.51
SOQPSK	452.9250	44.00	44.83	0.83	1.00	0.17
	457.9500	44.00	44.93	0.93	1.00	0.07

Table 8.2-6: *Rated vs measured power for FCC*

Modulation	Frequency, MHz	Rated power, dBm	Measured power, dBm	Difference, dB	Difference limit, ±dB	Margin, dB
FFSK	452.9375	44.00	44.41	0.41	6.99	6.58
	457.9375	44.00	44.52	0.52	6.99	6.47
FSK	452.9250	44.00	44.99	0.99	6.99	6.00
	457.9500	44.00	44.49	0.49	6.99	6.50
SOQPSK	452.9250	44.00	44.83	0.83	6.99	6.16
	457.9500	44.00	44.93	0.93	6.99	6.06

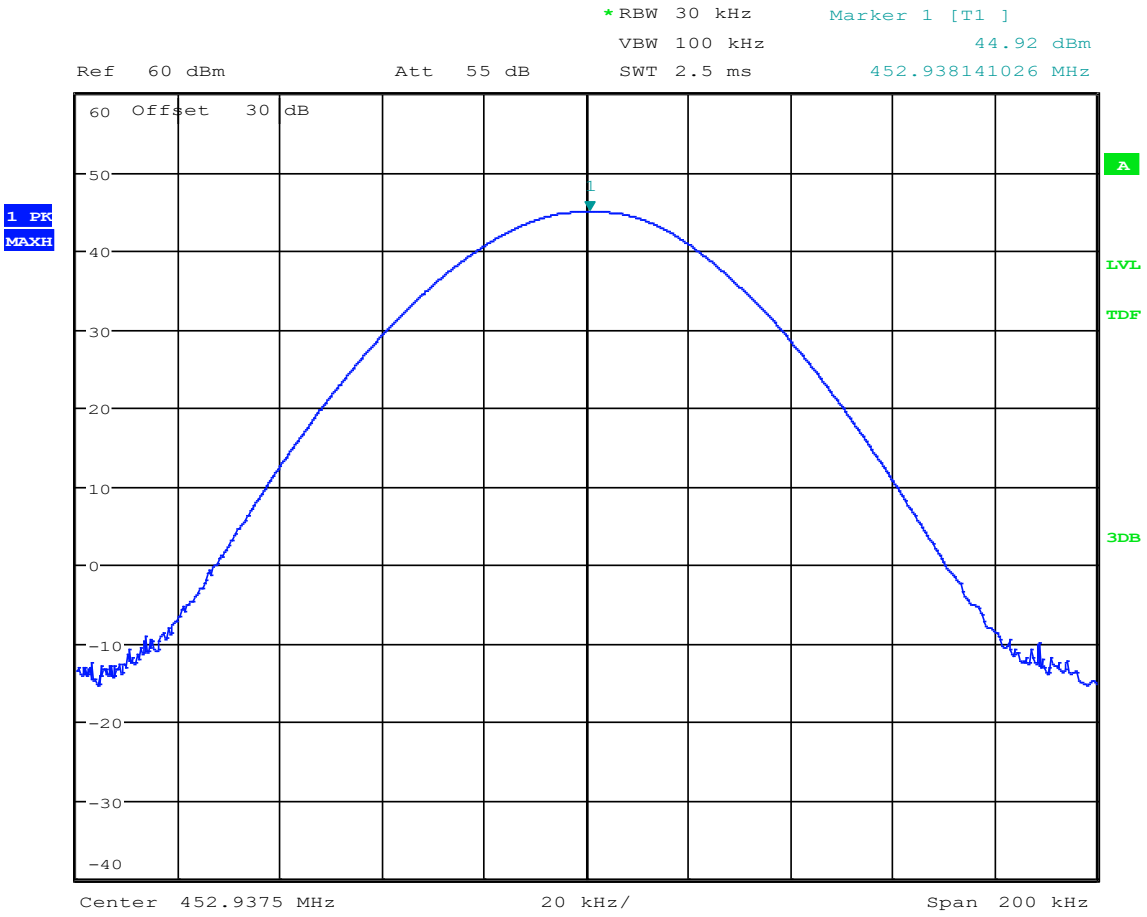

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Figure 8.2-1: *Output power measurement, sample plot*

8.3 FCC 90.209(b) and RSS-119, Clause 5.5 Bandwidth limitations

8.3.1 References, definitions and limits

FCC:

(b) The maximum authorized single channel bandwidth of emission corresponding to the type of emission specified in §90.207 is as follows:

(5) Unless specified elsewhere, channel spacings and bandwidths that will be authorized in the following frequency bands are given in the following table.

Table 8.3-1: *Standard Channel Spacing/Bandwidth*

Frequency band, MHz	Channel spacing, kHz	Authorized bandwidth[1], kHz
406–512	6.25	20 / 11.25 / 6

Note: [1]Operations using equipment designed to operate with a 25 kHz channel bandwidth will be authorized a 20 kHz bandwidth. Operations using equipment designed to operate with a 12.5 kHz channel bandwidth will be authorized a 11.25 kHz bandwidth. Operations using equipment designed to operate with a 6.25 kHz channel bandwidth will be authorized a 6 kHz bandwidth. All stations must operate on channels with a bandwidth of 12.5 kHz or less beginning January 1, 2013

(6)(i) Beginning January 1, 2011, no new applications for the 421–512 MHz bands will be acceptable for filing if the applicant utilizes channels with an authorized bandwidth exceeding 11.25 kHz, unless specified elsewhere or the operations meet the efficiency standards of §90.203(j)(3).

ISED:

For the purpose of this document, channel bandwidth is the channel width in which the equipment is designed to operate.

The maximum permissible occupied bandwidth shall not exceed the authorized bandwidth specified in Table below for the equipment's frequency band.

The authorized bandwidth is defined as the maximum width of the band of frequencies used to derive spectrum masks and is not necessarily equivalent to the bandwidth found on radio and spectrum licences.

The channel bandwidths and authorized bandwidths are given in Table below for equipment having an output power greater than 120 mW. For equipment with an output power that does not exceed 120 mW, Section 5.10 applies.

Table 8.3-2: *Channel Bandwidths, Authorized Bandwidths for 450–470 MHz frequency band*

Channel bandwidth, kHz	Authorized bandwidth, kHz
25.00	20.00
12.50	11.25
6.25	6.00

8.3.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	April 14, 2020

8.3.3 Observations, settings and special notes

The test was performed as per ANSI C63.26, subclause 5.4.4.

Spectrum analyser settings:

Resolution bandwidth	1–5% of OBW
Video bandwidth	≥3 × RBW
Frequency span	1.5 × OBW
Detector mode	Peak
Trace mode	Max Hold

8.3.4 Test data

Table 8.3-3: *99% occupied bandwidth results*

Modulation	Frequency, MHz	99% occupied bandwidth, kHz	Limit, kHz	Margin, kHz
FFSK	452.9375	7.147	11.250	4.103
	457.9375	7.115	11.250	4.135
FSK	452.9250	7.691	11.250	3.559
	457.9500	7.500	11.250	3.750
SOQPSK	452.9250	3.654	6.000	2.346
	457.9500	3.686	6.000	2.314

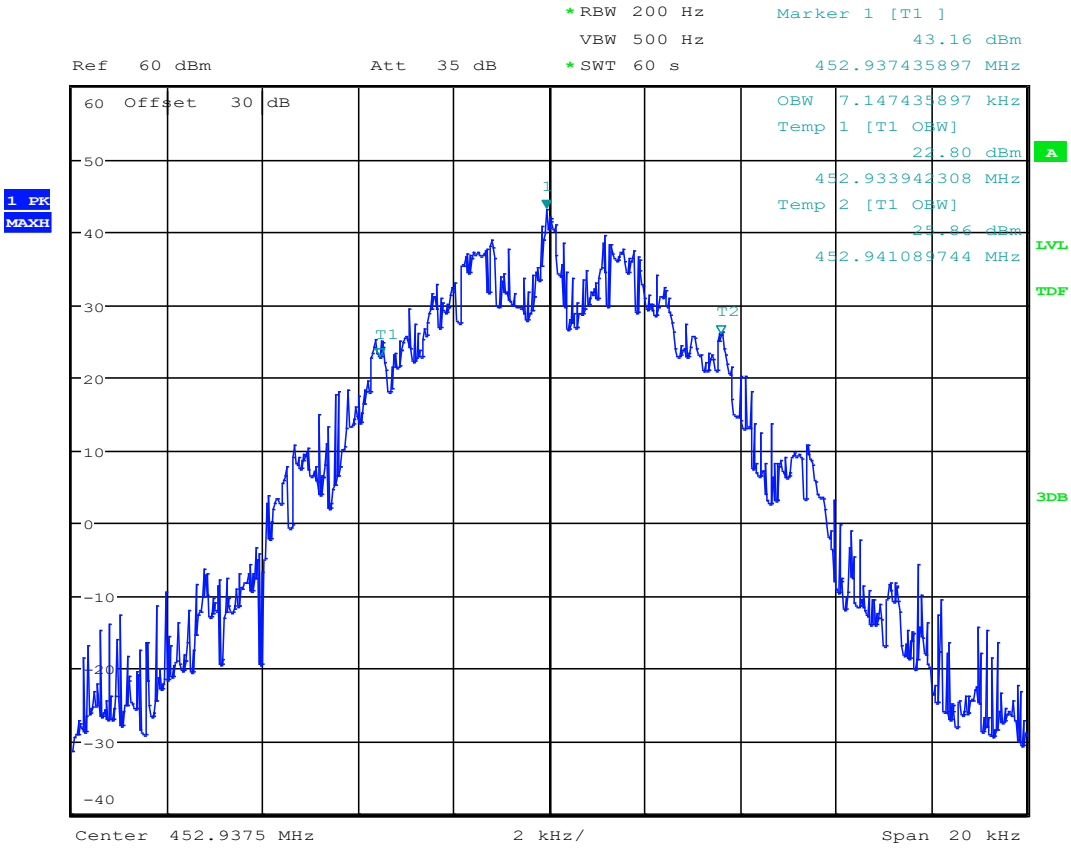

Figure 8.3-1: *99% occupied bandwidth sample plot*

8.4 FCC 90.210 and RSS-119, Clause 5.5 Spectrum mask and spurious emissions

8.4.1 References, definitions and limits

FCC:

Except as indicated elsewhere in this part, transmitters used in the radio services governed by this part must comply with the emission masks outlined in this section. Unless otherwise stated, per paragraphs (d)(4), (e)(4), and (o) of this section, measurements of emission power can be expressed in either peak or average values provided that emission powers are expressed with the same parameters used to specify the unmodulated transmitter carrier power. For transmitters that do not produce a full power unmodulated carrier, reference to the unmodulated transmitter carrier power refers to the total power contained in the channel bandwidth. Unless indicated elsewhere in this part, the table in this section specifies the emission masks for equipment operating under this part.

Table 8.4-1: *Applicable Emission Masks*

Frequency band, MHz	Mask for equipment with audio low pass filter	Mask for equipment with audio low pass filter
421–512[1,2]	B, D, or E	C, D, or E

Notes: [1]Equipment designed to operate with a 25 kHz channel bandwidth must meet the requirements of Emission Mask B or C, as applicable. Equipment designed to operate with a 12.5 kHz channel bandwidth must meet the requirements of Emission Mask D, and equipment designed to operate with a 6.25 kHz channel bandwidth must meet the requirements of Emission Mask E.
[2]Equipment designed to operate on 25 kilohertz bandwidth channels must meet the requirements of either Emission Mask B or G, whichever is applicable, while equipment designed to operate on 12.5 kilohertz bandwidth channels must meet the requirements of Emission Mask D. Equipment designed to operate on 25 kilohertz bandwidth channels may alternatively meet the Adjacent Channel Power limits of §90.221.

(d) **Emission Mask D**—12.5 kHz channel bandwidth equipment. For transmitters designed to operate with a 12.5 kHz channel bandwidth, any emission must be attenuated below the power (P) of the highest emission contained within the authorized bandwidth as follows:

(1) On any frequency from the center of the authorized bandwidth f_0 to 5.625 kHz removed from f_0: Zero dB.

(2) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 5.625 kHz but no more than 12.5 kHz: At least 7.27(f_d−2.88 kHz) dB.

(3) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 12.5 kHz: At least 50 + 10 log (P) dB or 70 dB, whichever is the lesser attenuation.

(4) The reference level for showing compliance with the emission mask shall be established using a resolution bandwidth sufficiently wide (usually two or three times the channel bandwidth) to capture the true peak emission of the equipment under test. In order to show compliance with the emission mask up to and including 50 kHz removed from the edge of the authorized bandwidth, adjust the resolution bandwidth to 100 Hz with the measuring instrument in a peak hold mode. A sufficient number of sweeps must be measured to insure that the emission profile is developed. If video filtering is used, its bandwidth must not be less than the instrument resolution bandwidth. For emissions beyond 50 kHz from the edge of the authorized bandwidth, see paragraph (o) of this section. If it can be shown that use of the above instrumentation settings do not accurately represent the true interference potential of the equipment under test, an alternate procedure may be used provided prior Commission approval is obtained.

(e) **Emission Mask E**—6.25 kHz or less channel bandwidth equipment. For transmitters designed to operate with a 6.25 kHz or less bandwidth, any emission must be attenuated below the power (P) of the highest emission contained within the authorized bandwidth as follows:

(1) On any frequency from the center of the authorized bandwidth f_0 to 3.0 kHz removed from f_0: Zero dB.

(2) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 3.0 kHz but no more than 4.6 kHz: At least 30 + 16.67(f_d−3 kHz) or 55 + 10 log (P) or 65 dB, whichever is the lesser attenuation.

(3) On any frequency removed from the center of the authorized bandwidth by more than 4.6 kHz: At least 55 + 10 log (P) or 65 dB, whichever is the lesser attenuation.

(4) The reference level for showing compliance with the emission mask shall be established using a resolution bandwidth sufficiently wide (usually two or three times the channel bandwidth) to capture the true peak emission of the equipment under test. In order to show compliance with the emission mask up to and including 50 kHz removed from the edge of the authorized bandwidth, adjust the resolution bandwidth to 100 Hz with the measuring instrument in a peak hold mode. A sufficient number of sweeps must be measured to insure that the emission profile is developed. If video filtering is used, its bandwidth must not be less than the instrument resolution bandwidth. For emissions beyond 50 kHz from the edge of the authorized bandwidth, see paragraph (o) of this section. If it can be shown that use of the above instrumentation settings do not accurately represent the true interference potential of the equipment under test, an alternate procedure may be used provided prior Commission approval is obtained.

ISED:

The authorized bandwidth is defined as the maximum width of the band of frequencies used to derive spectrum masks and is not necessarily equivalent to

the bandwidth found on radio and spectrum licences.
The spectrum masks is given in Table below for equipment having an output power greater than 120 mW. For equipment with an output power that does not exceed 120 mW, Section 5.10 applies.

Table 8.4-2: *Spectrum Masks*

Frequency band, MHz	Channel Bandwidth (kHz)	Authorized Bandwidth (kHz)	Mask for equipment with audio low pass filter	Mask for equipment with audio low pass filter
450–470	25.00	20.00	B	C
	12.50	11.25	D	D
	6.25	6.00	E	E

The spectrum plots of the unwanted emissions shall comply with the masks specified in tables below.
The term *displacement frequency, f_d,* used in these sections refers to the difference between the channel frequency and the emission component frequency expressed in kilohertz, and *p* is the transmitter output power in Watts.

5.8.3 **Emission Mask D** for Transmitters Equipped With or Without an Audio Low-Pass Filter
The power of any emission shall be attenuated below the transmitter output power P (dBW) as specified in Table below:

Table 8.4-3: *Emission Mask D*

Displacement Frequency, f_d (kHz)	Minimum Attenuation (dB)	Resolution Bandwidth (Hz)
$5.625 < f_d \leq 12.5$	$83 \times \text{Log}_{10}(f_d / 5)$	Specified in Section 4.2.2
$f_d > 12.5$	Whichever is the lesser: 70 *or* $50 \times \text{Log}_{10}(p)$	Specified in Section 4.2.2

5.8.4 **Emission Mask E** for Transmitters Equipped With or Without an Audio Low-Pass Filter
The power of any emission shall be attenuated below the transmitter output power P (dBW) as specified in Table below:

Table 8.4-4: *Emission Mask E*

Displacement Frequency, f_d (kHz)	Minimum Attenuation (dB)	Resolution Bandwidth (Hz)
$3 < f_d \leq 4.6$	Whichever is the lesser: $30 + 16.67 (f_d - 3)$ *or* $55 + 10 \times \text{Log}_{10}(p)$	Specified in Section 4.2.2
$f_d > 4.6$	Whichever is the lesser: 57 *or* $55 \times \text{Log}_{10}(p)$	Specified in Section 4.2.2

4.2.2 Emission Masks D, E, F and Y
In order to show compliance with the emission mask up to and including 50 kHz removed from the edge of the authorized bandwidth, adjust the resolution bandwidth to 100 Hz with the measuring instrument in a peak mode. For emissions beyond 50 kHz from the edge of the authorized bandwidth, the resolution bandwidth shall be 100 kHz for frequencies at or below 1 GHz, and 1 MHz for frequencies above 1 GHz. However, for emission mask F, at a displacement frequency of less than 3.75 kHz, the resolution bandwidth shall be 30 Hz.

8.4.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	April 14, 2020

8.4.3 Observations, settings and special notes

For 6.25 kHz channels, the limit 55 + 10 × Log10 (p) or **–25 dBm** was used. For 12.5 kHz channels, the limit 50 + 10 × Log10 (p) or **–20 dBm** was used.

Spectrum analyser settings for spectrum mask:

Resolution bandwidth:	100 Hz / 300 Hz
Video bandwidth:	> RBW
Detector mode:	Peak
Trace mode:	Max Hold

Conducted antenna port measurements were performed from 30 MHz up to OOB range, from OOB range up to 10th harmonic while EUT operates on low and high channels for each modulation type. Where applicable tabular data with test results is provided, spectral plots attached for reference information only. Spectrum analyser settings for spurious emissions were:

Resolution bandwidth:	100 kHz (below 1 GHz); 1 MHz (above 1 GHz)
Video bandwidth:	> RBW
Detector mode:	Peak
Trace mode:	Max Hold

8.4.4 Test data

Table 8.4-5: *Spurious emissions of cabinet radiation measurements results for 6.25 kHz channel*

Information	Frequency, MHz	Emission level, dBm	Limit, dBm	Margin, dB
SOQPSK, low channel	1358.78	-32.00	-25.00	7.00
	1811.70	-41.01	-25.00	16.01
	2717.55	-37.32	-25.00	12.32
	3170.48	-40.86	-25.00	15.86
	3623.40	-32.84	-25.00	7.84
	4076.33	-39.01	-25.00	14.01
SOQPSK, high channel	1373.85	-34.55	-25.00	9.55
	2289.75	-37.17	-25.00	12.17
	2747.70	**-30.80**	**-25.00**	**5.80**
	3663.60	-34.78	-25.00	9.78
	4579.50	-42.91	-25.00	17.91

Note: Worst case emission is at 2747.7 MHz with field strength calculated as follows: EIRP + 95.23 dB = –30.80 + 95.23 = 64.43 dBµ/m

Table 8.4-6: *Spurious emissions of cabinet radiation measurements results for 12.5 kHz channel*

Information	Frequency, MHz	Emission level, dBm	Limit, dBm	Margin, dB
FFSK, low channel	1358.81	-30.93	-20.00	10.93
	2264.69	-41.05	-20.00	21.05
	2717.63	-36.72	-20.00	16.72
	3170.56	-39.46	-20.00	19.46
	3623.50	-31.91	-20.00	11.91
	4076.44	-36.31	-20.00	16.31
FFSK, high channel	1373.81	-30.19	-20.00	10.19
	2289.69	-37.07	-20.00	17.07
	2747.63	-30.80	-20.00	10.80
	3663.50	-34.03	-20.00	14.03
	4579.38	-43.07	-20.00	23.07

Note: FFSK was selected as a representative modulation for 12.5 kHz channel radiated testing.

Table 8.4-7: *Spurious OOB band edge emissions at the antenna port measurements results*

Information	Frequency, MHz	Emission level, dBm/100 kHz	Limit, dBm/100 kHz	Margin, dB
SOQPSK, low channel	452.8750	-35.65	-25.00	10.65
	452.9750	-35.83	-25.00	10.83
SOQPSK, high channel	457.9000	-35.50	-25.00	10.50
	458.0000	-35.55	-25.00	10.55
FSK, low channel	452.8750	-35.29	-20.00	15.29
	452.9750	-35.88	-20.00	15.88
FSK, high channel	457.9000	-34.91	-20.00	14.91
	458.0000	-34.98	-20.00	14.98
FFSK, low channel	452.8875	-35.95	-20.00	15.95
	452.9875	-35.95	-20.00	15.95
FFSK, high channel	457.8875	-35.98	-20.00	15.98
	457.9875	-34.98	-20.00	14.98

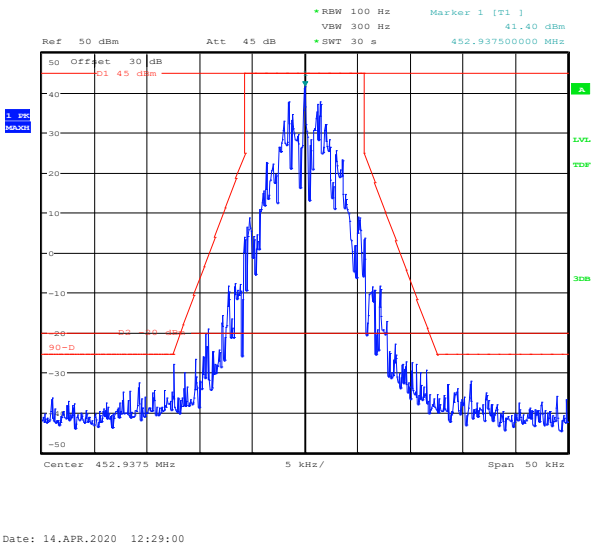

Figure 8.4-1: *Emission mask D for FFSK low channel*

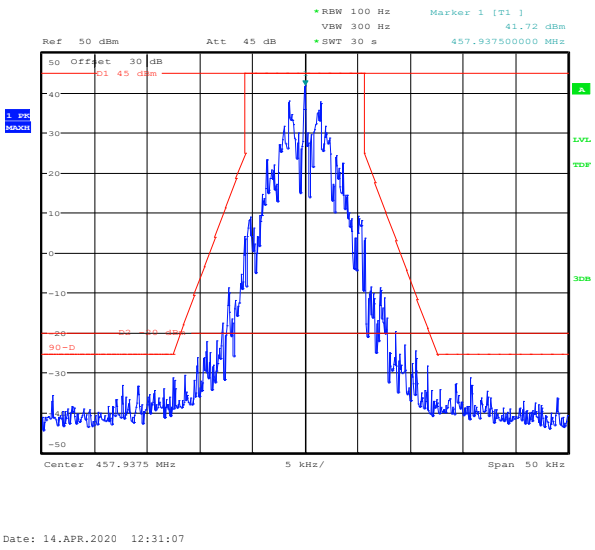

Figure 8.4-2: *Emission mask D for FFSK high channel*

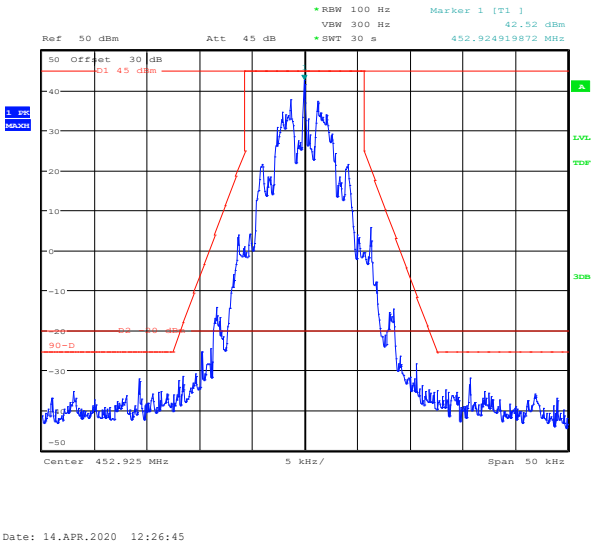

Figure 8.4-3: *Emission mask D for FSK low channel*

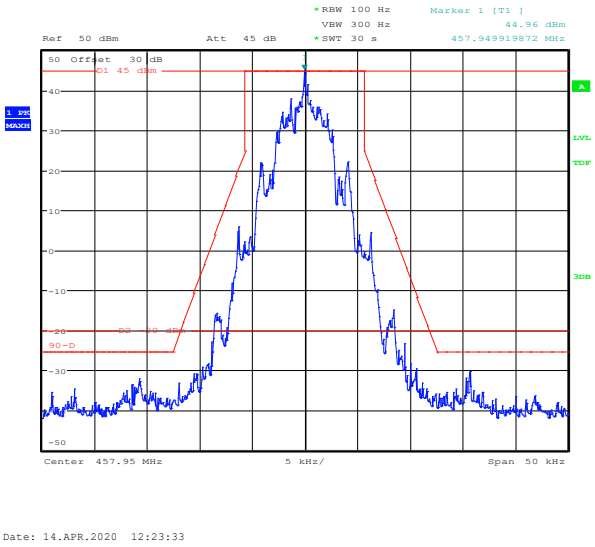

Figure 8.4-4: *Emission mask D for FSK high channel*

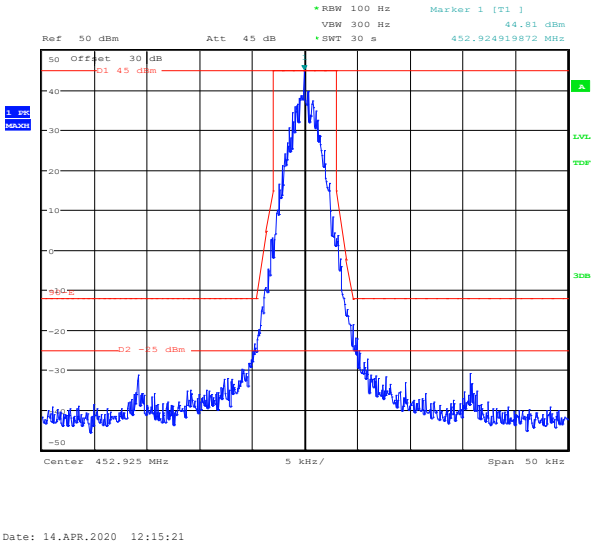

Figure 8.4-5: *Emission mask E for SOQPSK low channel*

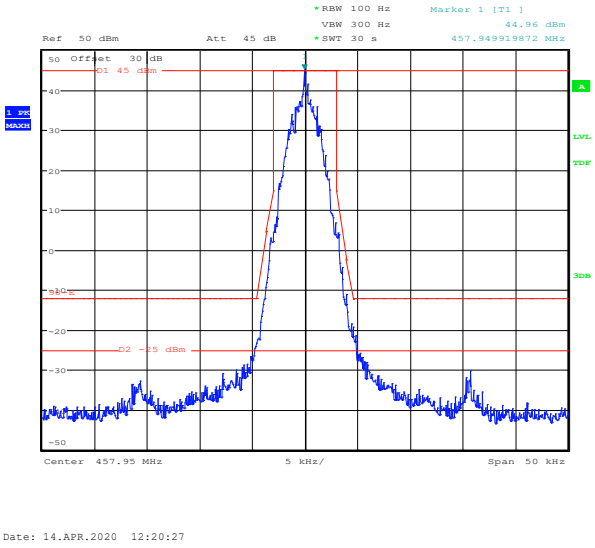

Figure 8.4-6: *Emission mask E for SOQPSK high channel*

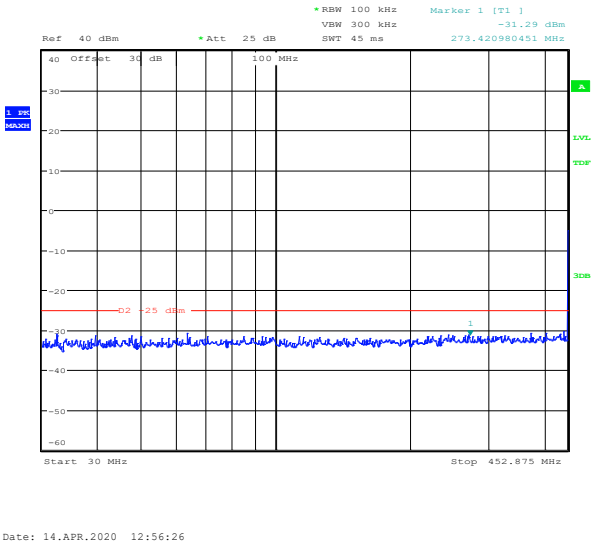

Figure 8.4-7: *Conducted spurious emissions within 30 MHz to OOB for SOQPSK modulation low channel*

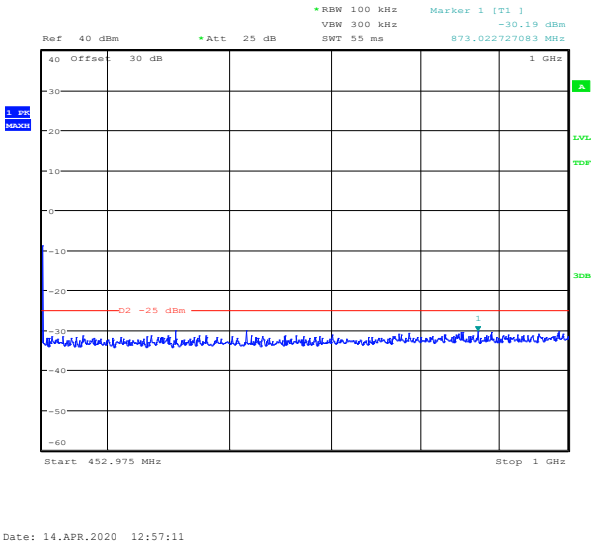

Figure 8.4-8: *Conducted spurious emissions within OOB to 1000 MHz for SOQPSK modulation low channel*

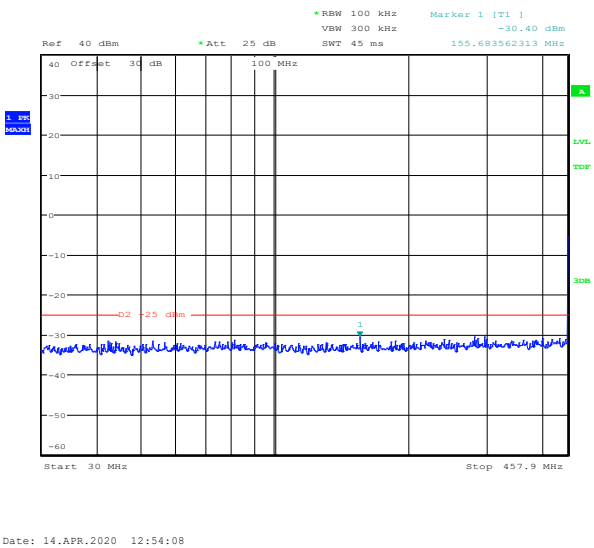

Figure 8.4-9: *Conducted spurious emissions within 30 MHz to OOB for SOQPSK modulation high channel*

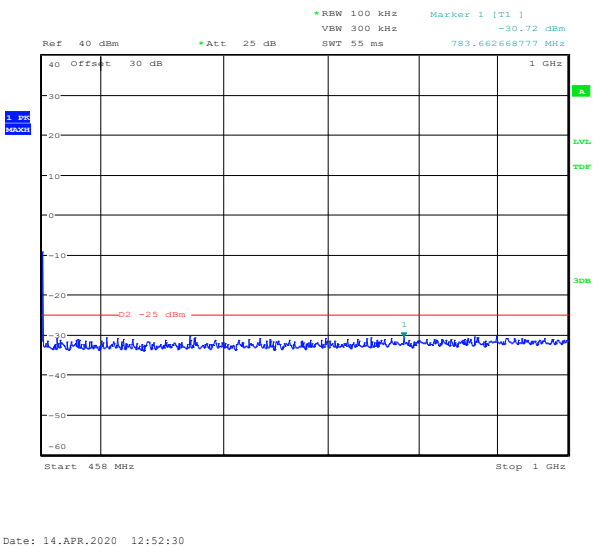

Figure 8.4-10: *Conducted spurious emissions within OOB to 1000 MHz for SOQPSK modulation high channel*

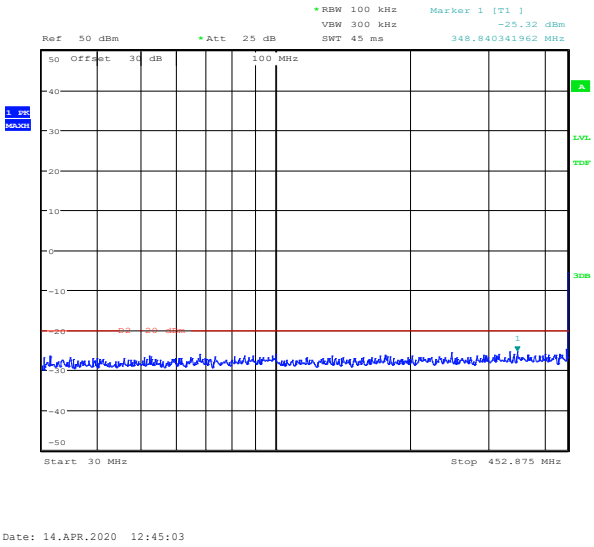

Figure 8.4-11: *Conducted spurious emissions within 30 MHz to OOB for FSK modulation, low channel*

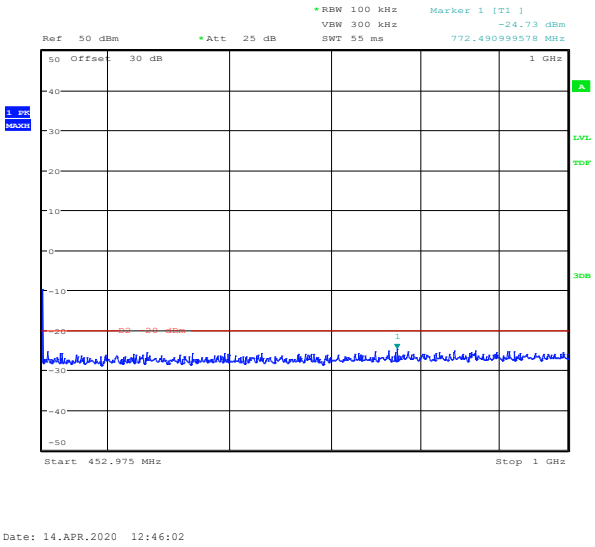

Figure 8.4-12: *Conducted spurious emissions within OOB to 1000 MHz FSK modulation, low channel*

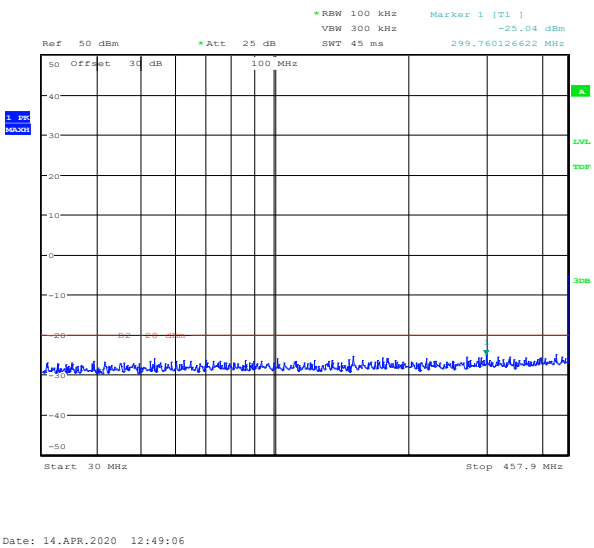

Figure 8.4-13: *Conducted spurious emissions within 30 MHz to OOB for FSK modulation, high channel*

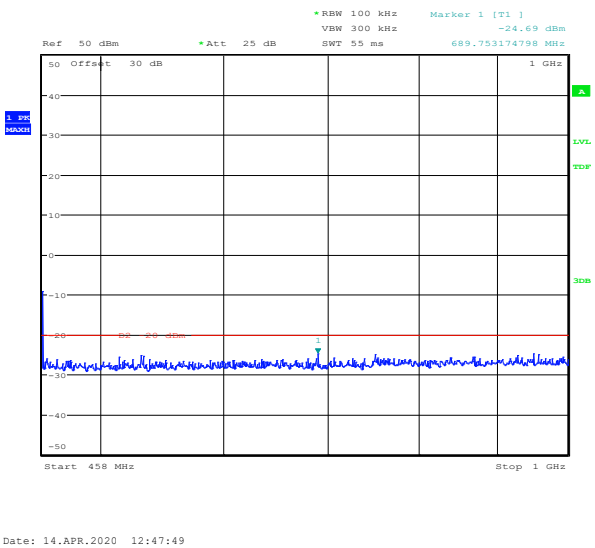

Figure 8.4-14: *Conducted spurious emissions within OOB to 1000 MHz FSK modulation, high channel*

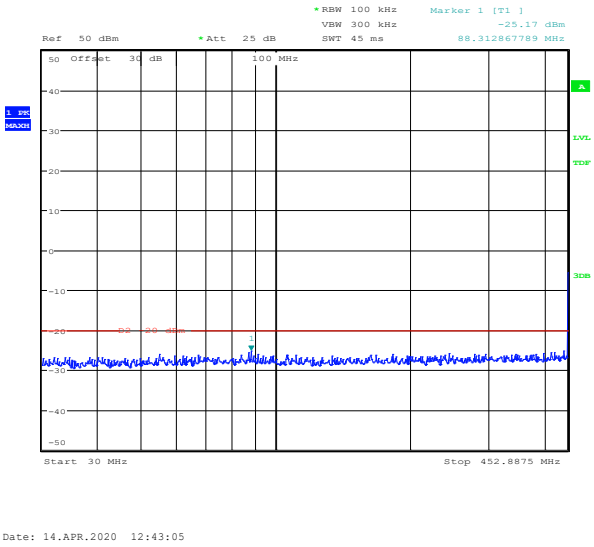

Figure 8.4-15: *Conducted spurious emissions within 30 MHz to OOB for FFSK modulation, low channel*

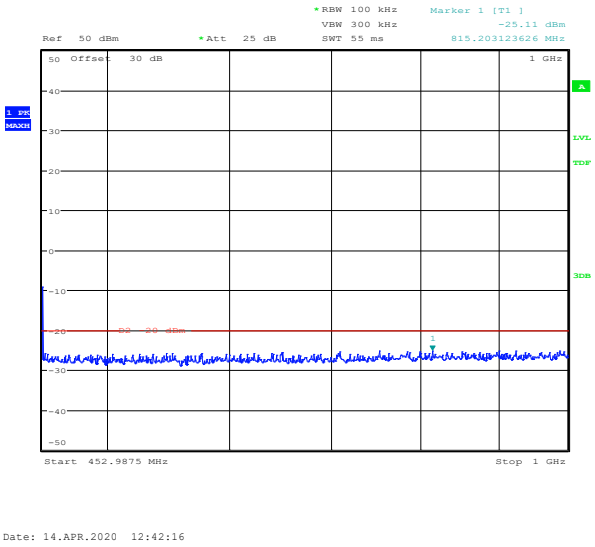

Figure 8.4-16: *Conducted spurious emissions within OOB to 1000 MHz FFSK modulation, low channel*

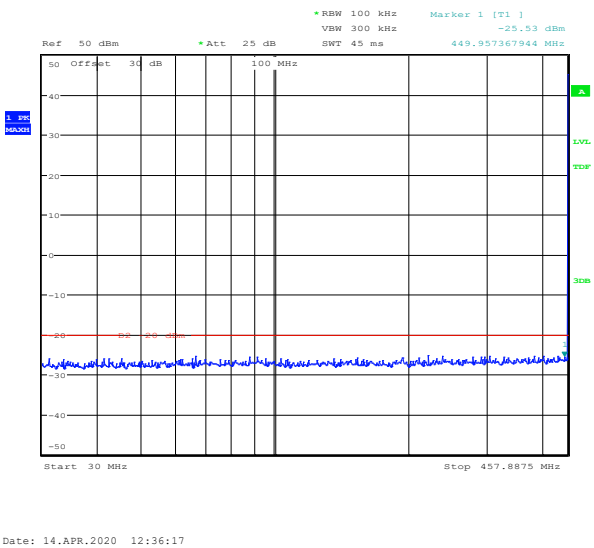

Figure 8.4-17: *Conducted spurious emissions within 30 MHz to OOB for FFSK modulation, high channel*

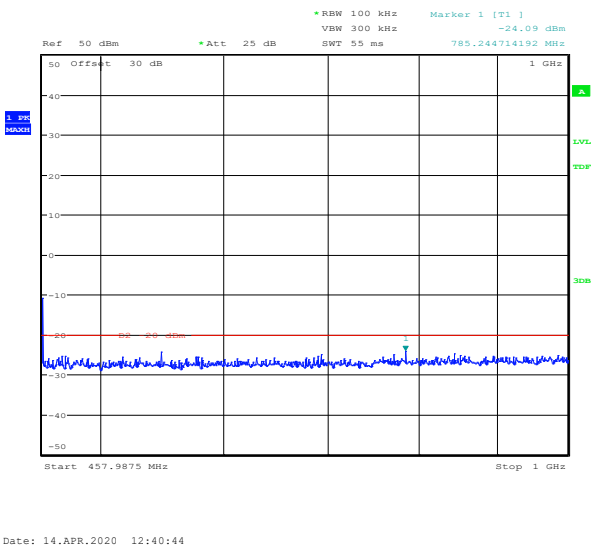

Figure 8.4-18: *Conducted spurious emissions within OOB to 1000 MHz FFSK modulation, high channel*

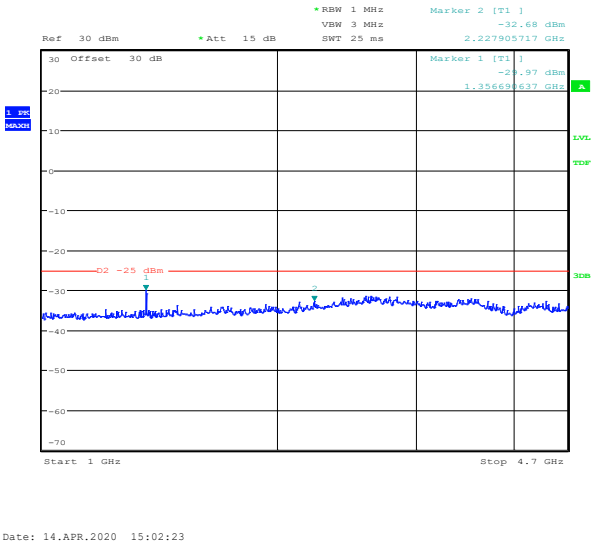

Figure 8.4-19: *Conducted spurious emissions above 1 GHz for SOQPSK modulation, low channel*

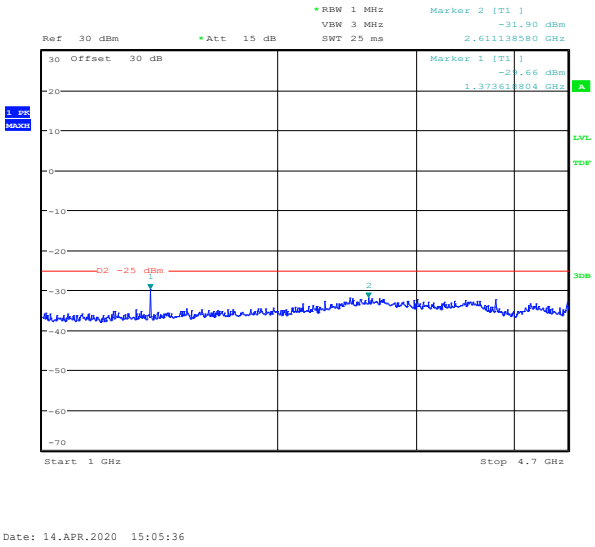

Figure 8.4-20: *Conducted spurious emissions above 1 GHz for SOQPSK modulation, high channel*

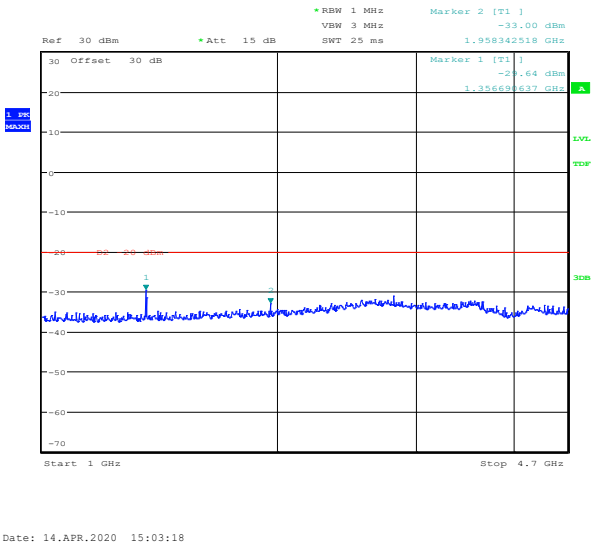

Figure 8.4-21: *Conducted spurious emissions above 1 GHz for FSK modulation, low channel*

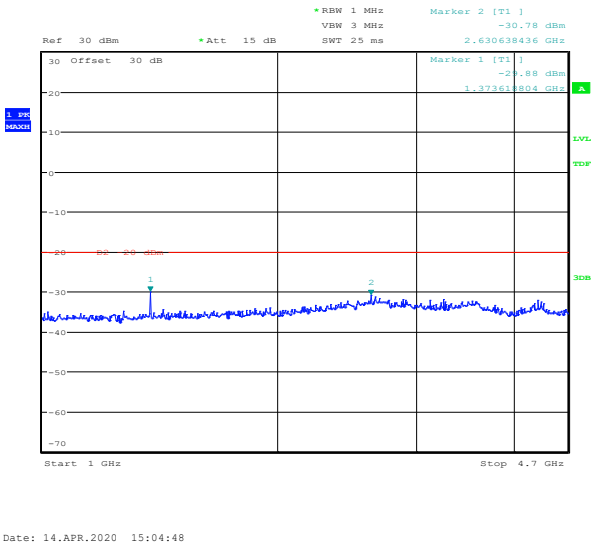

Figure 8.4-22: *Conducted spurious emissions above 1 GHz for FSK modulation, high channel*

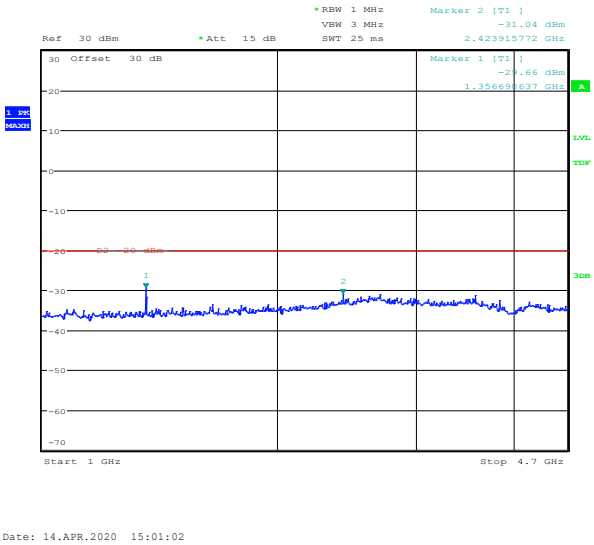

Figure 8.4-23: *Conducted spurious emissions above 1 GHz for FFSK modulation, low channel*

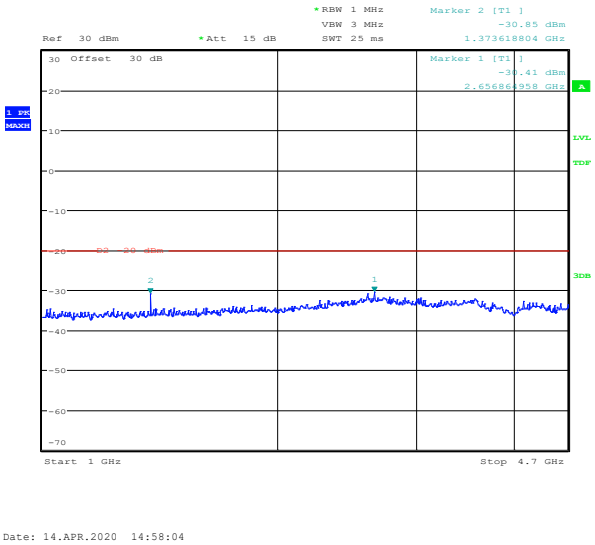

Figure 8.4-24: *Conducted spurious emissions above 1 GHz for FFSK modulation, high channel*

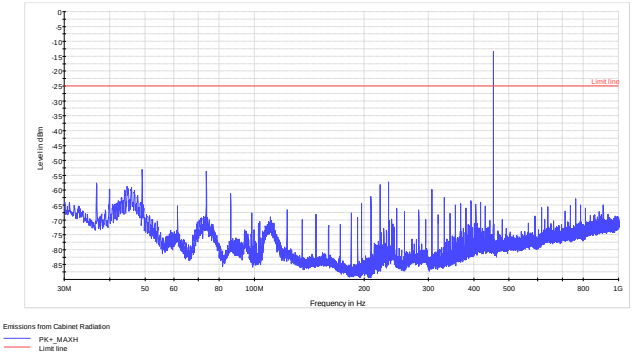

Figure 8.4-25: *Radiated spurious emissions below 1 GHz for 6.25 kHz channel BW sample plot*

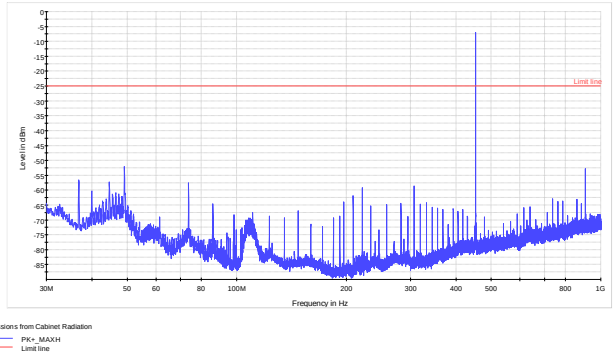

Figure 8.4-26: *Radiated spurious emissions below 1 GHz for 12.5 kHz channel BW sample plot*

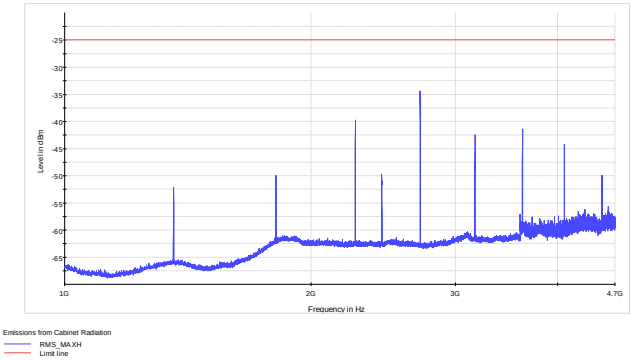

Figure 8.4-27: *Radiated spurious emissions above 1 GHz for 6.25 kHz channel BW sample plot*

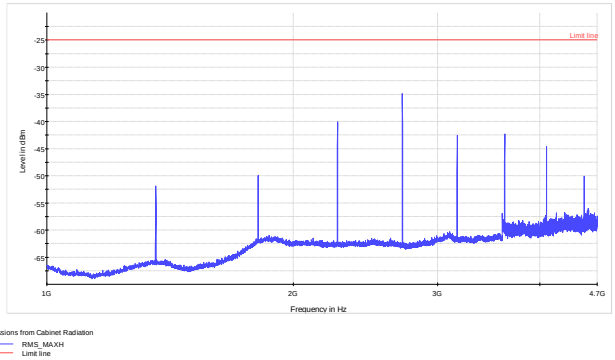

Figure 8.4-28: *Radiated spurious emissions above 1 GHz for 12.5 kHz channel BW sample plot*

8.5 FCC 90.214 and RSS-119, Clause 5.9 Transient frequency behavior

8.5.1 References, definitions and limits

FCC

Transmitters designed to operate in the 421–512 MHz frequency band must maintain transient frequencies within the maximum frequency difference limits during the time intervals indicated:

Table 8.5-1: *Transient frequency behavior*

Time intervals[1,2]	Maximum frequency difference[3]	Transient duration limit
Transient Frequency Behavior for Equipment Designed to Operate on 12.5 kHz Channels		
t_1[4]	±12.5 kHz	10.0 ms
t_2	±6.25 kHz	25.0 ms
t_3[4]	±12.5 kHz	10.0 ms
Transient Frequency Behavior for Equipment Designed to Operate on 6.25 kHz Channels		
t_1[4]	±6.25 kHz	10.0 ms
t_2	±3.125 kHz	25.0 ms
t_3[4]	±6.25 kHz	10.0 ms

Notes: [1]t_{on} is the instant when a 1 kHz test signal is completely suppressed, including any capture time due to phasing.
t_1 is the time period immediately following t_{on}.
t_2 is the time period immediately following t_1.
t_3 is the time period from the instant when the transmitter is turned off until t_{off}.
t_{off} is the instant when the 1 kHz test signal starts to rise.
[2]During the time from the end of t_2 to the beginning of t_3, the frequency difference must not exceed the limits specified in §90.213.
[3]Difference between the actual transmitter frequency and the assigned transmitter frequency.
[4]If the transmitter carrier output power rating is 6 watts or less, the frequency difference during this time period may exceed the maximum frequency difference for this time period.

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When a transmitter is turned on, the radio frequency may take some time to stabilize. During this initial period, the frequency error or frequency difference (i.e., between the instantaneous and the steady state frequencies) shall not exceed the limits specified in Table below.
Any suitable method of measurement can be used provided that it is fully described in the test report. A suitable and recommended method is given in TIA Standard 603.

Table 8.5-2: *Transient frequency behavior*

Channel Bandwidth (kHz)	Time intervals[1,2]	Maximum frequency difference	Transient duration limit
12.5	t_1	±12.5 kHz	10.0 ms
	t_2	±6.25 kHz	25.0 ms
	t_3	±12.5 kHz	10.0 ms
6.25	t_1	±6.25 kHz	10.0 ms
	t_2	±3.125 kHz	25.0 ms
	t_3	±6.25 kHz	10.0 ms

Notes: [1]t_{on}: the instant when a 1 kHz test signal is completely suppressed, including any capture time due to phasing.
t_1: the time period immediately following t_{on}.
t_2: the time period immediately following t_1.
t_3: the time period from the instant when the transmitter is turned off until t_{off}.
t_{off}: the instant when the 1 kHz test signal starts to rise.
[2]If the transmitter carrier output power rating is 6 W or less, the frequency difference during the time periods t_1 and t_3 may exceed the maximum frequency difference for these time periods. The corresponding plot of frequency versus time during t_1 and t_3 shall be recorded in the test report.

8.5.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	April 4, 2020

8.5.3 Observations, settings and special notes

None

8.5.4 Test data

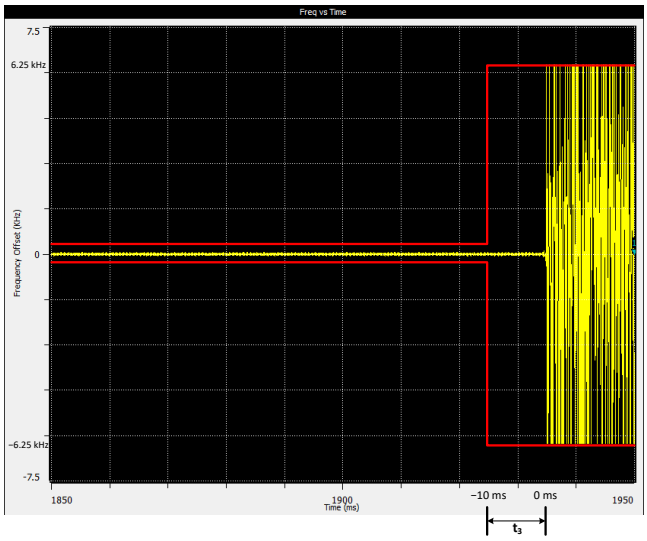

Figure 8.5-1: *Transient Frequency behavior for 6.25 kHz, Tx switch ON*

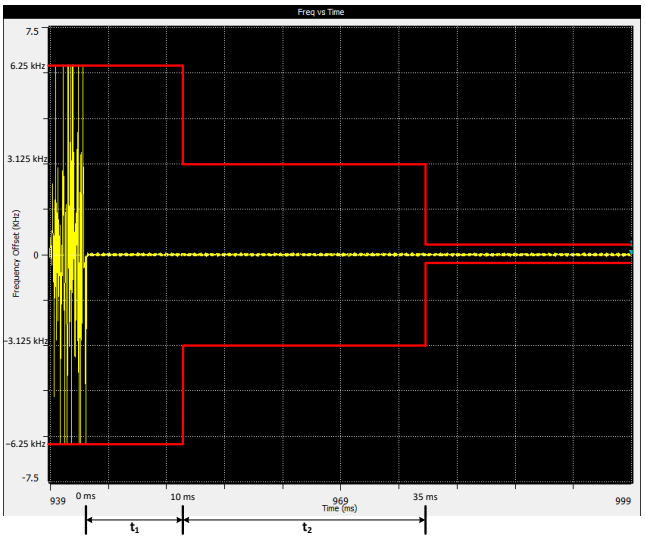

Figure 8.5-2: *Transient Frequency behavior for 6.25 kHz, Tx switch OFF*

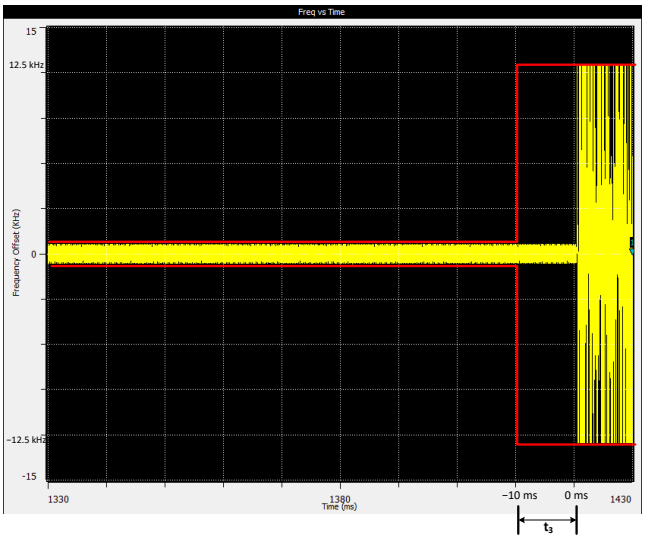

Figure 8.5-3: *Transient Frequency behavior for 12.5 kHz, Tx switch ON*

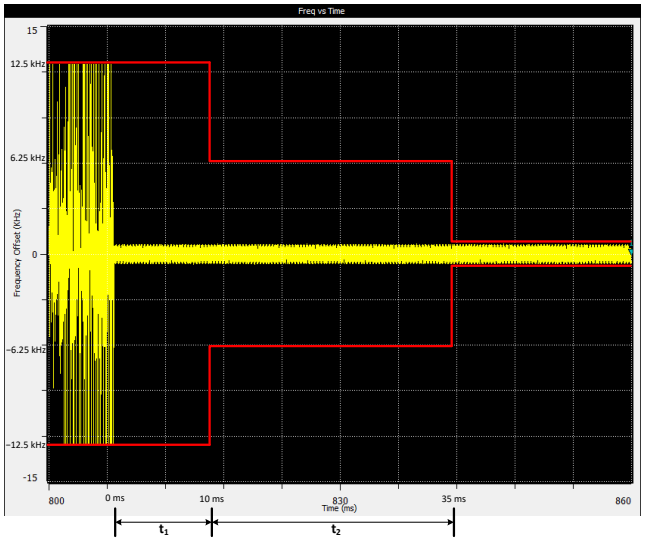

Figure 8.5-4: *Transient Frequency behavior for 12.5 kHz, Tx switch OFF*

8.6 FCC 90.213(a) and RSS-119, Clause 5.3 Transmitter frequency stability

8.6.1 References, definitions and limits

FCC

Unless noted elsewhere, transmitters used in the services governed by this part must have a minimum frequency stability as specified in the following table.

Table 8.6-1: *Minimum frequency stability*

Frequency range (MHz)	Fixed and base stations	Mobile stations over 2 watts output power	Mobile stations 2 watts or less output power
421–512	±2.5 ppm[1]	±5 ppm[2]	±5 ppm[2]

Notes: [1]In the 421–512 MHz band, fixed and base stations with a 12.5 kHz channel bandwidth must have a frequency stability of 1.5 ppm. Fixed and base stations with a 6.25 kHz channel bandwidth must have a frequency stability of 0.5 ppm.
[2]In the 421–512 MHz band, mobile stations designed to operate with a 12.5 kHz channel bandwidth must have a frequency stability of 2.5 ppm. Mobile stations designed to operate with a 6.25 kHz channel bandwidth must have a frequency stability of 1.0 ppm.

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The carrier frequency shall not depart from the reference frequency in excess of the values given in Table below. For transmitters that have an output power of less than 120 mW, the frequency stability shall comply with the limits listed in Table below or, alternatively, with the conditions in Section 5.10. For fixed and base station equipment, in lieu of meeting the frequency stability limit specified in Table below, the test report can show that the frequency stability is met by demonstrating that the unwanted emission limits, related to the equipment's nominal carrier frequency measured under normal operation, are met when the equipment is tested at the temperature and supply voltage variations specified for the frequency stability measurement in RSS-Gen.

Table 8.6-2: *Transmitter frequency stability*

Frequency range (MHz)	Channel bandwidth (kHz)	Frequency stability for Base/Fixed stations (±ppm)	Frequency stability for mobile stations with output power >2 W (±ppm)	Frequency stability for mobile stations with output power ≤2 W (±ppm)
450–470	25	2.5	5	5
	12.5	1.5	2.5	2.5
	6.25	0.5	1	1

8.6.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	April 4, 2020

8.6.3 Observations, settings and special notes

Test was performed while EUT was transmitting with absence of modulation (CW). The minimum limit of 6.25 kHz was selected as a representative one.
Spectrum analyser settings:

Resolution bandwidth	30 Hz
Video bandwidth	100 Hz
Frequency span	500 Hz
Detector mode	Peak
Trace mode	Free run

8.6.4 Test data

Table 8.6-3: *Transmitter frequency stability results at extreme temperature*

Test conditions	Frequency, Hz	Drift, Hz	Drift, ±ppm	Limit ±ppm	Margin, ppm
+50 °C, 13.6 V_{DC}	469787458.316	19.213	0.0409	1.0000	0.8265
+40 °C, 13.6 V_{DC}	469787431.848	-7.255	0.0154	1.0000	0.8845
+30 °C, 13.6 V_{DC}	469787370.877	-68.226	0.1452	1.0000	0.8143
+20 °C, 13.6 V_{DC}	469787439.103	Reference	Reference	Reference	Reference
+10 °C, 13.6 V_{DC}	469787464.380	25.277	0.0538	1.0000	0.9718
0 °C, 13.6 V_{DC}	469787479.724	40.621	0.0865	1.0000	0.9175
−10 °C, 13.6 V_{DC}	469787501.914	62.811	0.1337	1.0000	0.9119
−20 °C, 13.6 V_{DC}	469787480.102	40.999	0.0873	1.0000	0.9948
−30 °C, 13.6 V_{DC}	469787519.257	80.154	0.1706	1.0000	0.8715

Table 8.6-4: *Transmitter frequency stability results at extreme voltages*

Test conditions	Frequency, Hz	Drift, Hz	Drift, ±ppm	Limit ±ppm	Margin, ±ppm
+20 °C, 15.6 V_{DC}	469787446.314	7.211	0.0153	1.0000	0.9847
+20 °C, 13.6 V_{DC}	469787439.103	*Reference*	*Reference*	*Reference*	*Reference*
+20 °C, 11.6 V_{DC}	469787350.096	-89.007	0.1895	1.0000	0.8105

Section 9 EUT photos

9.1 External photos

Figure 9.1-1: *Front view photo*

Figure 9.1-2: *Rear view photo*

Figure 9.1-3: *Side views photos*

Figure 9.1-4: *Bottom view photo*

End of the test report