

Test Report

Product	Telematics unit for mounting on forklifts
Name and address of the applicant	Toyota Material Handling, Inc. 5559 Inwood Drive, Columbus IN 47201, USA
Name and address of the manufacturer	Toyota Material Handling, Inc. 5559 Inwood Drive, Columbus IN 47201, USA
Model	DHUnx
Rating	External DC supply (12-48 V _{DC})
Trademark	TOYOTA
Serial number	2117000000251
Additional information	WiFi, BT Classic, BLE, WCDMA, LTE
Tested according to	Parts of FCC Part 15.247 Frequency Hopping Transmitters Parts of ISED Canada RSS-247, Issue 2 Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
Order number	433049
Tested in period	2021-09-15 to 2021-10-26 and 2022-03-29
Issue date	2022-03-29
Name and address of the testing laboratory	 Instituttveien 6 Kjeller, Norway www.nemko.com CAB Number: FCC: NO0001 ISED: NO0470   An accredited technical test executed under the Norwegian accreditation scheme
 Prepared by [Frode Sveinsen]  Approved by [G.Suhanthakumar]	
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Revision history

Revision	Date	Comment	Sign
00	2022-02-24	First edition	FS
01	2022-03-29	Output Power measured at antenna connector	FS



THIS TEST REPORT APPLIES ONLY TO THE ITEM(S) AND CONFIGURATIONS TESTED.

Deviations from, additions to, or exclusions from the test specifications are described in "Summary of Test Data".

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1 INFORMATION

1.1 Test Item

Name	Toyota
Model/version	DHUnx
FCC ID	2A226-TELETMH01
ISED ID	27732-TELETMH01
Serial number	2117000000251
Hardware version	Rev. B
Software version	dv_b1_2021-05-05
Frequency Range	2402–2480 MHz, 1MHz Channel Separation
Number of Channels	79
Operating Modes	Bluetooth Classic
Type of Modulation	GFSK (1M Basic Rate) $\pi/4$ -DQPSK (2M EDR) 8-DPSK (3M EDR)
Conducted Output Power	1M BR: 4.72 mW 2M EDR: 3.82 mW 3M EDR: 4.13 mW
Antenna Connector	Quad MiniFakra
Antenna Type	Molex Antenna, P/N: 2144500750 (P/N is for version with 750mm cable length, longer cables may also be used) Antenna element LTE1: Rx/Tx Antenna element LTE2: Rx Only Antenna element WiFi/BT: Rx/Tx 2.4GHz WiFi/BT/BLE and 5GHz WiFi Antenna element GNSS: Rx Only GNSS/GPS
Antenna Diversity Supported	Not for Bluetooth
Smart Antennas Supported	No
Power Source	External DC Supply (12-48V _{DC} , supplied through MX23 connector)
Interfaces	MX23 Connector HSD Connector (100TX Ethernet)

Description of Test Item

The EUT is a telematics unit with radio modules for BT/BLE/WiFi and Mobile (WCDMA and LTE). Both radio modules are certified radio modules. The EUT also contains a GPS receiver.

This test report covers only additional radiated tests for the new antennas.

1.2 Normal test conditions

Temperature:	20 - 24 °C
Relative humidity:	20 - 50 %
Normal test voltage:	24V _{DC} (2x 12V lead acid batteries, Fiamm FG20451)

The EUT was powered from two fully charged batteries during all tests.

The values are the limit registered during the test period.

1.3 Test Engineer

Frode Sveinsen

1.4 Antenna Requirement

Does the EUT have detachable antenna(s)?	☒ YES	☐ NO
If detachable, is the antenna connector(s) non-standard?	☒ YES	☐ NO
Antenna Connector: Quad MiniFakra		

Requirement: FCC 15.203, 15.204

1.5 EUT Operating Modes

Description of operating modes	Continuous TX, 1Mb Basic Rate, 2Mb EDR and 3Mb EDR
Additional information	EUT was controlled from a computer and programmed from Qualcomm Test Software. The following settings were used for all tests: Power Setting: 9 (same for all channels and modulations) Bit Pattern: PSRB Frame Type: DH5, 2-DH5, 3-DH5

1.6 Radio Modules

Data for radio modules				
Manufacturer	Model No	Identification	Original Test Report	Technology
Quectel	FC20	FCC ID: XMR201703FC20 IC: 10224A-201703FC20 P/N: FC20-Q73	Siemic 16050028-FCC-R3 TA R2105A0465-R2	BT Classic
			Siemic 16050028-FCC-R4 TA R2105A0465-R1	BT Low Energy
			Siemic 16050028-FCC-R1 TA R2105A0465-R1	WLAN
			Siemic 16050028-FCC-R2 TA R2105A0465-R3	UNII 2TX
			TA R2105A0465-R4V1	DFS
Quectel	EG25	FCC ID: XMR201903EG25G IC: 10224A-201903EG25G P/N: EG25GGB-256-SGNS	SGS HR/2019/1001601 SGS HR/2019/1001603	WCDMA/LTE

1.7 Comments

The EUT uses the Bluetooth Classic protocol with Frequency Hopping.

All ports were populated during spurious emission measurements.

This test report covers only selected tests for new antennas, all other tests are covered by the original Test Report.

2 TEST REPORT SUMMARY

2.1 General

All measurements are traceable to national standards.

The tests were conducted for demonstrating compliance with FCC CFR 47 Part 15, paragraph 15.247 and Industry Canada RSS-247 Issue 2 and RSS-GEN Issue 5.

Tests were performed in accordance with ANSI C63.4-2014 and and ANSI C63.10-2013.

Radiated tests were made in a semi-anechoic chamber at measuring distance of 1m and 3m.

A description of the test facility is on file with FCC and ISED.

☒ New Submission

☒ Production Unit

☐ Class II Permissive Change

☐ Pre-production Unit

DSS Equipment Code

☐ Family Listing

2.2 Test Summary

Name of test	FCC Part 15 reference	RSS-247 Issue 2, RSS-GEN Issue 5 reference	ANSI C63.10-2013 Reference	Result
Supply Voltage Variations	15.31(e)	6.11 (RSS-GEN)	5.13	Complies
Antenna Requirement	15.203	6.8 (RSS-GEN)	5.8	Complies
Power Line Conducted Emission	15.107(a) 15.207(a)	7.2 / 8.8 (RSS-GEN)	6.2	N/A
Channel Separation and 20 dB BW	15.247(a)(1)	5.1 (4) (RSS-247)	7.8.2 (FHSS)	N/T
Number of Hopping Frequencies	15.31(m)	5.1 (6) (RSS-247)	7.8.3 (FHSS)	N/T
Pseudorandom Hopping Algorithm	15.247(a)(1)	5.1 (3) (RSS-247)	N/A (FHSS)	N/T
Time of Occupancy (dwell time)	15.247(a)(1)(iii)	5.1 (5) (RSS-247)	7.8.4 (FHSS)	N/T
Occupied Bandwidth	15.247(a)(1)	5.1 (7) (RSS-247)	6.9.2 FHSS)	N/T
Occupied Bandwidth (99% BW)	N/A	6.7 (RSS-GEN)	6.9.3	N/T
Peak Power Output	15.247(b)	5.4 (RSS-247)	11.9.1.1	Complies
Spurious Emissions (Antenna Conducted)	15.247(c)	5.5 (RSS-247)	6.7 7.8.6 (FHSS) 7.8.8 (FHSS)	N/T
Spurious Emissions (Radiated)	15.247(c) 15.109(a) 15.209(a)	5.5 (RSS-247) 7.3 (RSS-GEN) 8.9 (RSS-GEN)	6.3, 6.5, 6.6, 6.10	Complies

3 TEST RESULTS

3.1 Peak Power Output

FCC Part 15.247 (b)

ISED Canada RSS-247 Issue 2, Clause 5.4

Measurement procedure: ANSI C63.10-2013 Clause 11.9.1.2

Test Results: Complies

Measurement Data:

Carrier Frequency (MHz)	Modulation Type	Output Power (dBm)	Output Power (mW)
2402	GFSK	4.36	2.73
	$\pi/4$ -DQPSK	3.34	2.16
	8-DPSK	3.75	2.37
2440	GFSK	5.34	3.42
	$\pi/4$ -DQPSK	4.50	2.82
	8-DPSK	4.86	3.06
2480	GFSK	5.13	3.26
	$\pi/4$ -DQPSK	4.22	2.64
	8-DPSK	4.60	2.88

Output Power reported is Maximum Peak Power measured at antenna connector.

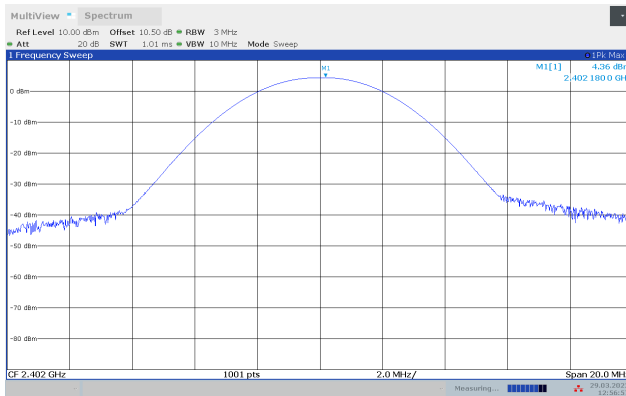
See attached plots.

Requirements:

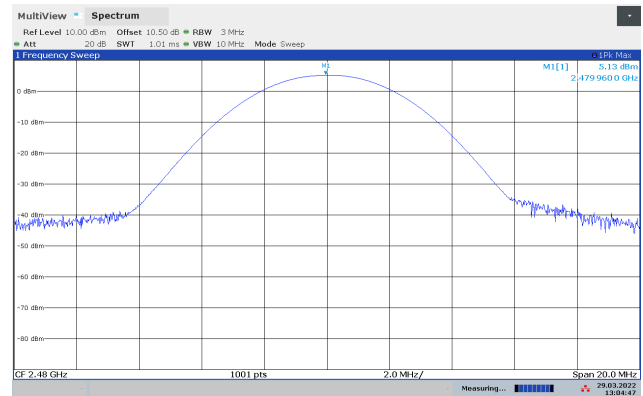
The maximum peak output power shall not exceed the following limits:

For frequency hopping systems employing at least 75 hopping channels: 1 Watt

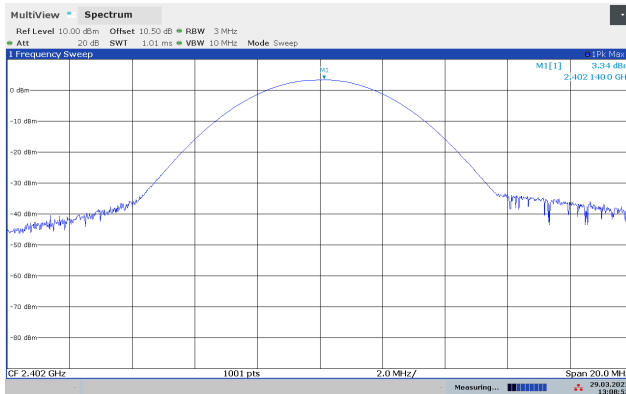
If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power from the intentional radiator shall be reduced below the stated value above by the amount in dB that the directional gain of the antenna exceeds 6 dBi.



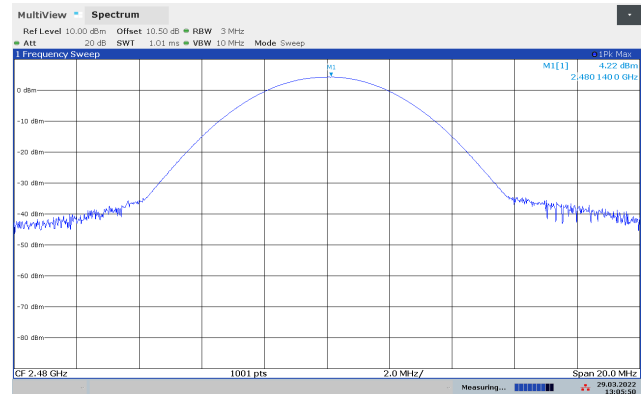
Peak Output Power, 2402 MHz, GFSK



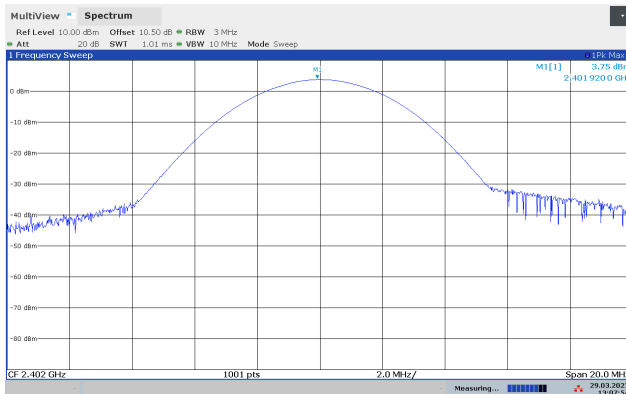
Peak Output Power, 2480 MHz, GFSK



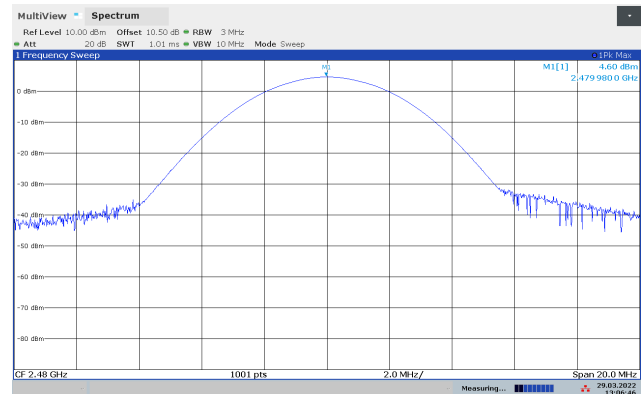
Peak Output Power, 2402 MHz, $\pi/4$ -DQPSK



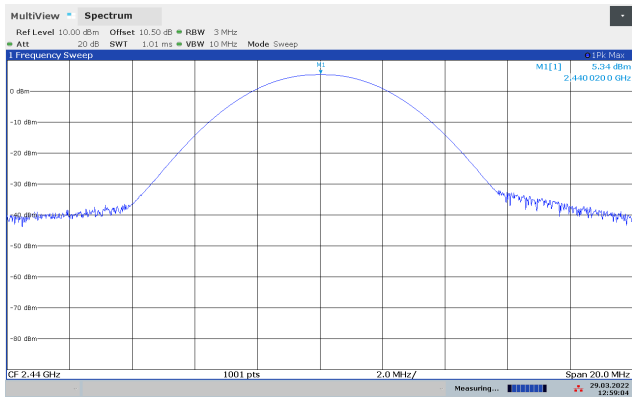
Peak Output Power, 2480 MHz, $\pi/4$ -DQPSK



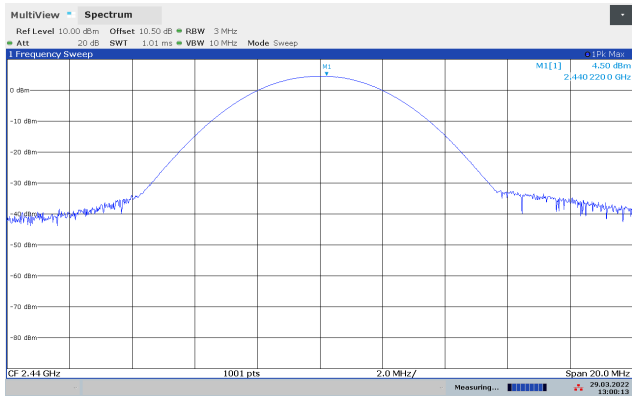
Peak Output Power, 2402 MHz, 8-DPSK



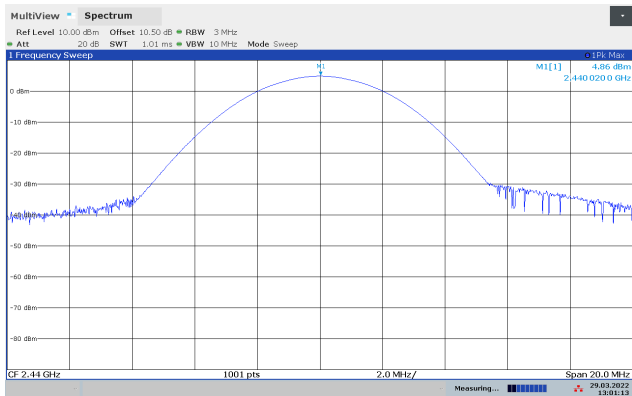
Peak Output Power, 2480 MHz, 8-DPSK



Peak Output Power, 2440 MHz, GFSK



Peak Output Power, 2440 MHz, $\pi/4$ -QPSK



Peak Output Power, 2440 MHz, 8-DPSK

3.2 Restricted Bands of operation

Restricted Bands of operation for FCC and ISSED are defined in FCC Part 15.205 and ISSED RSS-GEN, Issue 5 clause 8.10.

Generally, no fundamentals are allowed in the restricted bands and all emissions must comply with the limits in FCC 15.209 or RSS-GEN, Issue 5, clause 8.9.

FCC (MHz)	ISSED Canada (MHz)	FCC (GHz)	ISSED Canada (GHz)
0.090-0.110		0.96-1.24 1.3-1.427	0.96-1.427
0.495-0.505		1.435-1.6265	
2.1735-2.1905		1.6455-1.6465	
	3.020-3.026	1.660-1.710	
4.125-4.128		1.7188-1.7222	
4.17725-4.17775		2.2-2.3	
4.20725-4.20775		2.31-2.39	
	5.677-5.683	2.4835-2.5	
6.215-6.218		2.69-2.9	2.655-2.9
6.26775-6.26825		3.26-3.267	
6.31175-6.31225		3.332-3.339	
8.291-8.294		3.3458-3.358	
8.362-8.366		3.6-4.4	3.5-4.4
8.37625-8.38675		4.5-5.15	
8.41425-8.41475		5.35-5.46	
12.29-12.293		7.25-7.75	
12.51975-12.52025		8.025-8.5	
12.57675-12.57725		9.0-9.2	
13.36-13.41		9.3-9.5	
16.42-16.423		10.6-12.7	
16.69475-16.69525		13.25-13.4	
16.80425-16.80475		14.47-14.5	
25.5-25.67		15.35-16.2	
37.5-38.25		17.7-21.4	
73-74.6		22.01-23.12	
74.8-75.2		23.6-24.0	
108-121.94 123-138	108-138	31.2-31.8	
149.9-150.05		36.43-36.5	
156.52475-156.52525		Above 38.6	
156.7-156.9			
162.0125-167.17			
167.72-173.2			
240-285			
322-335.4			
399.9-410			
608-614			

Frequencies in **Bold** text are specific for FCC or ISSED, all other frequencies are common.

3.3 Radiated Emissions, Band Edge

FCC Part 15.209 (a)

ISED Canada RSS-GEN Issue 5, Clause 7.3 / 8.9

Measurement procedure: ANSI C63.10-2013 Clause 11.12

Test Results: Complies

Measurement Data:

Carrier Frequency and Modulation	Band Edge Frequency	Measured Field Strength (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
		Peak Detector	Average Detector	Peak Det	Average Det	Peak Det	Average Det
2402MHz GFSK	2390MHz	53.0	33.0	74	54	21.0	21.0
2402MHz π/4-DQPSK	2390MHz	52.8	32.8			21.2	21.2
2402MHz 8-DPSK	2390MHz	53.3	33.3			20.7	20.7
2480MHz GFSK	2483.5MHz	61.5	41.5			12.5	12.5
2480MHz π/4-DQPSK	2483.5MHz	61.0	41.0			13.0	13.0
2480MHz 8-DPSK	2483.5MHz	61.0	41.0			13.0	13.0

Average Detector values are measured with Peak Detector and corrected for Duty Cycle.

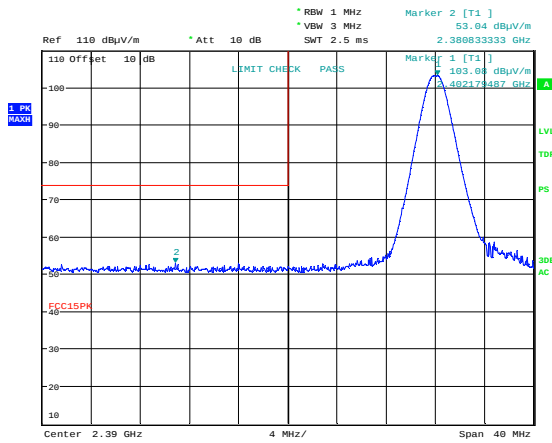
See attached plots.

Duty Cycle Correction Factor Calculation:

Duty Cycle = slot length / (frame length * number of hopping frequencies)

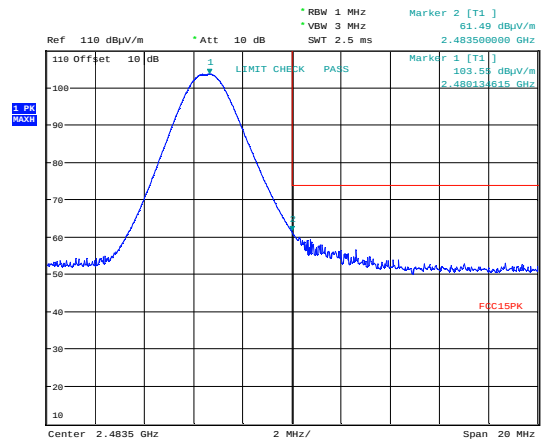
Duty Cycle Correction factor = $-20 \cdot \log(\text{Duty Cycle}) = 27.5 \text{ dB}$

Maximum Duty Cycle Correction Factor according to Para 15.35 (b): 20 dB



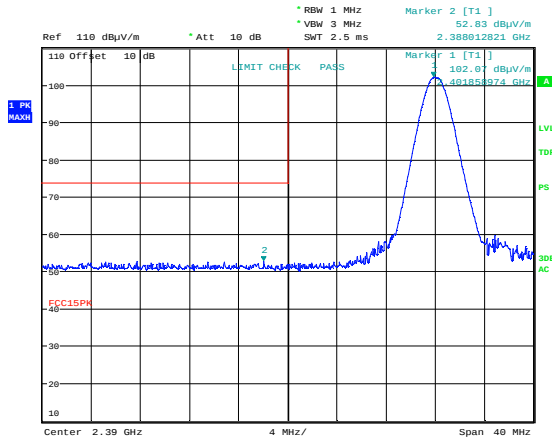
Date: 15. SEP. 2021 16:40:52

Lower Band Edge 2402 MHz, GFSK, Peak



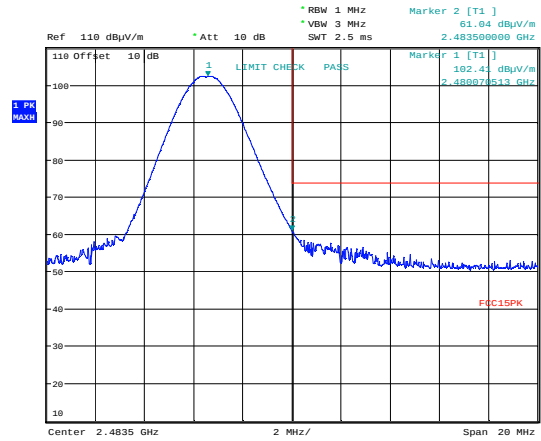
Date: 15. SEP. 2021 16:24:36

Upper Band Edge 2480 MHz, GFSK, Peak



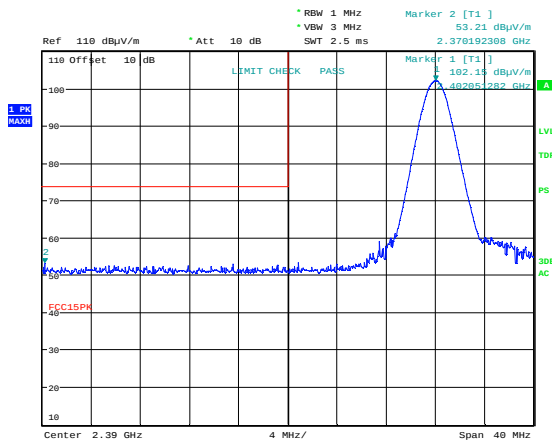
Date: 15. SEP. 2021 16:36:22

Lower Band Edge 2402 MHz, $\pi/4$ -DQPSK, Peak



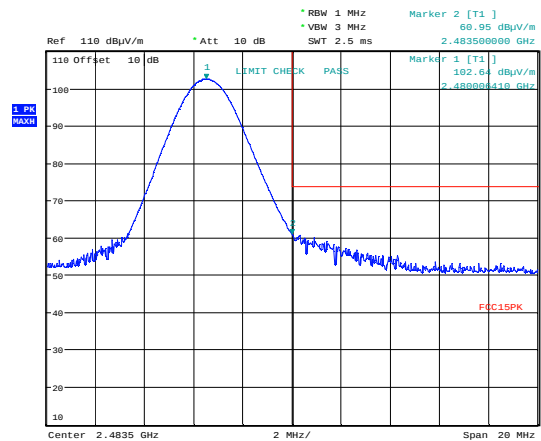
Date: 15. SEP. 2021 16:26:39

Upper Band Edge 2480 MHz, $\pi/4$ -DQPSK, Peak



Date: 15. SEP. 2021 16:34:17

Lower Band Edge 2402 MHz, 8-DPSK, Peak



Date: 15. SEP. 2021 16:28:36

Upper Band Edge 2480 MHz, 8-DPSK, Peak

3.4 Radiated Emission, 30 – 1000 MHz

FCC Part 15.209 (a)

ISED Canada RSS-GEN Issue 5, Clause 7.3/8.9

Measurement procedure: ANSI C63.10-2013 Clause 11.12

Test Results: Complies

Measurement Data:

Detector: Peak Detector for Pre-scan (Measurements with Quasi-Peak Detector)

Measuring distance 3m

Tested with BT Active

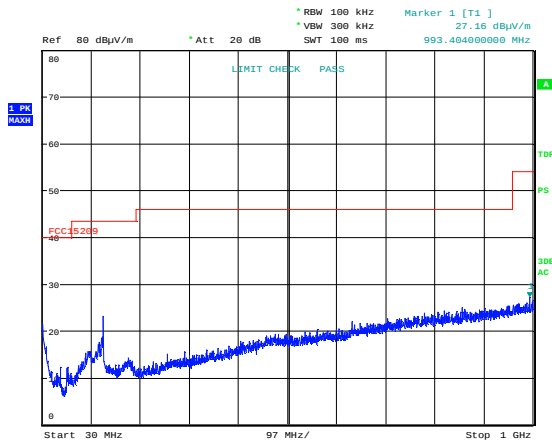
Measured Frequency (MHz)	Carrier Frequency (MHz)	Modulation	Measured Emission (dBμV/m)	Limit (dBμV/m)	Margin (dB)
30 – 88	2440	Any	<25	40.0	>15
88 – 216	2440	Any	<30	43.5	>13.5
216 – 960	2440	Any	<30	46.0	>16
960 – 1000	2440	Any	<30	54.0	>24
150.0	Any	Any	26.0	43.5	17.5

See attached plots.

The spurious at 150 MHz is not from the BT Transmitter.

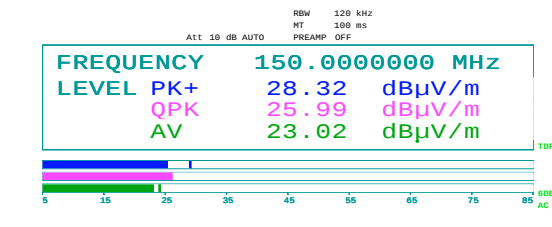
Requirements/Limit

FCC	Part 15.209 @ frequencies defined in §15.205	
ISED	RSS-GEN Issue 5, Clause 8.9 @ frequencies defined in clause 8.10	
Frequency	Radiated emission limit @3 meters	
30 – 88 MHz	100 μV/m	40.0 dBμV/m
88 – 216 MHz	150 μV/m	43.5 dBμV/m
216 – 960 MHz	200 μV/m	46.0 dBμV/m
960 – 1000 MHz	500 μV/m	54.0 dBμV/m
Limits above are with Quasi Peak Detector		



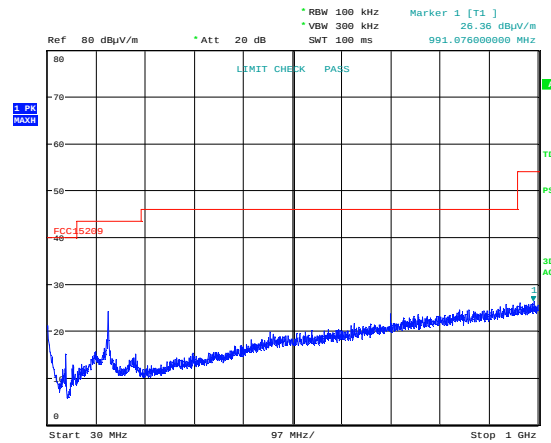
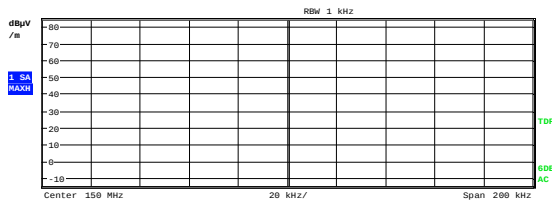
Date: 25.OCT.2021 19:00:29

Radiated Emissions 30 - 1000 MHz, GFSK, VP



Date: 25.OCT.2021 19:14:34

Radiated Emissions 150 MHz, HP



Date: 25.OCT.2021 19:02:40

Radiated Emissions 30 - 1000 MHz, GFSK, HP

3.5 Radiated Emissions, 1-26 GHz

FCC Part 15.209 (a)

ISED Canada RSS-GEN Issue 5, Clause 7.3/8.9

Measurement procedure: ANSI C63.10-2013 Clause 11.12

Test Results: Complies

Measurement Data:

Measuring distance: 3m (1 – 18 GHz)
1m (18 – 26 GHz)

RBW=1 MHz

Carrier Freq.	Measured Freq. (GHz)	Modulation	Measured Emission (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
			Peak	Average	Peak	Average	Peak	Average
Any	1 – 26	Any	< 60	< 44	74	54	> 14	> 10

Average Detector values are calculated from Peak values by Duty Cycle Correction Factor.

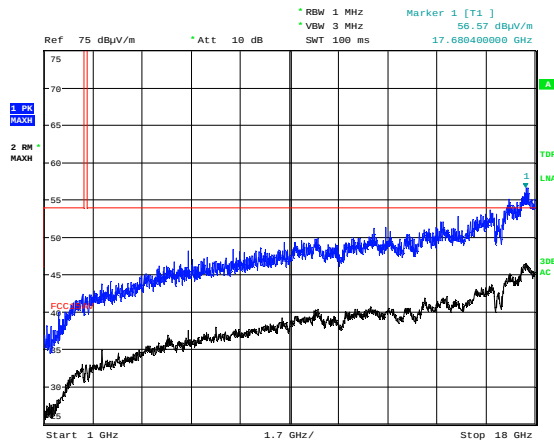
A 2.4GHz Band Reject Filter was used for measurements from 1 GHz to 18 GHz.

Antenna factor, amplifier gain and cable loss are included in spectrum analyzer "Transducer factor".

See plots.

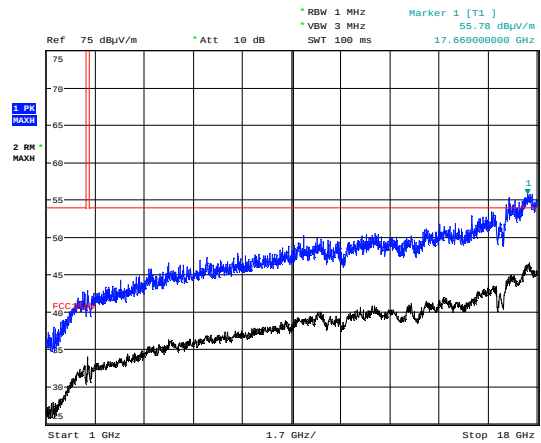
Requirements/Limit

FCC	Part 15.209 @ frequencies defined in §15.205	
ISED	RSS-GEN Issue 5, clause 8.9 @ frequencies defined in clause 8.10	
	Radiated emission limit @3 meters	
Frequency	Average Detector	Peak Detector
1 – 26 GHz	54.0 dBμV/m	74.0 dBμV/m



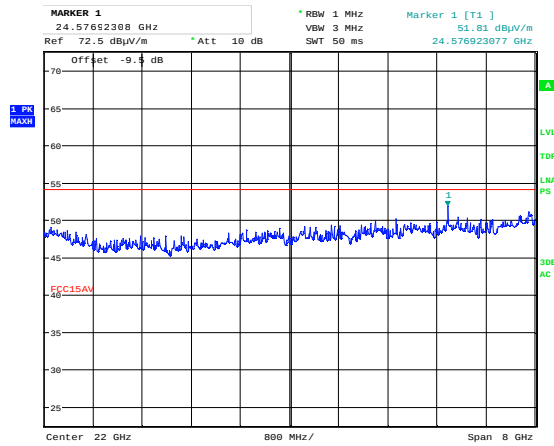
Date: 25.OCT.2021 14:32:39

Radiated Emissions 1 - 18 GHz, 2440 MHz, GFSK, VP



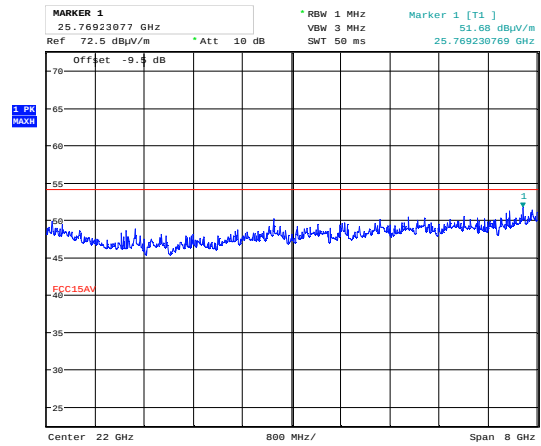
Date: 25.OCT.2021 14:34:52

Radiated Emissions 1 - 18 GHz, 2440 MHz, GFSK, HP



Date: 12.OCT.2021 15:32:17

Radiated Emissions 18 - 26 GHz, 2440 MHz, GFSK, VP, @1m



Date: 12.OCT.2021 15:33:28

Radiated Emissions 18 - 26 GHz, 2440 MHz, GFSK, HP, @1m

4 Measurement Uncertainty

Measurement Uncertainty Values		
Test Item		Uncertainty
Output Power		±0.5 dB
Power Spectral Density		±0.5 dB
Out of Band Emissions, Conducted	< 3.6 GHz	±0.6 dB
	> 3.6 GHz	±0.9 dB
Spurious Emissions, Radiated	< 1 GHz	±2.5 dB
	> 1 GHz	±2.2 dB
Emission Bandwidth		±4 %
Power Line Conducted Emissions		+2.9 / -4.1 dB
Spectrum Mask Measurements	Frequency	±5 %
	Amplitude	±1.0 dB
Frequency Error		±0.6 ppm
Temperature Uncertainty		±1 °C

All uncertainty values are expanded standard uncertainty to give a confidence level of 95%, based on coverage factor k=2

5 LIST OF TEST EQUIPMENT

To facilitate inclusion on each page of the test equipment used for related tests, each item of test equipment and ancillaries are identified (numbered) by the Test Laboratory.

No.	Model number	Description	Manufacturer	Ref. no.	Cal. date	Cal. Due
1	ESU40	Measuring Receiver	Rohde & Schwarz	LR 1639	2021-02 2022-01	2022-02 2023-01
2	6810-17B	Attenuator	Suhner	LR 1669	2021-08	2022-08
3	N0324415	BandStop Filter (2.4GHz)	Microwave Circuits	LR 1760	COU	
4	WLK5-1100-1485-7000-40SS	Low Pass Filter (1.0 GHz)	Wainwright Inst.	LR 1761	COU	
5	317	Preamplifier	Sonoma Inst.	LR 1687	2021-08	2022-08
6	8449A	Pre-amplifier	Hewlett Packard	LR 1322	2021-08	2022-08
7	3115	Horn Antenna	EMCO	LR 1330	N/A	
8	3117-PA	Horn Antenna +PreAmp	EMCO	LR 1717	2021-08	2022-08
9	Model 638	Antenna Horn	Narda	LR 1480	N/A	
10	Model 87 V	Multimeter	Fluke	LR 1599	2021-01	2023-01
11	FSW43	Spectrum Analyzer	Rohde & Schwarz	LR 1690	2022-01	2023-01

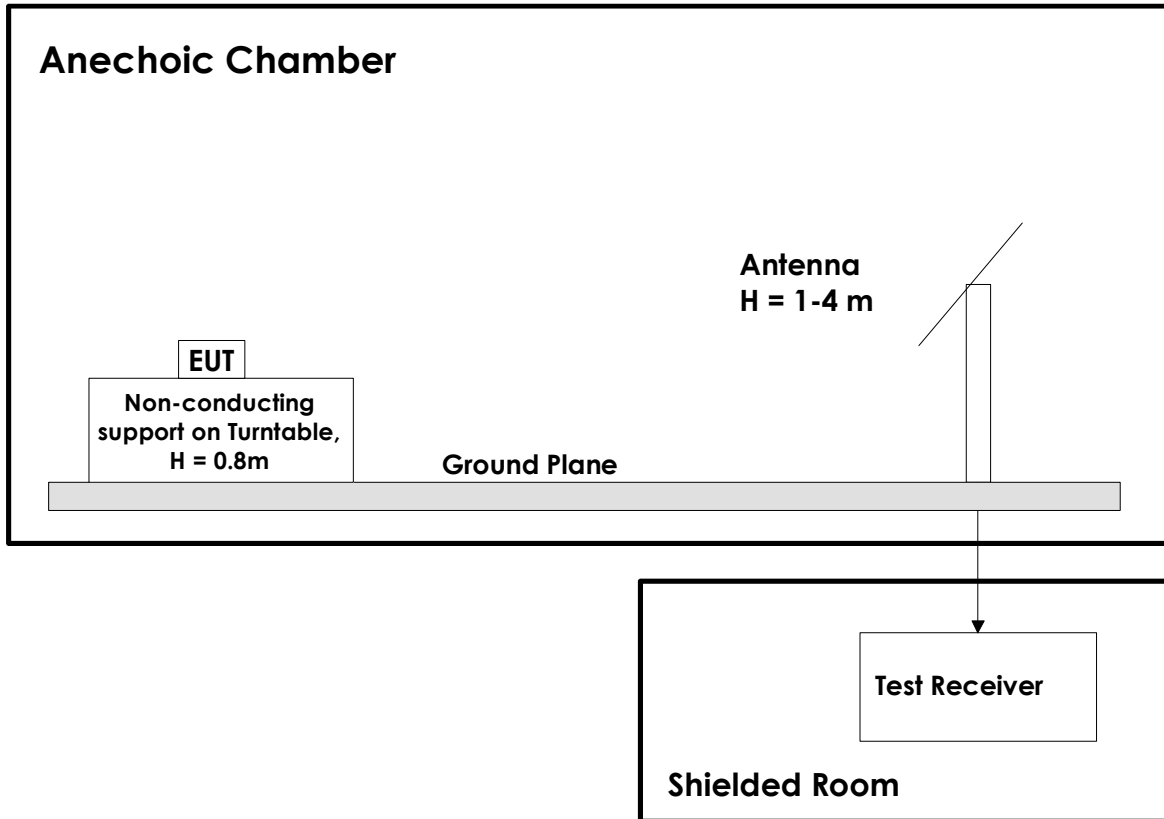
Note: COU – calibrate on use; N/A – Not Applicable

The software listed below has been used for one or more tests.

No.	Manufacturer	Name	Version	Comment
1	Nemko AS	RSPlot	1.0.8.0	Screenshots from R&S Spectrum Analyzers

6 BLOCK DIAGRAM

6.1 Test Site Radiated Emission



This test setup is used for all radiated emissions tests. For frequencies below 30 MHz the measuring distance is 10m, for all other frequencies it is 3m or 1m. Emissions above 1 GHz are measured with a Spectrum Analyzer and Horn Antenna. For measurements above 18 GHz the test receiver is moved inside the anechoic chamber and located next to the antenna to minimize the cable loss. All measurements at 1GHz and above were performed with turntable height 1.5m and with the ground plane covered by absorbers. A pre-amplifier is used for all measurements above 30 MHz, and High-Pass or Band-Pass filter is used for all harmonics.