Certification Test Report

FCC ID: 2AVE9-TILE01
IC: 25817-TILE01

FCC Rule Part: 25 Subpart C
ISED Canada Radio Standards Specification: RSS-170 Issue 3

Report Number: AT72154447-1C1

Manufacturer: Swarm Techologies, Inc.
Product: Tile
Model: TILE01

Test Begin Date: January 27, 2020
Test End Date: March 24, 2020

Report Issue Date: April 9, 2020

FOR THE SCOPE OF ACCREDITATION UNDER Certificate Number: 2955.09

This report must not be used by the client to claim product certification, approval, or endorsement by A2LA, NIST, or any agency of the Federal Government.

Prepared By:

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Reviewed by:

Ryan McGann
Senior Engineer
TÜV SÜD America Inc.

This report contains 22 pages

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1 GENERAL

1.1 Purpose

The purpose of this report is to demonstrate compliance with Part 25 Subpart C of the FCC's Code of Federal Regulations and Innovation, Science and Economic Development Canada's Radio Standards Specification RSS-170 Certification for an original certification.

1.2 Product Description

The Tile satellite data modem transmits and receives data to and from Swarm's space network and is designed to be embedded into a third-party product. Swarm backend systems can support delivery of customer data via a Swarm REST API to the Swarm cloud or user email, text message, AWS, Slack, etc. Communication can also be point-to-point between Swarm devices (no Internet involvement).

This report covers the VHF radio testing

Technical Information:

Detail	Description
Frequency Range	148.0039 – 150.0461 MHz
Emission Designator	F1D
Operating Voltage	5Vdc USB-C
Antenna Type / Gain	¼ Wave Whip, 2dBi (PulseLarsen, P/N: NMOQ) ½ Wave Whip, 2dBi (PulseLarsen, P/N: WB VHF)
Dimensions	59 mm x 27 mm x 5 mm

Manufacturer Information:
Swarm Technologies, Inc.
435 N Whisman Rd Ste 100
Mountainview, CA 94043

Test Sample Serial Number: C3

Test Sample Condition: The test samples were provided in good working order with no visible defects.

1.3 Test Methodology and Considerations

For radiated emissions, the EUT was evaluated in three orthogonal orientations. The worst-case orientation was Y-position. The EUT was programmed to generate a continuously modulated signal on each channel evaluated. The antenna port was terminated through an attenuator into a 50-Ohm load.

For RF Conducted measurements, the EUT antenna port was directly connected to the test equipment. The EUT was programmed to generate a continuously modulated signal on each channel evaluated.

Software power setting during test: 14 (28dBm)

2 TEST FACILITIES

2.1 Location

The radiated and conducted emissions test sites are located at the following addresses:

TÜV SÜD America, Inc.
5945 Cabot Pkwy, Suite 100
Alpharetta, GA 30005
Phone: (678) 341-5900

2.2 Laboratory Accreditations/Recognitions/Certifications

TÜV SÜD America, Inc. is accredited to ISO/IEC 17025 by the American Association for Laboratory Accreditation/A2LA accreditation program and has been issued certificate number 2955.09 in recognition of this accreditation.

Unless otherwise specified, all tests methods described within this report are covered under the ISO/IEC 17025 scopes of accreditation.

The Semi-Anechoic Chamber Test Sites and Conducted Emissions Sites have been fully described, submitted to, and accepted by the FCC, ISED Canada and the Japanese Voluntary Control Council for Interference by information technology equipment.

FCC Designation Accreditation Number:	US1233
ISED Canada Lab Code:	23932
VCCI Member Number:	1831
• VCCI Registration Number	A-0295

2.3 Radiated Emissions Test Site Description

2.3.1 Semi-Anechoic Chamber Test Site

The Semi-Anechoic Chamber Test Site consists of a 20'W x 30'L x 20'H shielded enclosure. The chamber is lined with ETS-Lindgren Ferrite Absorber, model number FT-1500. The ferrite tile 600 mm x 600 mm (2.62 in x 23.62 in) panels and are mounted directly on the inner walls of the chamber shield.

The specular regions of the chamber are lined with additional ETS-Lindgren PS-600 hybrid absorber to extend its frequency range up to 18GHz and beyond.

The turntable is a 2m ETS-Lindgren Model 2170 and installed off the center axis is located 5'6" from the back wall of the chamber. The chamber is grounded via 1 - 8' copper ground rod, installed at the center of the back wall, it is bound to the shield using #8 solid copper wire.

The antenna mast is an EMCO 1060 and is remotely controlled from the control room for both antenna height and polarization.

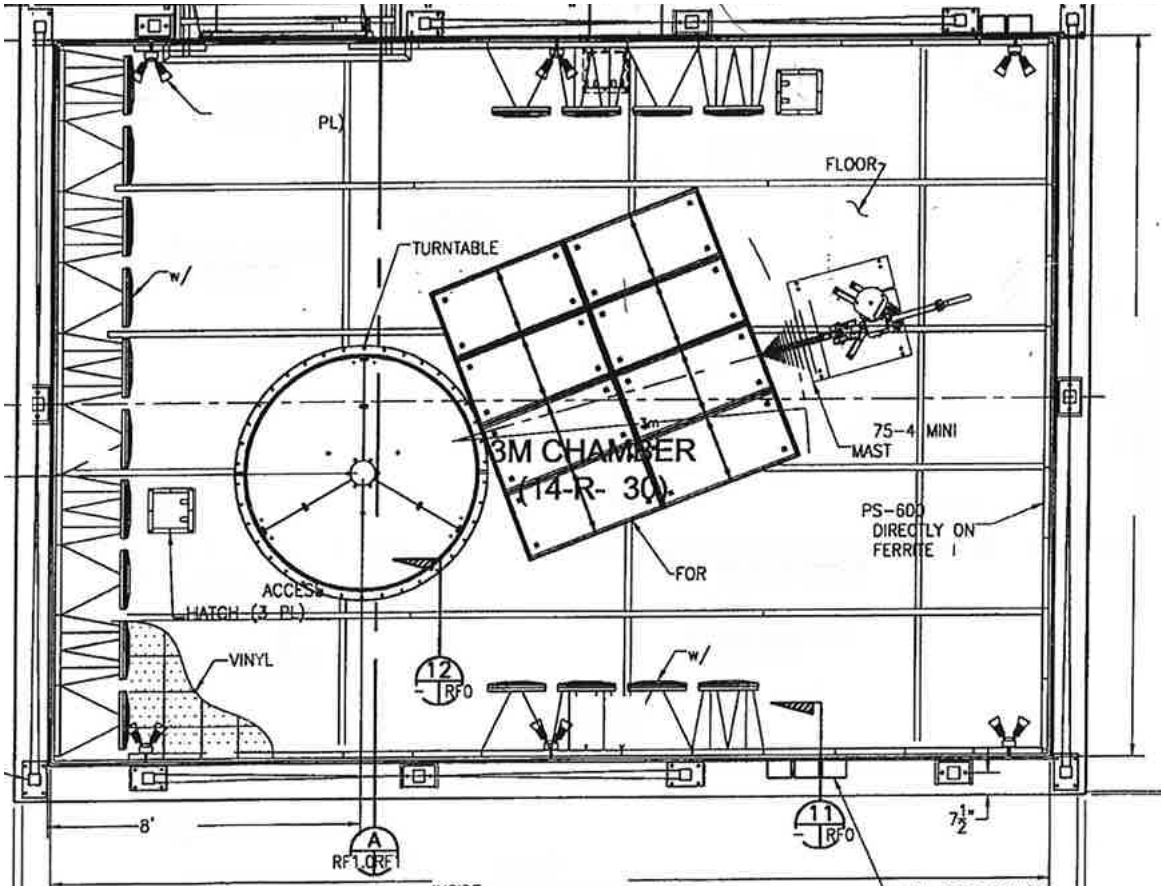


Figure 2.3.1-1: Semi-Anechoic Chamber Test Site

2.4 Conducted Emissions Test Site Description

2.4.1 Conducted Emissions Test Site

The AC mains conducted EMI site is located in the main EMC lab. It consists of a 12' x 10' horizontal coupling plane (HCP) as well as a 12'x8' vertical coupling plane (VCP). The HGP is constructed of 4' x 10' sheets of particle board sandwiched by galvanized steel sheets. These panels are bonded using 11AWG 1/8" x 2" by 10' galvanized sheet steel secured to the panels via by screws. The VCP is constructed of three 4'x8' sheets of 11AWG solid aluminum.

The HCP and VCP are electrically bonded together using 1"x1" angled aluminum secured with screws.

The site is of sufficient size to test tabletop and floor standing equipment in accordance with section 6.1.4 of ANSI C63.10.

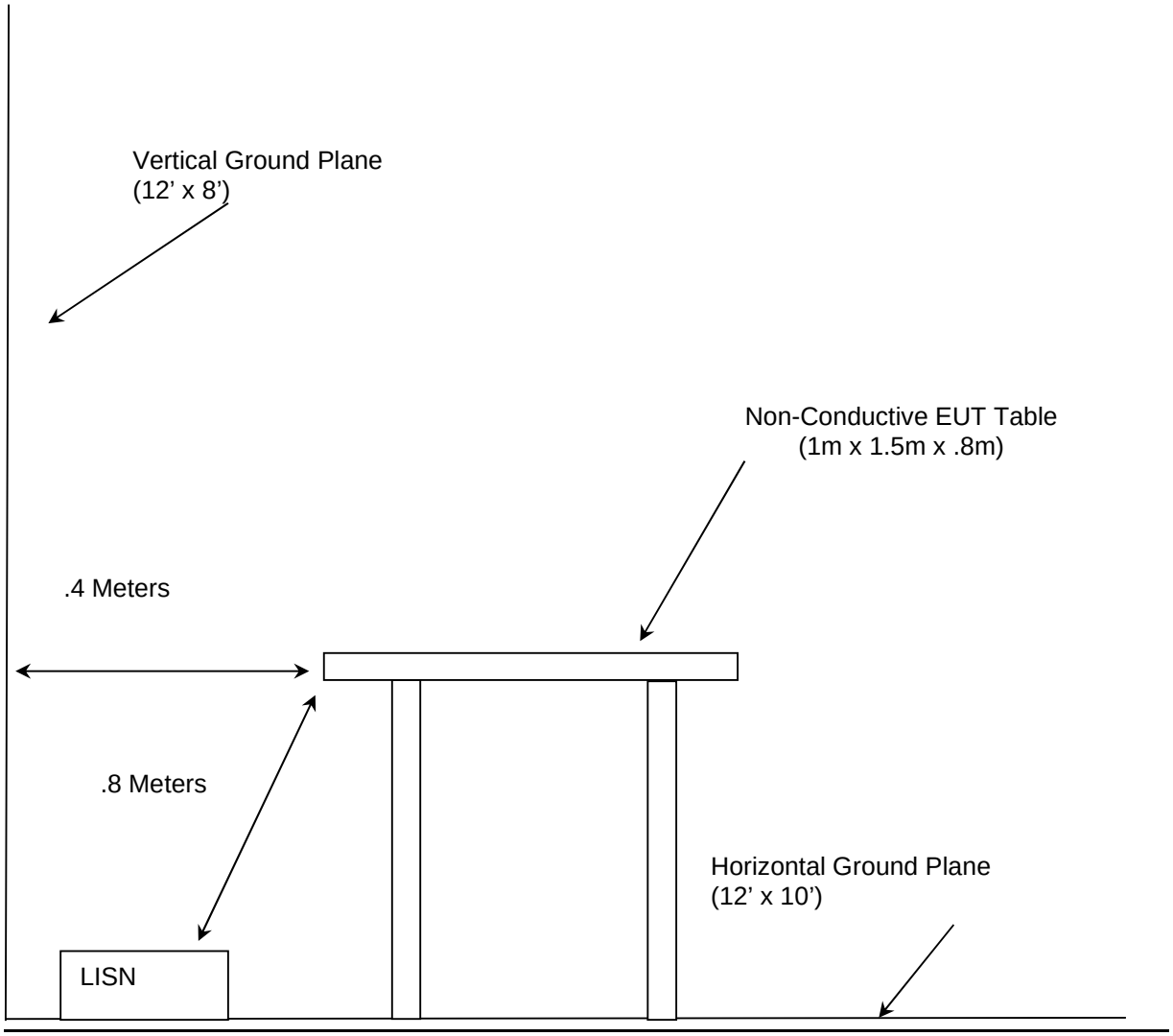


Figure 2.4.1-1: AC Mains Conducted EMI Site

3 APPLICABLE STANDARD REFERENCES

The following standards were used:

- ANSI C63.26-2015: American National Standard of Procedures for Compliance Testing of Transmitters Used in Licensed Radio Services.
- US Code of Federal Regulations (CFR): Title 47, Part 2, Subpart J: Equipment Authorization Procedures, 2020
- US Code of Federal Regulations (CFR): Title 47, Part 25, Subpart C: Satellite Communications
- ISED Canada Radio Standards Specification: RSS-170 – Mobile Earth Stations (MESs) and Ancillary Terrestrial Component (ATC) Equipment Operating in the Mobile-Satellite Service (MSS) Bands, Issue 3, July 2015.
- ISED Canada Radio Standards Specification: RSS-GEN – General Requirements for Compliance of Radio Apparatus, Issue 5, March 2015.

4 LIST OF TEST EQUIPMENT

The calibration interval of test equipment is annually or the manufacturer's recommendations. Where the calibration interval deviates from the annual cycle based on the instrument manufacturer's recommendations, it shall be stated below.

Table 4-1: Test Equipment

Asset ID	Manufacturer	Model	Equipment Type	Serial Number	Last Calibration Date	Calibration Due Date
213	TEC	PA 102	Amplifier	44927	07/22/2019	07/22/2020
338	Hewlett Packard	8449B	High Frequency Pre-Amp	3008A01111	07/15/2019	07/15/2021
345	Suhner Sucoflex	102A	Cable 42(GHZ)	1077/2A	07/09/2019	07/09/2020
622	Rohde & Schwarz	FSV40 (v3.40)	FSV Signal Analyzer 10Hz to 40GHz	101338	07/30/2018	07/30/2020
694	Thermotron	S-1.2C	Thermotron temperature chamber	19753	NCR	NCR
695	Fluke	51II	Digital Thermometer	76440097	06/05/2019	06/05/2020
827	(-)	TS8997 Rack Cable Set	TS8997 Rack Cable Set	N/A	05/01/2019	05/01/2020
836	ETS Lindgren	SAC Cable Set	SAC Cable Set includes 620, 837, 838	N/A	05/01/2019	05/01/2020
853	Teseq	CBL 6112D; 6804.17.A	Bilog Antenna; Attenuator	51616; 20181110A	10/15/2018	10/15/2020
857	ETS Lindgren	3117	Horn Antenna 1-18GHz	00153608	11/12/2019	11/12/2021
RE880	Rhode & Schwarz USA	Test Recever	R&S ESW44	1206247	11/06/2019	11/6/2020

5 SUPPORT EQUIPMENT

Table 5-1: Support Equipment

Item	Equipment Type	Manufacturer	Model Number	Serial Number
1	EUT	Swarm Technologies	TILE01	Not Labeled
2	Wall Wart Power Supply	Anker Innovations Limited	A2627	AFYQAJ0926171083
3	50-ohm Termination	Mini Circuits	ANNE-50+	N/A
4	Test Board	Swarm Technologies	0015-X1	Not Labeled

Table 5-2: Cable Description

Item	Cable Type	Length	Shield	Termination
A	USB-C Cable	2 m	Yes	1 – 2

6 EQUIPMENT UNDER TEST SETUP BLOCK DIAGRAM

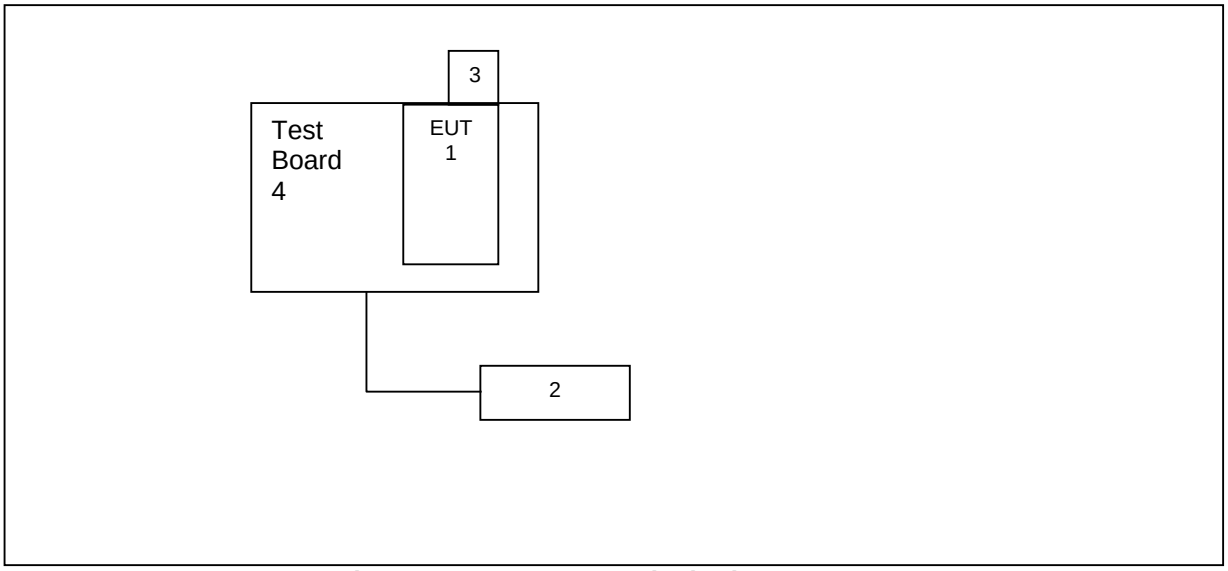


Figure 6-1: Test Setup Block Diagram

7 SUMMARY OF TESTS

Along with the tabular data shown below, plots were taken of all signals deemed important enough to document.

7.1 99% Occupied Bandwidth – FCC CFR Part 2, Section 2.1049, RSS-GEN 6.7

7.1.1 Measurement Procedure

The occupied bandwidth measurement function of the spectrum analyzer was used to measure the 99% bandwidth. The span of the analyzer was set to capture all products of the modulation process, including the emission sidebands. The resolution bandwidth was set from 1% to 5% of the occupied bandwidth and the video bandwidth set to at least 3 times the resolution bandwidth. A peak detector was used.

7.1.2 Measurement Results

Performed by: Jeremy Pickens

Table 7.1.2-1: 99% Occupied Bandwidth

Bandwidth Setting	Frequency (MHz)	99% Bandwidth (kHz)
0	148.0039	7.818
	150.0461	7.887
1	148.0052	10.420
	150.0448	10.420
2	148.0078	15.340
	150.0422	15.485
3	148.0104	20.695
	150.0396	20.695
4	148.0157	30.970
	150.0344	30.970
5	148.0209	41.100
	150.0292	41.100
6	148.0313	62.229
	150.0188	62.229

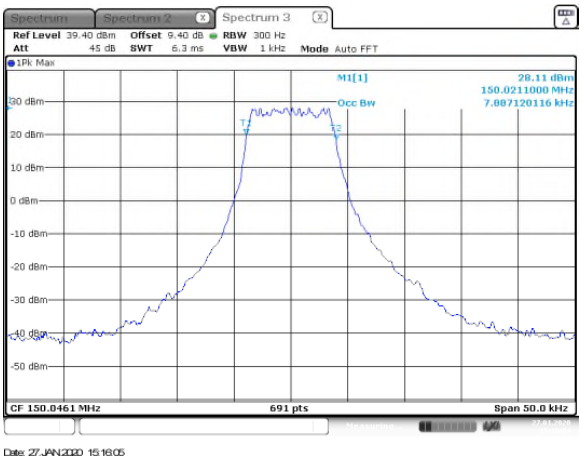


Figure 7.1.2-1: Sample Plot - 99% OBW (Lowest BW Setting)

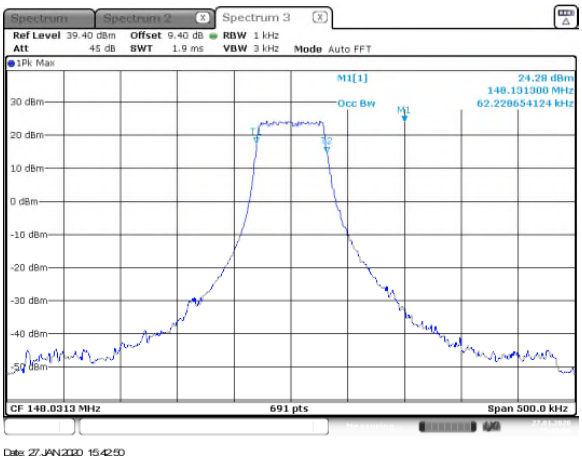


Figure 7.1.2-2: Sample Plot - 99% OBW (Highest BW Setting)

7.2 Fundamental Emission Output Power – FCC: Part 25 Subpart C §25.204; ISED Canada: RSS-170 Section 5.3.2

7.2.1 Measurement Procedure

The antenna port conducted power was measured with the output of the equipment under test directly connected to the input of the spectrum analyzer through suitable attenuation.

No maximum RF peak power limit exists for this band (148-150.05MHz) per Part 25

7.2.2 Measurement Results

Performed by: Jeremy Pickens

Table 7.2.2-1: Maximum Conducted Output Power (Peak)

Bandwidth Setting	Frequency (MHz)	Peak Power (dBm)
0	148.0039	29.34
	150.0461	29.03
1	148.0052	29.29
	150.0448	29.01
2	148.0078	29.26
	150.0422	28.97
3	148.0104	29.24
	150.0396	28.98
4	148.0157	29.24
	150.0344	28.97
5	148.0209	29.23
	150.0292	28.97
6	148.0313	28.97
	150.0188	28.99

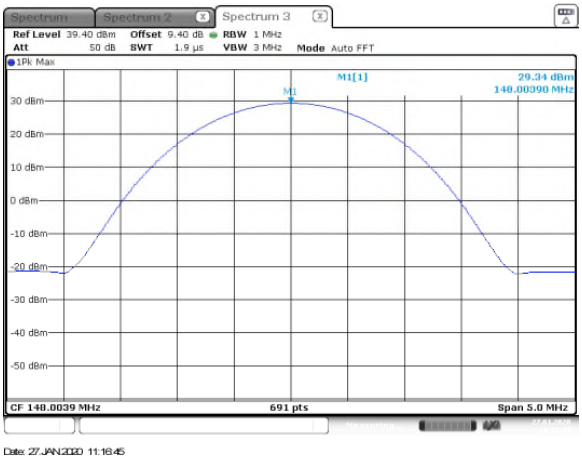


Figure 7.2.2-1: Conducted Output Power – Sample Plot

7.3 Emission Levels

7.3.1 Spurious Emissions at Antenna Terminals – FCC: Section 25.202(f); ISED Canada: RSS-170 issue 3, Section 5.4.3

7.3.1.1 Measurement Procedure

The antenna port emissions were measured with the output of the equipment under test directly connected to the input of the spectrum analyzer applying suitable attenuation.

Compliance was determined using the following guidance from the specifications:

FCC CFR Part 25, Section 25.202(f):
(f) Emission limitations. Except for SDARS terrestrial repeaters, the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the schedule set forth in paragraphs (f)(1) through (f)(4) of this section. The out-of-band emissions of SDARS terrestrial repeaters shall be attenuated in accordance with the schedule set forth in paragraph (h) of this section.

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;
(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;
(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts;
(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (f) (1), (2) and (3) of this section.

RSS-170 issue 3, Section 5.4.3:
The average power of unwanted emissions shall be attenuated below the average output power, P (dBW), of the transmitter, as specified below:

(1) 25 dB in any 4 kHz band, the centre frequency of which is offset from the channel frequency by more than 50%, up to and including 100% of the occupied bandwidth or necessary bandwidth, whichever is greater;
(2) 35 dB in any 4 kHz band, the centre frequency of which is offset from the channel frequency by more than 100%, up to and including 250% of the occupied bandwidth or necessary bandwidth, whichever is greater; and
(3) 43 + 10 log p (watts) in any 4 kHz band, the centre frequency of which is offset from the channel frequency by more than 250% of the occupied bandwidth or necessary bandwidth, whichever is greater.

Note: Since a 4kHz resolution bandwidth was not available, a 3kHz RBW was applied and adjusted by 1.2dB.

7.3.1.2 Measurement Results

Performed by: Jeremy Pickens

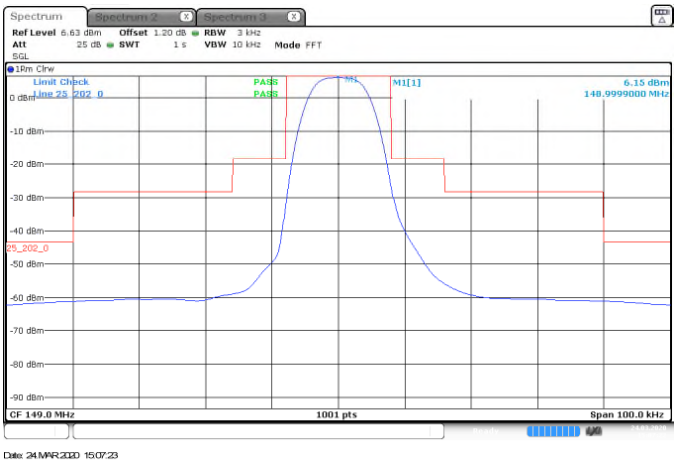


Figure 7.3.1.2-1: Emission Mask – BW0 (7.8kHz)

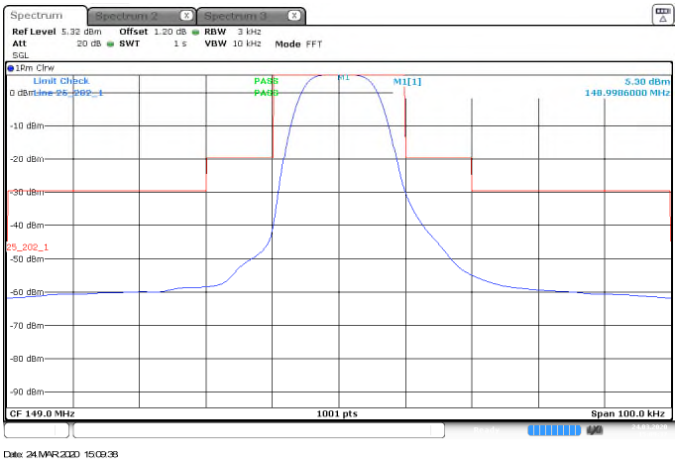


Figure 7.3.1.2-2: Emission Mask – BW1 (10.4kHz)

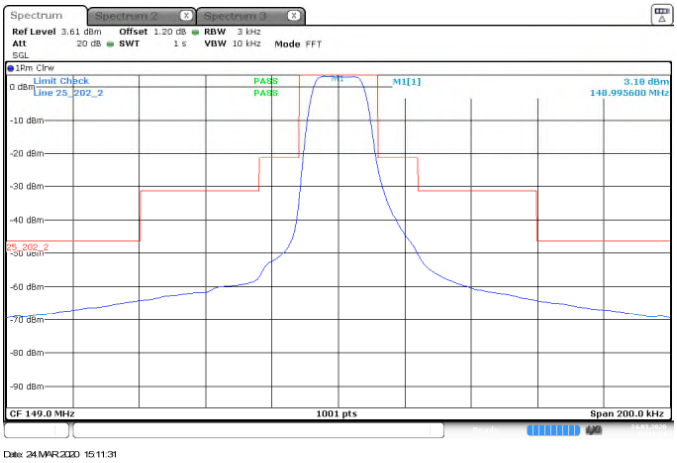


Figure 7.3.1.2-3: Emission Mask – BW2 (15.6kHz)

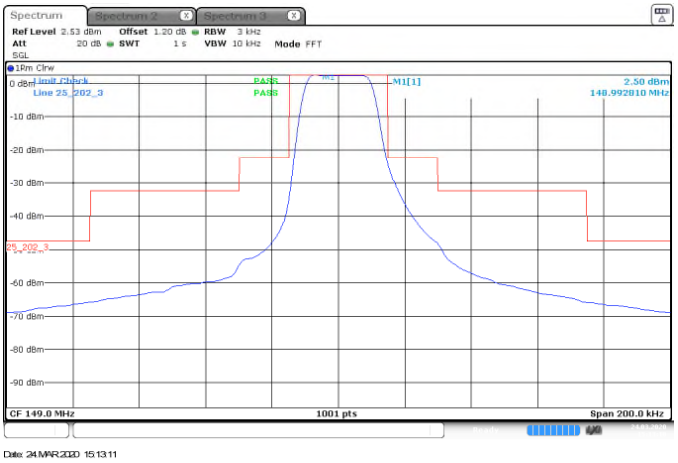


Figure 7.3.1.2-4: Emission Mask – BW3 (20.8kHz)

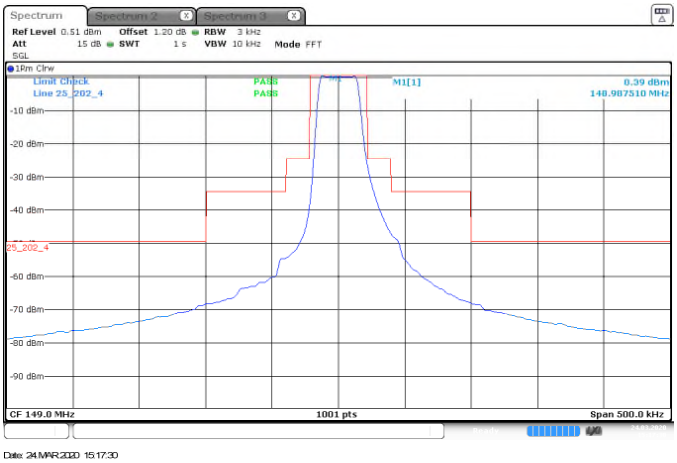


Figure 7.3.1.2-5: Emission Mask – BW4 (31.3kHz)

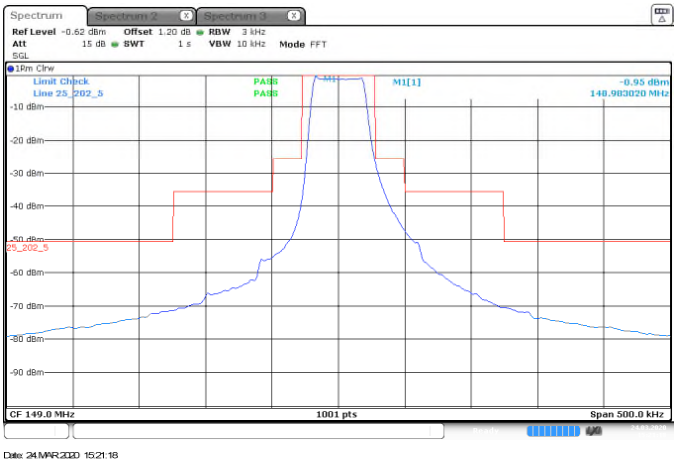


Figure 7.3.1.2-6: Emission Mask – BW5 (41.7kHz)

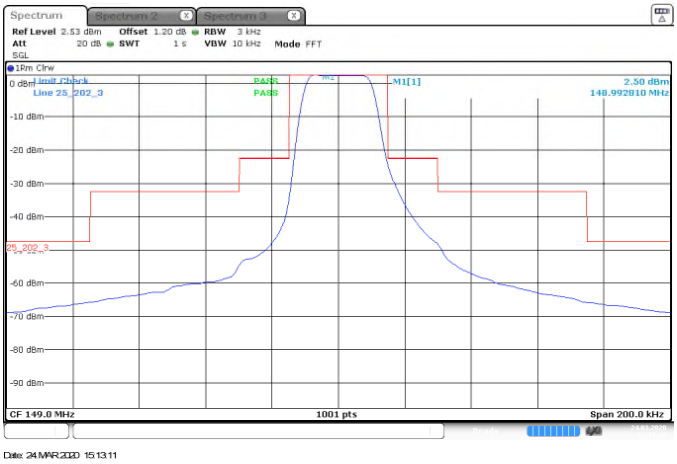


Figure 7.3.1.2-7: Emission Mask – BW6 (62.5kHz)

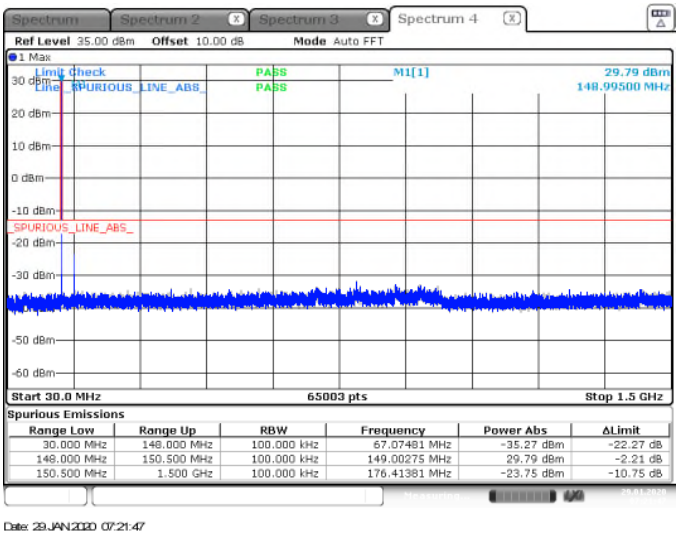


Figure 7.3.1.2-8: Conducted Spurious Emissions

7.3.2 Field Strength of Radiated Spurious Emissions – Section 25.202(f) as required by Part 2 Section 2.1053; ISED Canada: RSS-170, Section 5.4.3

7.3.2.1 Measurement Procedure

The unwanted emissions were measured radiated over the frequency range of 30 MHz to 1.6 GHz, more than 10 times the highest fundamental frequency using the methods defined in ANSI C63.26.

The EUT was rotated through 360° and the receive antenna height was varied from 1 meter to 4 meters so that the maximum radiated emissions level would be detected. For frequencies below 1000 MHz, peak measurements were made using a resolution bandwidth (RBW) of 100 kHz and a video bandwidth VBW of 300 kHz. For frequencies above 1000 MHz, peak and average measurements were made with RBW and VBW of 1 MHz and 3 MHz respectively.

Compliance was determined using the following guidance from the specifications:
FCC CFR Part 25, Section 25.202(f):

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

RSS-170 issue 3, Section 5.4.3:

> (3) 43 + 10 log p (watts) in any 4 kHz band, the centre frequency of which is offset from the channel frequency by more than 250% of the occupied bandwidth or necessary bandwidth, whichever is greater.

Note: Although a 4kHz resolution bandwidth is stated in the specification, the higher bandwidth settings mentioned above were applied to facilitate testing.

7.3.2.2 Measurement Results

Performed by: Jeremy Pickens

Table 7.3.2.2-1: Radiated Spurious Emissions Tabulated Data

Frequency (MHz)	Level (dBuV)	Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)	Limit (dBuV/m)	Margin
	pk	(H/V)	(dB)	pk	RMS	
Low Channel						
296.0104	28.30	H	-6.42	21.88	82.2	60.3
296.0104	25.80	V	-6.42	19.38	82.2	62.8
740.026	29.50	H	-6.42	23.08	82.2	59.1
740.026	27.90	V	-6.42	21.48	82.2	60.7
High Channel						
300.0896	27.20	H	-6.34	20.86	82.2	61.3
300.0896	26.50	V	-6.34	20.16	82.2	62.0
750.224	29.20	H	-6.34	22.86	82.2	59.3
750.224	27.10	V	-6.34	20.76	82.2	61.4

Note: Peak measurements were compared to the RMS limit.

7.3.2.3 Sample Calculation:

$R_C = R_U + CF_T$

Where:

CF_T	=	Total Correction Factor (AF+CA+AG)-DC (Average Measurements Only)
R_U	=	Uncorrected Reading
R_C	=	Corrected Level
AF	=	Antenna Factor
CA	=	Cable Attenuation
AG	=	Amplifier Gain
DC	=	Duty Cycle Correction Factor

Example Calculation: Peak

Corrected Level: 29.5 + -6.42 = 23.08dBuV/m
Margin: 82.2dBuV/m – 23.08dBuV/m = 59.1dB

7.4 Frequency Stability - §2.1055, ISED Canada: RSS-170, Section 5.2

7.4.1 Measurement Procedure

The frequency stability was measured in accordance with Subclause 5.6 of ANSI C63.26.

For mobile earth station equipment, the carrier frequency shall not depart from the reference frequency by more than ±10 ppm.

7.4.2 Measurement Results

Performed by: Jeremy Pickens

Table 7.4.2-1: Frequency Stability Tabulated Data

Nominal Voltage		5Vdc	Nominal Frequency (MHz)	149
Voltage (VDC)	Temperature (°C)	Frequency Center (MHz)		Deviation (ppm)
5	-30	149.0000889		0.6
	-20	149.0000936		0.63
	-10	149.0000967		0.65
	0	149.0000862		0.58
	+10	149.0000645		0.43
	+20	149.0000498		0.33
	+30	149.0000208		0.14
	+40	148.9999989		-0.01
	+50	149.0000283		0.19
4.25	+20	149.0000622		0.42
5.75	+20	149.0000706		0.47

8 ESTIMATION OF MEASUREMENT UNCERTAINTY

The expanded laboratory measurement uncertainty figures (U_{Lab}) provided below correspond to an expansion factor (coverage factor) k = 1.96 which provide confidence levels of 95%.

Table 8-1: Estimation of Measurement Uncertainty

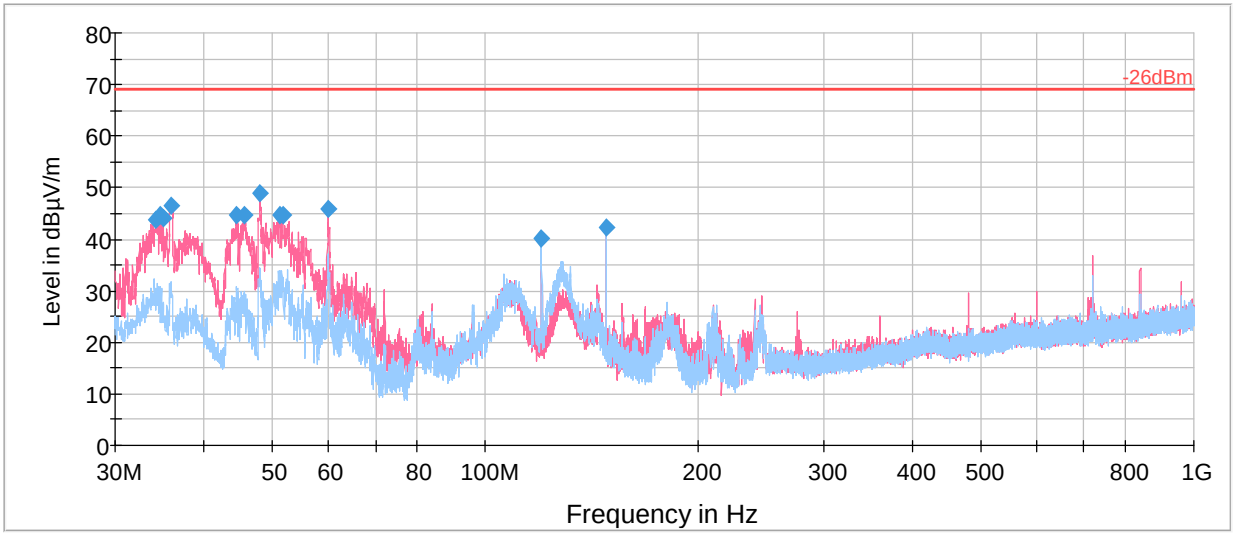
Parameter	U_{lab}
Occupied Channel Bandwidth	± 0.009 %
RF Conducted Output Power	± 0.349 dB
Power Spectral Density	± 0.372 dB
Antenna Port Conducted Emissions	± 1.264 dB
Radiated Emissions ≤ 1 GHz	± 5.814 dB
Radiated Emissions > 1 GHz	± 4.318 dB
Temperature	± 0.860 °C
Radio Frequency	± 2.832 x 10^{-8}
AC Power Line Conducted Emissions	± 3.360 dB

9 CONCLUSION

In the opinion of TÜV SÜD America, Inc. the Tile, manufactured by Swarm Techologies, Inc. meets the requirements of FCC Part 25 subpart C and ISED Canada's Radio Standards Specification RSS-170 for the tests documented herein.

Appendix A: Plots

Full Spectrum



Note: Except for the fundamental, emissions above the noise floor are from the digital sections of the DUT and not associated with the radio.

Figure A-1: Radiated Spurious Emissions: 30MHz-1GHz

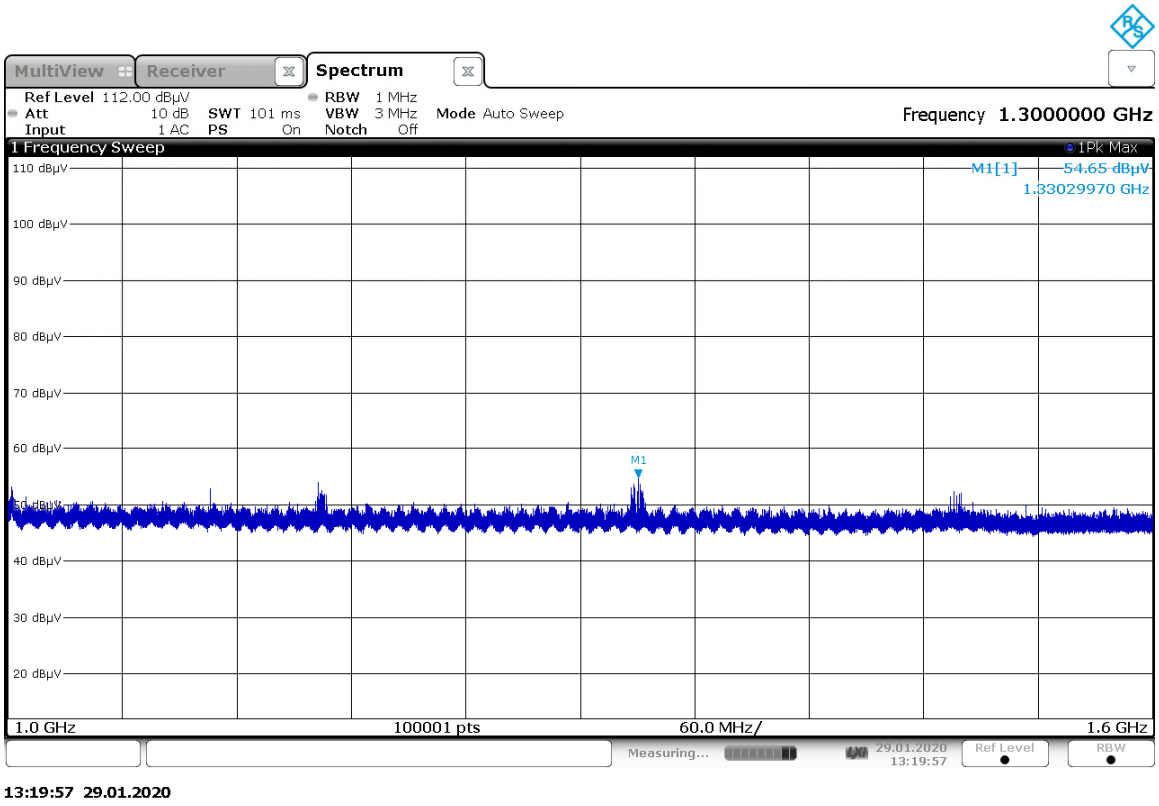


Figure A-2: Radiated Spurious Emissions: 1GHz-1.6GHz

END REPORT