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Wabash Heartland Innovation Network TEST REPORT

SCOPE OF WORK
EMC TESTING – WHIN_WAN GATEWAYMODEL WHIN-WAN-GW

REPORT NUMBER
105270108LEX-002.1

ISSUE DATE **REVISION DATE**
1/27/2023 2/13/2023

PAGES
54

DOCUMENT CONTROL NUMBER
Non-Specific EMC Report Shell Rev. December 2017

EMC TEST REPORT

(FULL COMPLIANCE)

Report Number: 105270108LEX-002.1.1
Project Number: G105270108

Report Issue Date: 1/27/2023
Revision Date: 2/13/2023

Model(s) Tested: WHIN_WAN Gateway model WHIN-WAN-GW

Standards: Title 47 CFR Part 15.247
RSS-247 Issue 2
RSS-Gen Issue 5

Tested by:
Intertek Testing Services NA, Inc.
731 Enterprise Dr.
Lexington, KY 40510
USA

Client:
Wabash Heartland Innovation Network
1281 WIN HENTSCHEL BOULEVARD Suite 2161
West Lafeyette, IN 47906
USA

Report prepared by

David Perry, Engineer

Report reviewed by

Brian Lackey, Team Leader

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1 Introduction and Conclusion

The tests indicated in section 2.0 were performed on the product constructed as described in section 4.0. The remaining test sections are the verbatim text from the actual data sheets used during the investigation. These test sections include the test name, the specified test Method, a list of the actual Test Equipment Used, documentation Photos, Results, and raw Data. No additions, deviations, or exclusions have been made from the standard(s) unless specifically noted.

Based on the results of our investigation, we have concluded the product tested **complies** with the requirements of the standard(s) indicated. The results obtained in this test report pertain only to the item(s) tested. Intertek does not make any claims of compliance for samples or variants which were not tested.

2 Test Summary

Section	Test full name	Result
6	Occupied Bandwidth (FCC Part 15.215(c), RSS-247 Issue 2 § 5.1(c))	Pass
7	Output Power (FCC Part 15.247(b)(2), RSS-247 Issue 2 § 5.4(a))	Pass
8	Carrier Frequency Separation (FCC Part 15.247(a)(1), RSS-247 Issue 2 § 5.1(b))	Pass
9	Number of Hopping Frequencies (FCC Part 15.247(a)(1)(i), RSS-247 Issue 2 § 5.1(c))	Pass
10	Time of Occupancy (FCC Part 15.247(a)(1)(i), RSS-247 Issue 2 § 5.1(c))	Pass
11	Radiated Spurious Emissions & Band Edge (FCC Part 15.247(d), RSS-247 Issue 2 § 5.5)	Pass
12	Conducted Spurious Emissions (FCC Part 15.247(d), RSS-247 Issue 2 § 5.5)	Pass
13	Antenna Requirement (FCC Part 15.203, RSS-Gen Issue 5 § 6.8)	Pass

3 Client Information

This product was tested at the request of the following:

Client Information	
Client Name:	Wabash Heartland Innovation Network
Address:	1281 WIN HENTSCHEL BOULEVARD Suite 2161 West Lafeyette, IN 47906 USA
Contact:	Gary Gentry
Email:	gary@estk-design.com
Manufacturer Information	
Manufacturer Name:	Wabash Heartland Innovation Network
Manufacturer Address:	1281 WIN HENTSCHEL BOULEVARD Suite 2161 West Lafeyette, IN 47906 USA

4 Description of Equipment under Test and Variant Models

Equipment Under Test	
Product Name	WHIN_WAN Gateway
Model Number	WHIN-WAN-GW
Test Start Date	12/27/2022
Test End Date	1/27/2023
Device Received Condition	Good
Test Sample Type	Production
Transmit Band	902 MHz – 915 MHz
Test Channels	902.3 MHz, 908.5 MHz, 914.9 MHz
Equipment Time	Frequency Hopping Spread Spectrum (FHSS)
Antenna Make, Model, and Gain[1]	WHIN, Monopole Ant, 7.47 dB (Measured)
Input Rating	6V DC Battery
Description of Equipment Under Test (provided by client)	
LoRaWAN Weather Station Gateway #6612	

4.1 Variant Models:

There were no variant models covered by this evaluation.

[1] This information was provided by the client and deviations from these values may affect compliance. Intertek does not make any claim of compliance for other than these values.

5 System Setup and Method

5.1 Method:

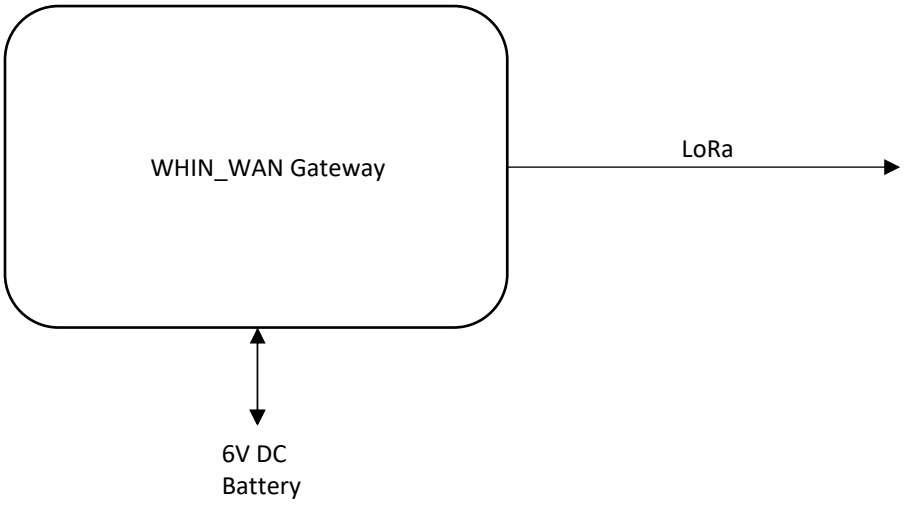
Configuration as required by ANSI C63.10:2013

No.	Descriptions of EUT Exercising
1	The EUT was powered by 6V DC and configured to transmit continuously at a low, mid, or high channel.
2	The EUT was powered by 6V DC and configured to transmit continuously using frequency hopping.

Cables					
Qty	Description	Length (m)	Shielding	Ferrites	Termination
-	None	-	-	-	-

Support Equipment			
Description	Manufacturer	Model Number	Serial Number
None	-	-	-

5.2 EUT Block Diagram:



6 Occupied Bandwidth

6.1 Test Limit

FCC Part 15.247(a)(1)(i):

For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

FCC Part 15.215(c):

Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§ 15.217 through 15.257 and in subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. In the case of intentional radiators operating under the provisions of subpart E, the emission bandwidth may span across multiple contiguous frequency bands identified in that subpart. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

RSS-247 Issue 2 § 5.1(c):

For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

6.2 Test Method

Tests are performed in accordance with ANSI C63.10: 2013 clause 6.9.2.

6.3 Test Equipment Used:

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
Signal Analyzer	3981	Rohde & Schwarz	FSU	9/16/2022	9/16/2023

6.4 Test Results

The device was found to be **compliant**. The 20dB bandwidth was found to be contained wholly within the authorized frequency band, and less than 500kHz.

6.5 Test Conditions

Test Personnel:	David Perry, Seth Parker	Test Date:	1/1/2023-1/9/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	500KHz
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	52.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

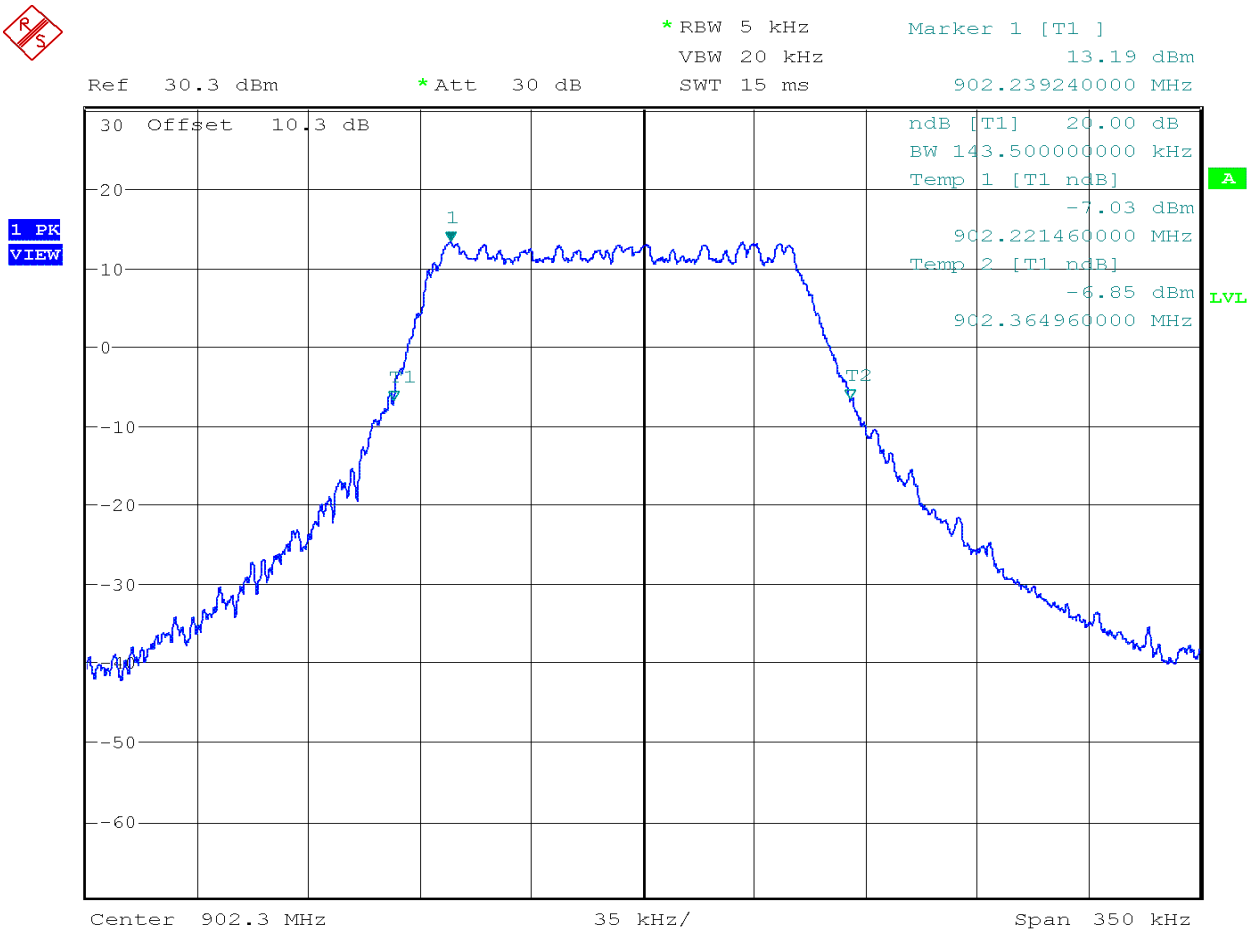
Deviations, Additions, or Exclusions: None

6.6 Test Data

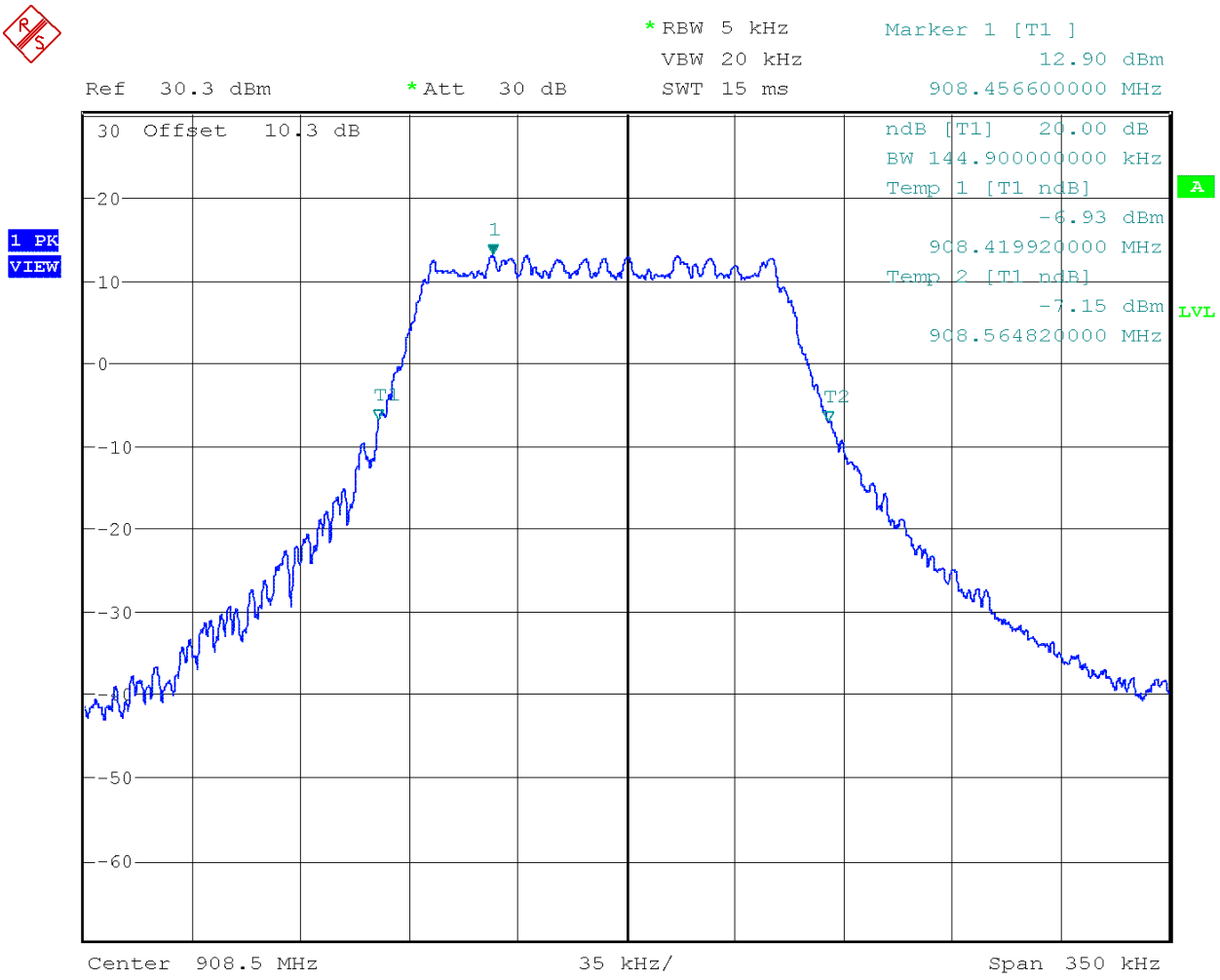
Frequency (MHz)	20dB Bandwidth (kHz)	99% Bandwidth (kHz)	Limit (kHz)
902.3	143.5	127.3	500
908.5	144.9	127.3	500
914.9	145.9	127.3	500

6.7 Spectrum Plots

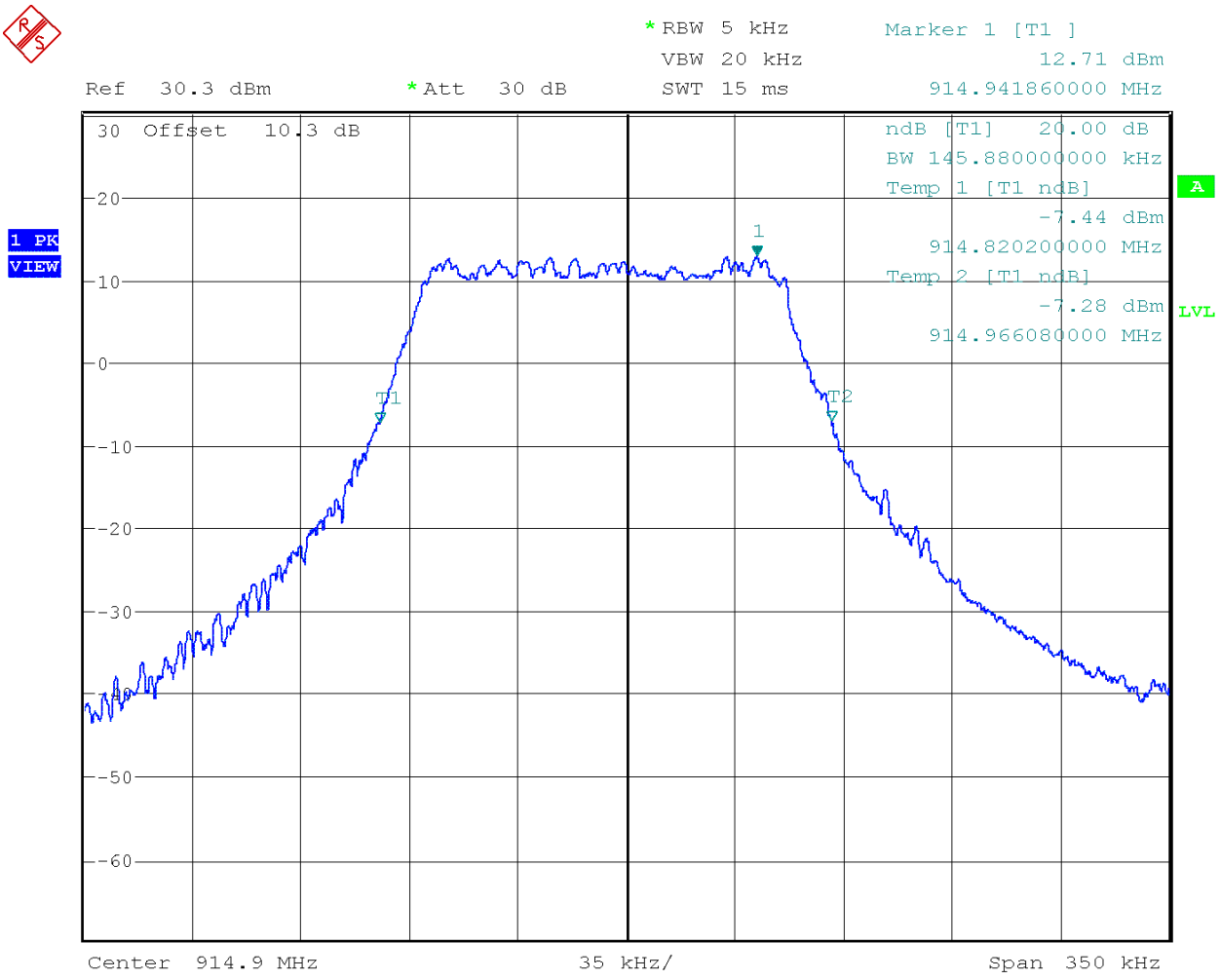
6.7.1 902.3 MHz, 20dB Bandwidth



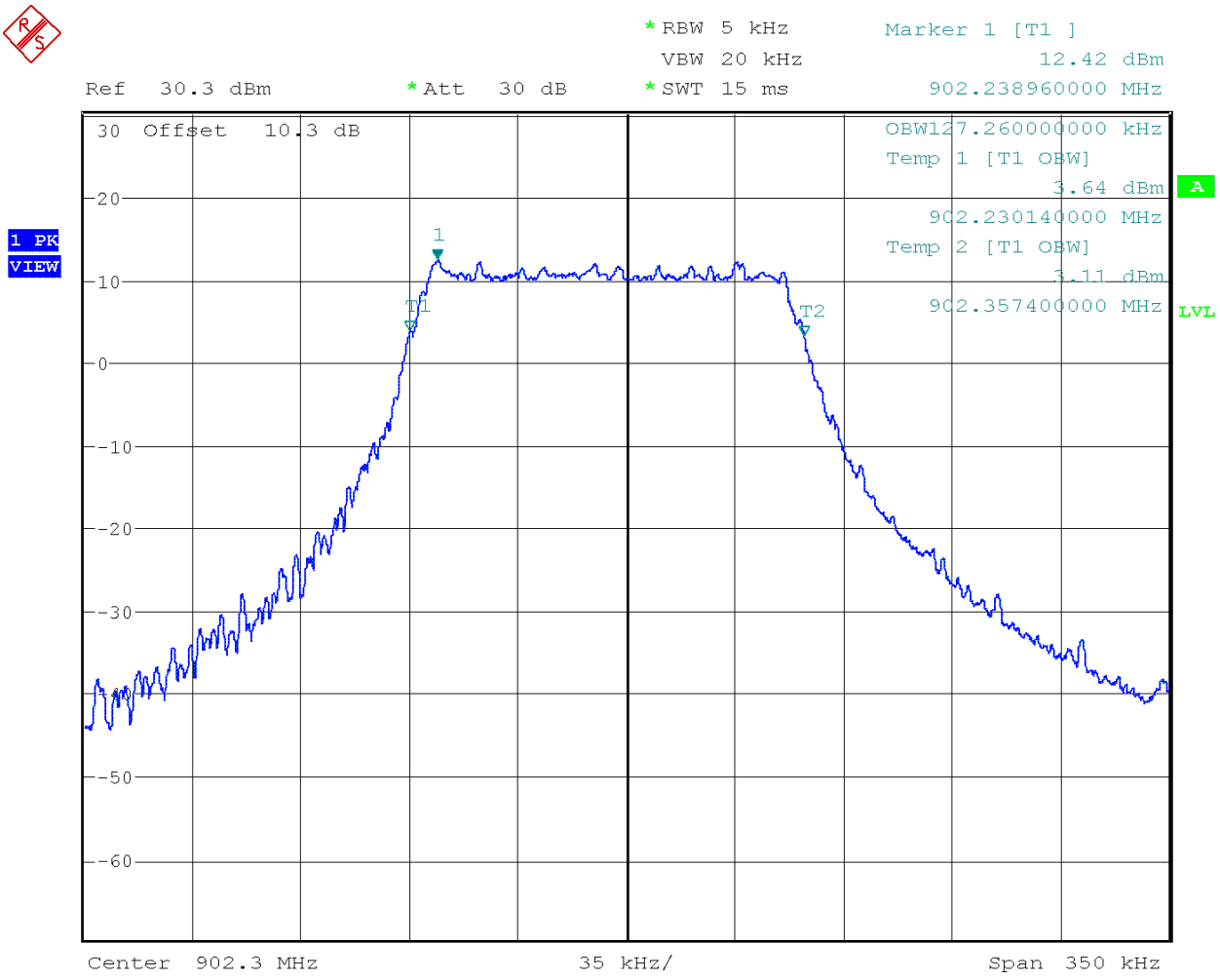
6.7.2 908.5 MHz, 20dB Bandwidth



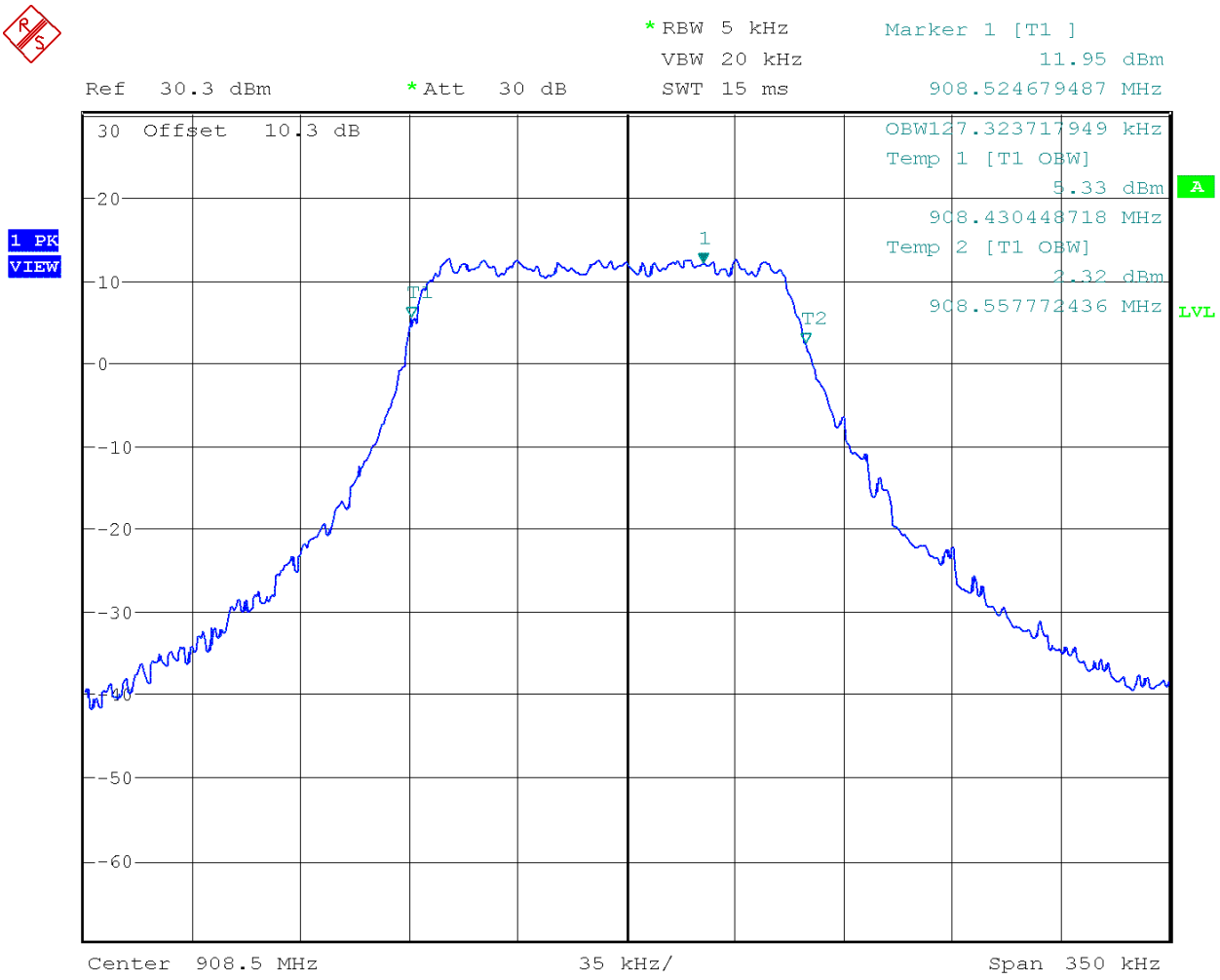
6.7.3 914.9 MHz, 20dB Bandwidth



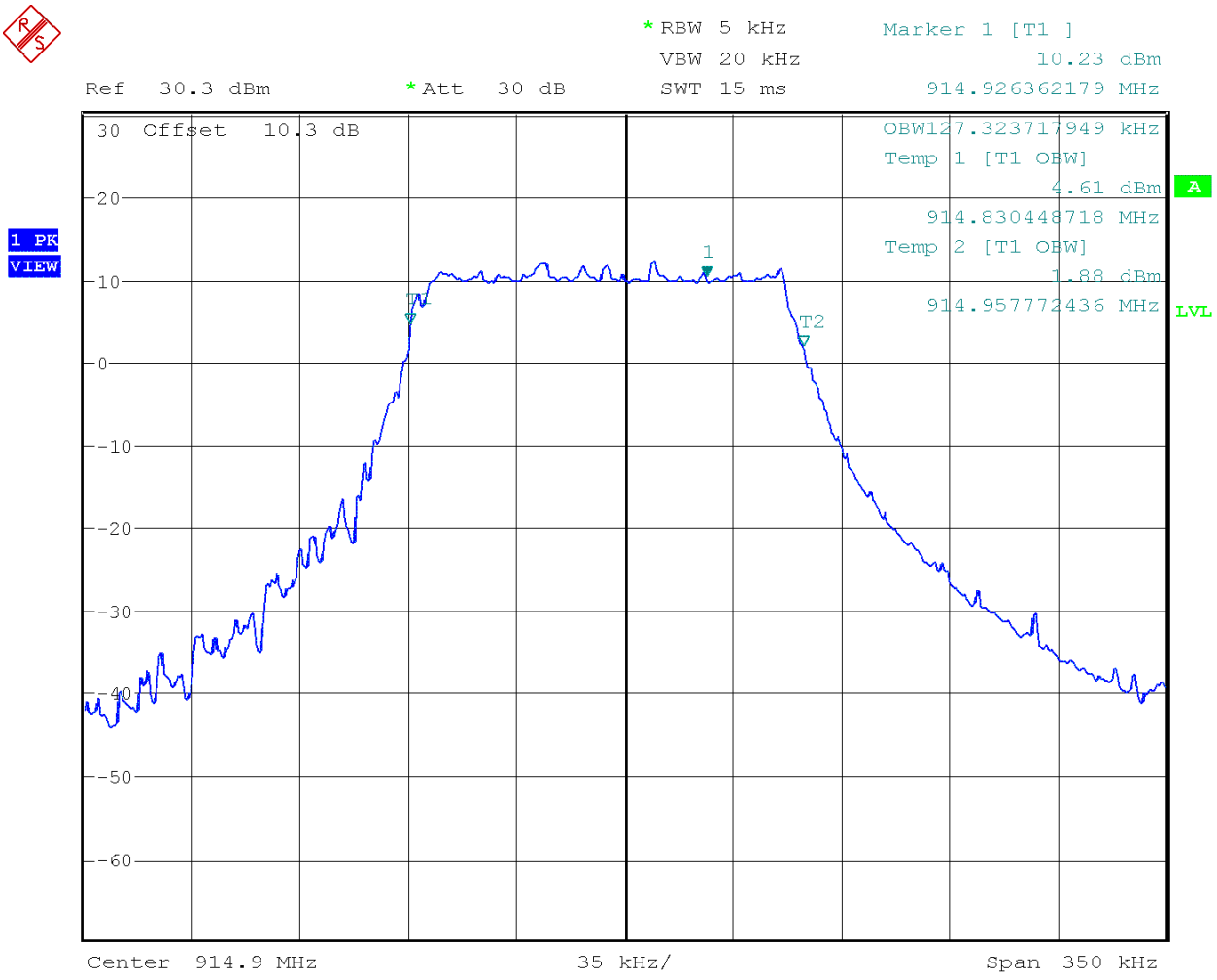
6.7.4 902.3 MHz, 99% Bandwidth



6.7.5 908.5 MHz, 99% Bandwidth



6.7.6 914.9 MHz, 99% Bandwidth



7 Maximum Peak Output Power

7.1 Test Limits

FCC Part 15.247(b)(2):

For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

RSS-247 Issue 2 § 5.4(a):

For FHSs operating in the band 902-928 MHz, the maximum peak conducted output power shall not exceed 1.0 W, and the e.i.r.p. shall not exceed 4 W if the hopset uses 50 or more hopping channels; the maximum peak conducted output power shall not exceed 0.25 W and the e.i.r.p. shall not exceed 1 W if the hopset uses less than 50 hopping channels.

7.2 Test Method

Tests are performed in accordance with ANSI C63.10:2013 § 7.8.5., § 6.5, and Annex G

7.3 Test Equipment Used:

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
Signal Analyzer	3981	Rohde & Schwarz	FSU	9/16/2022	9/16/2023
EMI Test Receiver	8285	Rohde & Schwarz	EW44	12/23/2022	12/23/2023
Bilog Antenna	3133	ETS	3142C	8/10/2022	8/10/2023
System Controller	3957	Sunol Sciences	SC99V	Verify at Time of Use	Verify at Time of Use
30M-1G 3m Signal Path without Preamplifier	3339, 2592, 8188, 8185			1/12/2023	1/12/2024

7.4 Test Results

The device was found to be **compliant**. The peak conducted output power was less than 1W. The maximum EIRP was less than 4W.

7.5 Test Conditions

Test Personnel:	David Perry	Test Date:	1/6/2023-1/8/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	See Above
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	52.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

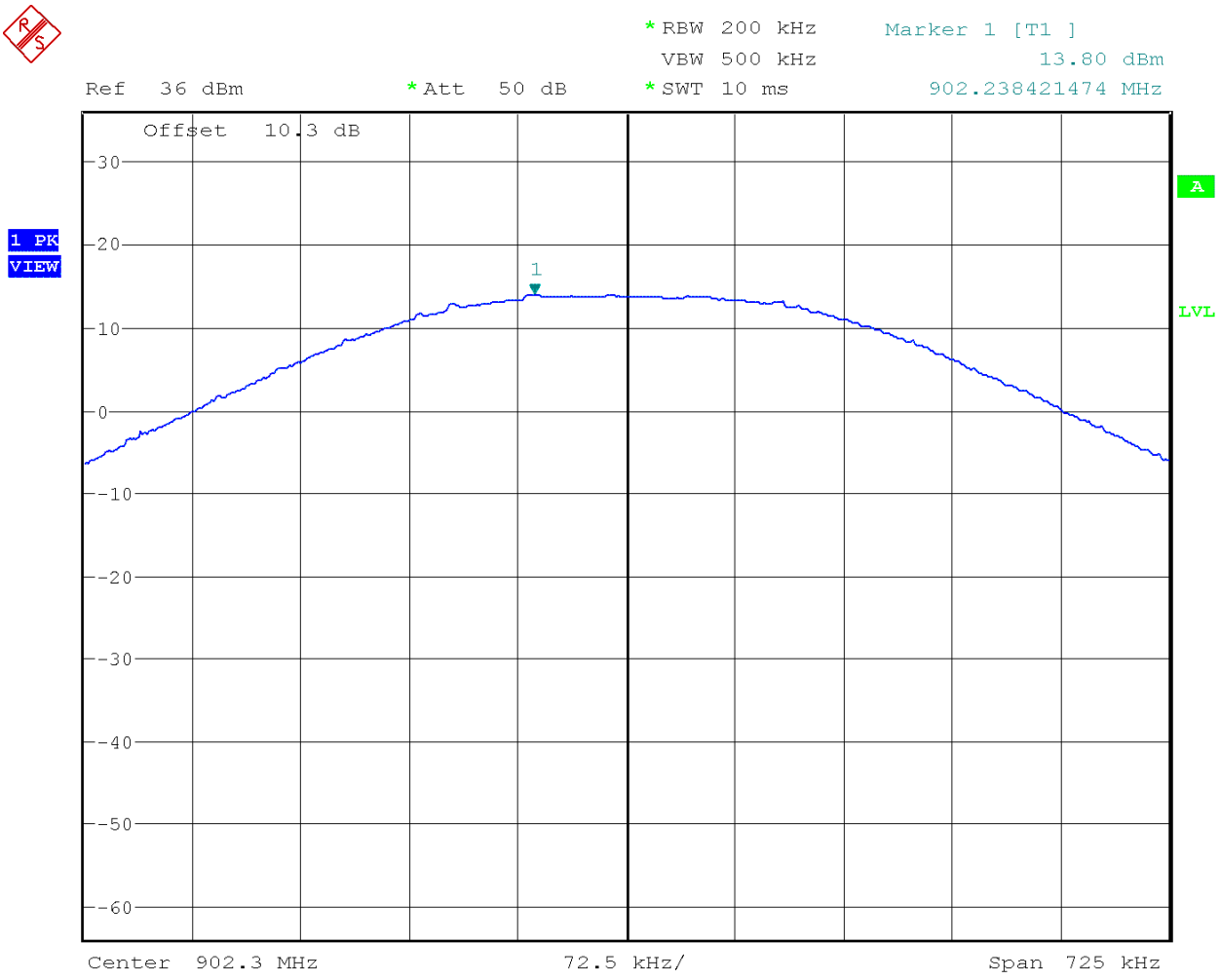
Deviations, Additions, or Exclusions: None

7.6 Test Data

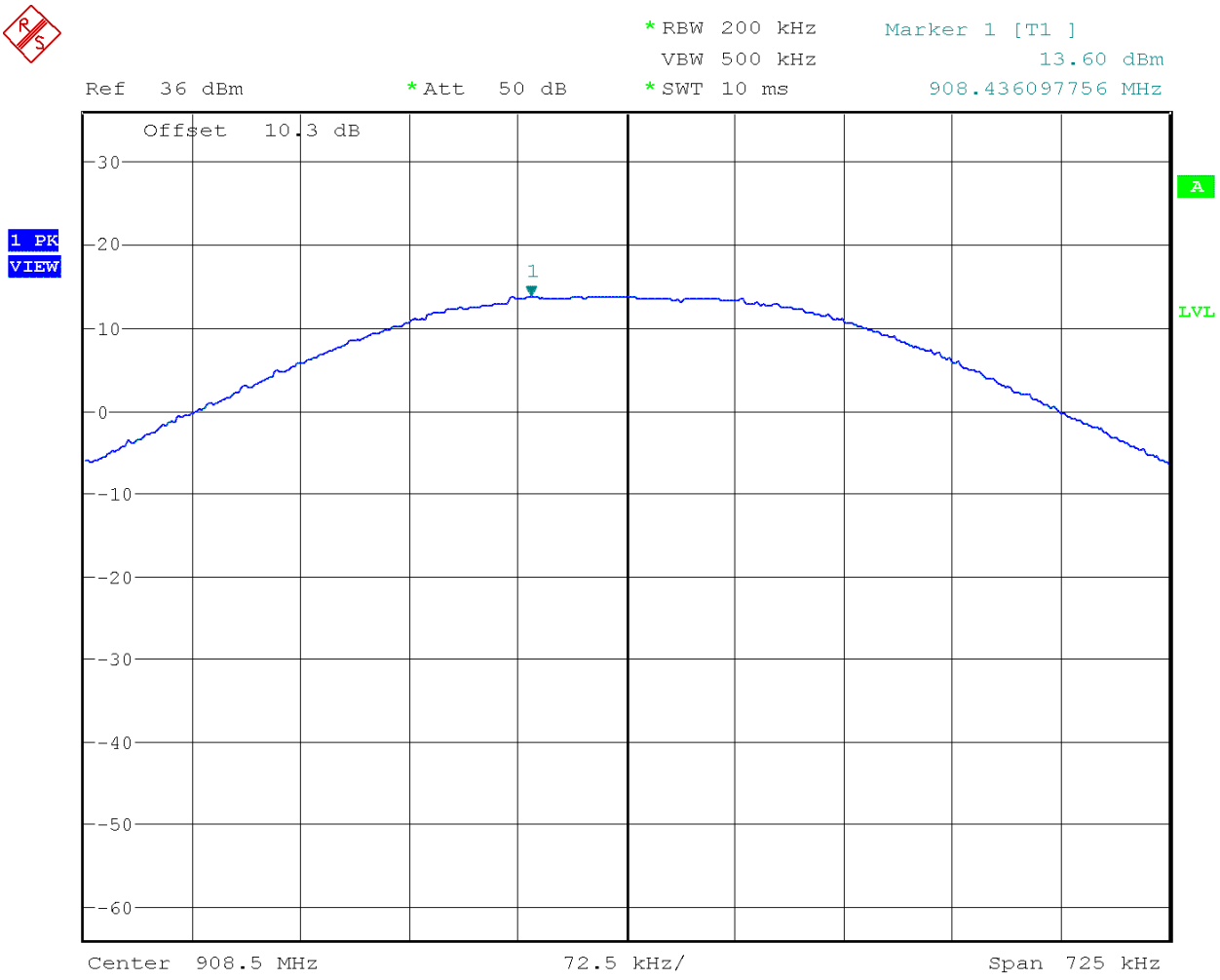
Frequency (MHz)	Measured Conducted Power (dBm)	Conducted Power Limit (dBm)
902.3	13.8	30
908.5	13.6	30
914.5	13.42	30

7.7 Conducted Output Power Spectrum Plots

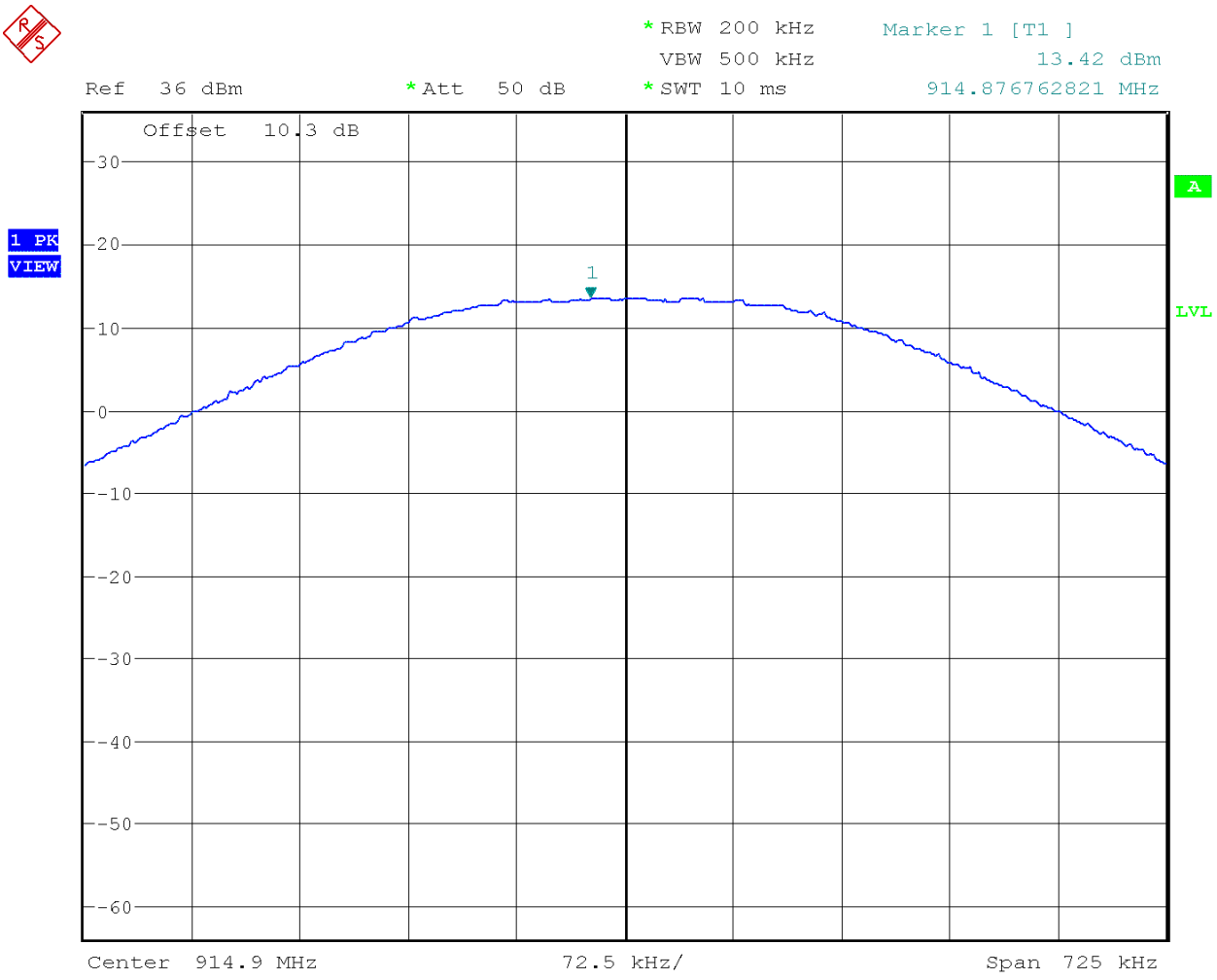
7.7.1 902.3 MHz



7.7.2 908.5 MHz


*RBW 200 kHz
VBW 500 kHz
*SWT 10 ms
Marker 1 [T1]
13.60 dBm
908.436097756 MHz
Ref 36 dBm
*Att 50 dB
Offset 10.3 dB
1 PK
VIEW
A
LVL
30
20
10
0
-10
-20
-30
-40
-50
-60
Center 908.5 MHz
72.5 kHz/
Span 725 kHz

7.7.3 914.9 MHz


*RBW 200 kHz
VBW 500 kHz
*SWT 10 ms
Marker 1 [T1]
13.42 dBm
914.876762821 MHz
Ref 36 dBm
*Att 50 dB
Offset 10.3 dB
1 PK
VIEW
A
LVL
30
20
10
0
-10
-20
-30
-40
-50
-60
Center 914.9 MHz
72.5 kHz/
Span 725 kHz

7.8 Test Conditions

Test Personnel:	David Perry	Test Date:	1/27/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	See Above
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	53.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

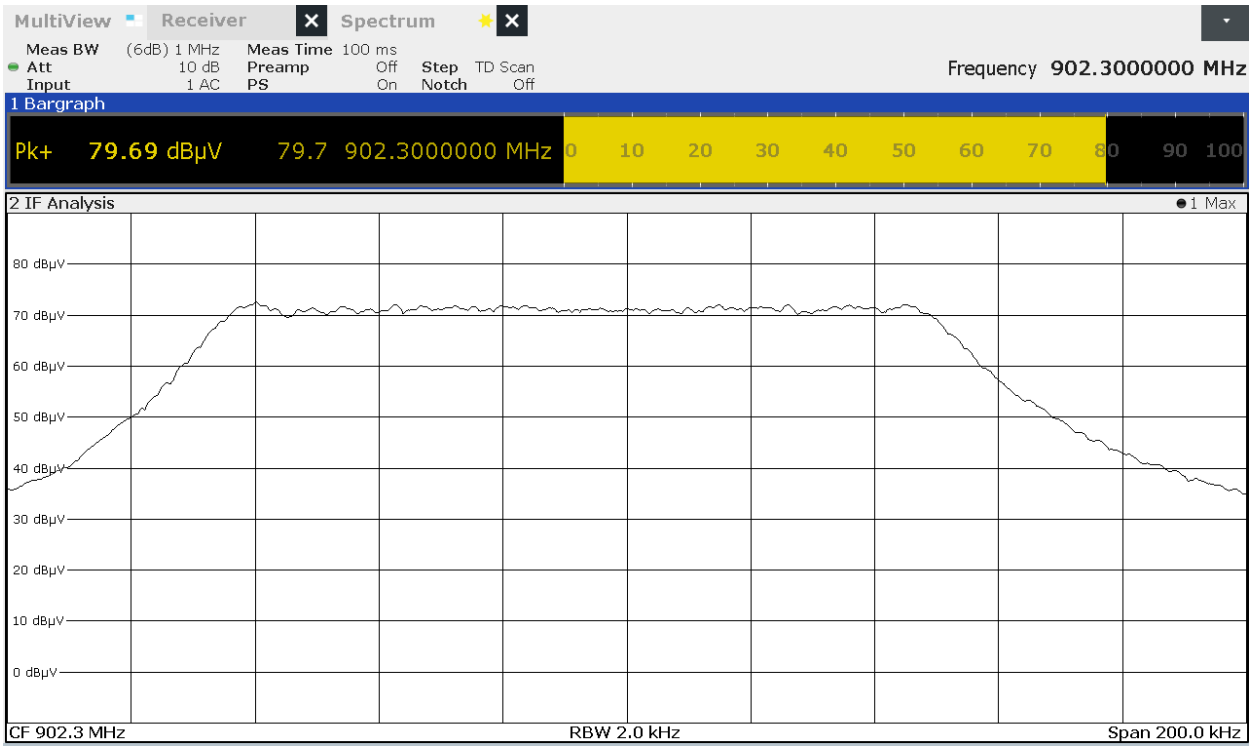
Deviations, Additions, or Exclusions: For EIRP measurements, measured at 3 meters.

7.9 Test Data

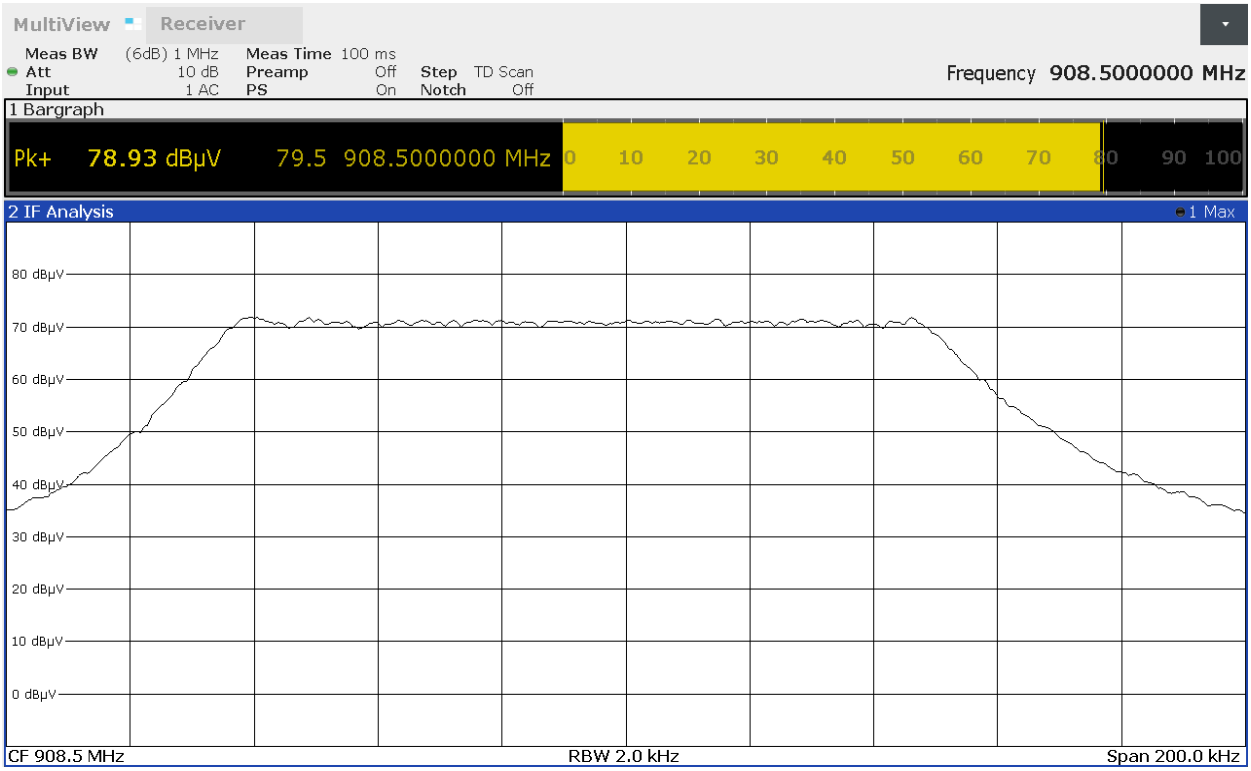
Frequency (MHz)	Receiver Reading (dBµV/m)	Correction (dB/m)	Field Strength (dBµV/m)	EIRP (dBm)	EIRP Limit (dBm)
902.3	79.7	36.8	116.5	21.27	36.02
908.5	79.5	36.8	116.3	21.07	36.02
914.9	79.2	36.8	116.0	20.77	36.02

7.10 EIRP Spectrum Plots

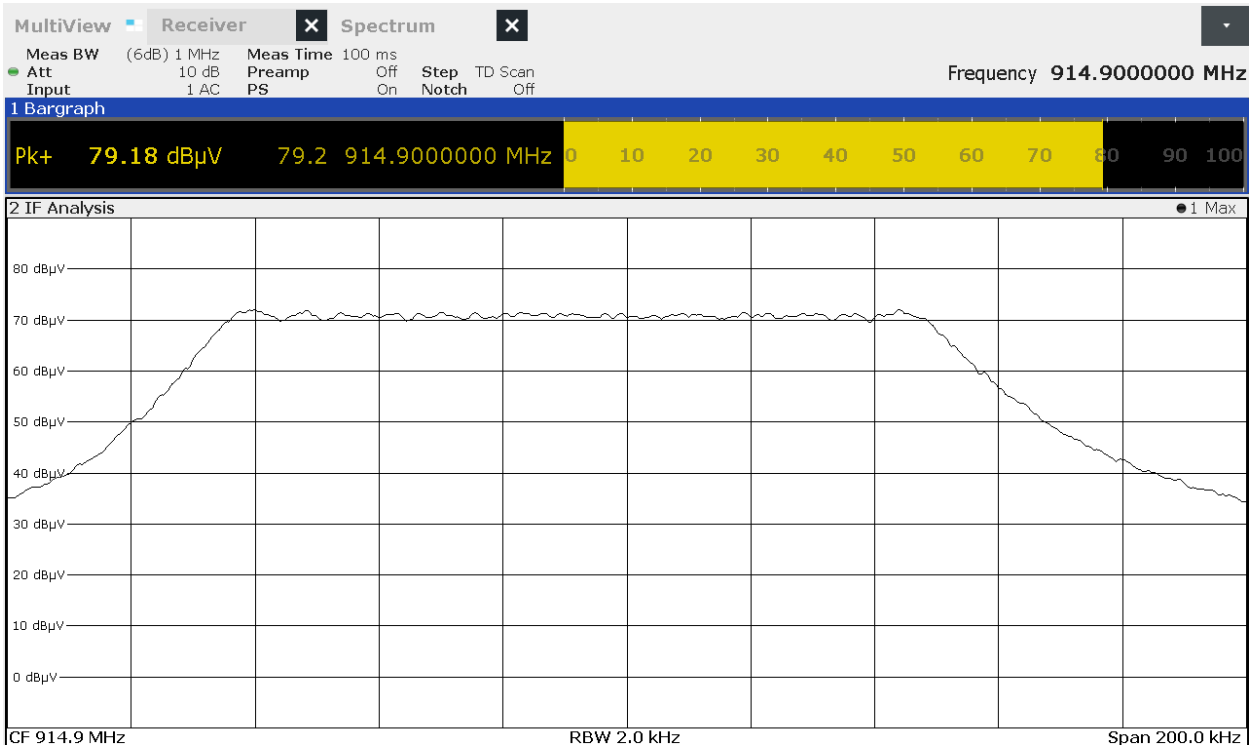
7.10.1 902.3 MHz Max Peak Radiated Power



7.10.2 908.5 MHz Max Peak Radiated Power



7.10.3 908.5 MHz Max Peak Radiated Power



8 Carrier Frequency Separation

8.1 Test Limit

FCC Title 47 CFR Part 15.247(a)(1):

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

RSS-247 Issue 2 § 5.1(b):

FHSs shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, FHSs operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

8.2 Test Method

Tests are performed in accordance with ANSI C63.10: 2013 clause 7.8.2.

8.3 Test Equipment Used:

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
Spectrum Analyzer	3981	Rohde & Schwarz	FSU	9/16/2022	9/16/2023

8.4 Test Results

The device was found to be **compliant**. The carrier frequency separation was at least 146 kHz.

8.5 Test Conditions

Test Personnel:	David Perry	Test Date:	1/5/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	See Above
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	52.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

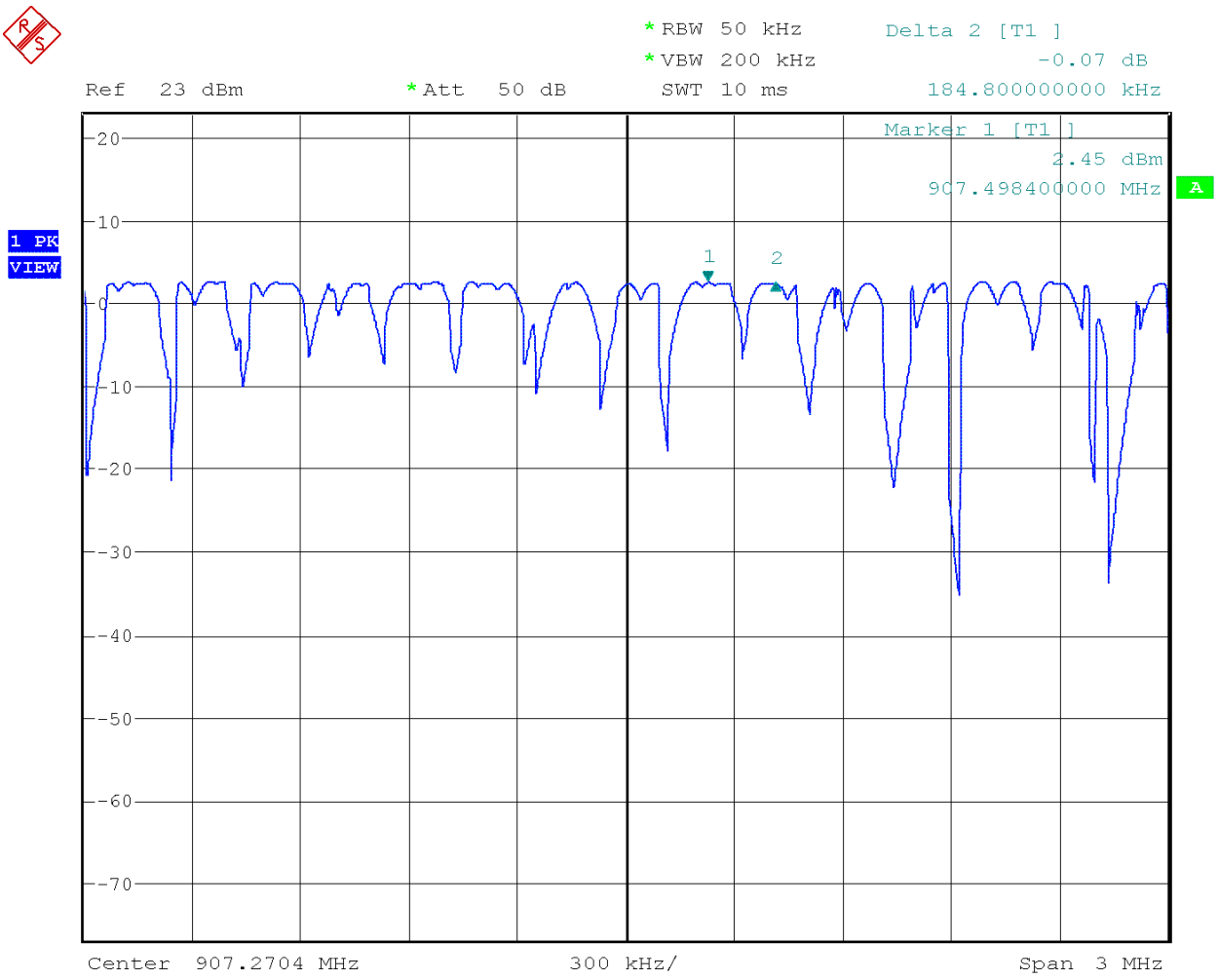
Deviations, Additions, or Exclusions: Limits were applied to the 20dB bandwidth as reported in section 6.6.

8.6 Test Data

Frequency (kHz)	Measured Separation (kHz)	Limit (kHz)
902.3	184.8	≥ 146
908.5		≥ 146

8.7 Spectrum Plots

8.7.1 907.5 MHz



9 Number of Hopping Frequencies

9.1 Test Limits

FCC Part 15.247(a)(1)(i):

For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

RSS-247 Issue 2 § 5.1(c):

For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

9.2 Test Method

Tests are performed in accordance with ANSI C63.10: 2013 clause 7.8.3.

9.3 Test Results

The device was found to be **compliant**. There were 64 measured hopping channels.

9.4 Test Equipment Used:

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
Spectrum Analyzer	3981	Rohde & Schwarz	FSU	9/16/2022	9/16/2023

9.5 Test Conditions

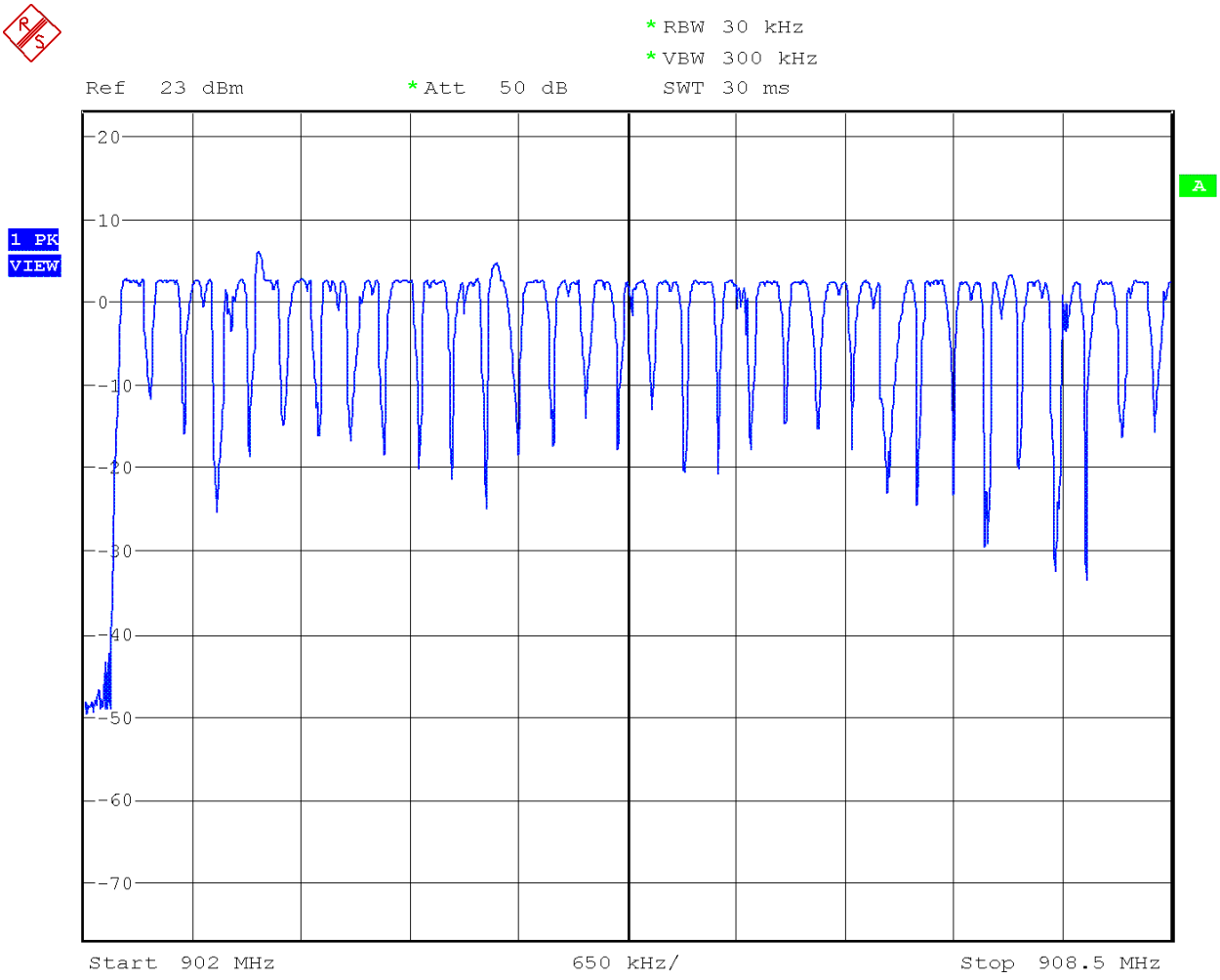
Test Personnel:	David Perry	Test Date:	1/5/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	See Above
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	52.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

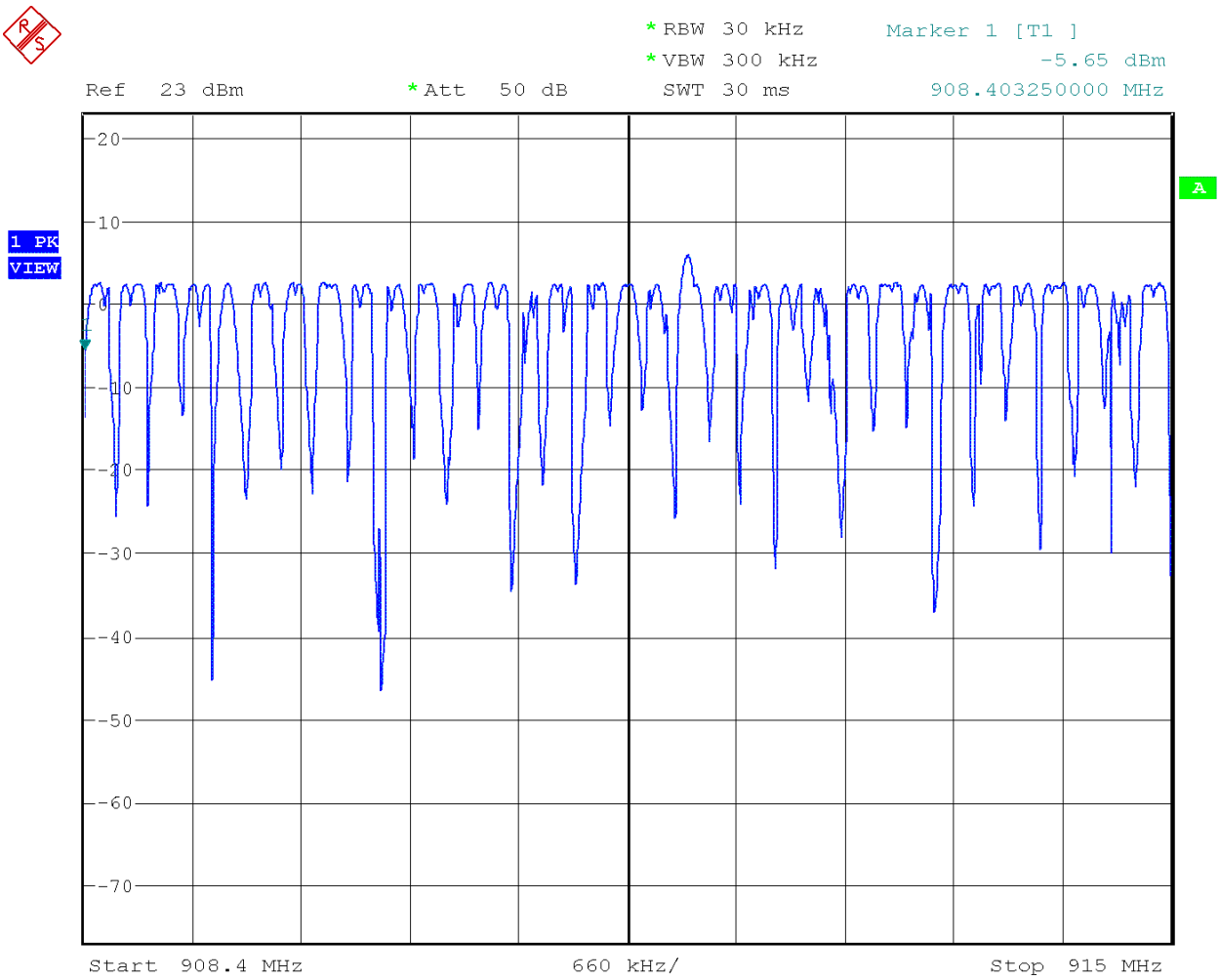
Deviations, Additions, or Exclusions: None

9.6 Test Data

Operating Mode	Measured Value (Count)	Limit
FHSS	64	≥ 50

9.7 Spectrum Plots




RBW 30 kHz
VBW 300 kHz
SWT 30 ms
Marker 1 [T1]
-5.65 dBm
908.403250000 MHz
Ref 23 dBm
Att 50 dB
1 PK
VIEW
A
20
10
0
-10
-20
-30
-40
-50
-60
-70
Start 908.4 MHz
660 kHz/
Stop 915 MHz

10 Time of Occupancy

10.1 Test Limits

FCC Part 15.247(a)(1)(i):

For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

RSS-247 Issue 2 § 5.1(c):

For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

10.2 Test Method

Tests are performed in accordance with ANSI C63.10: 2013 clause 7.8.4.

10.3 Test Equipment Used:

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
Spectrum Analyzer	3981	Rohde & Schwarz	FSU	9/16/2022	9/16/2023

10.4 Test Results

The device was found to be **compliant**. The maximum accumulated transmit time on any single channel was less than 0.4 seconds within a 20 second period.

10.5 Test Conditions

Test Personnel:	David Perry	Test Date:	1/5/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	See Above
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	52.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

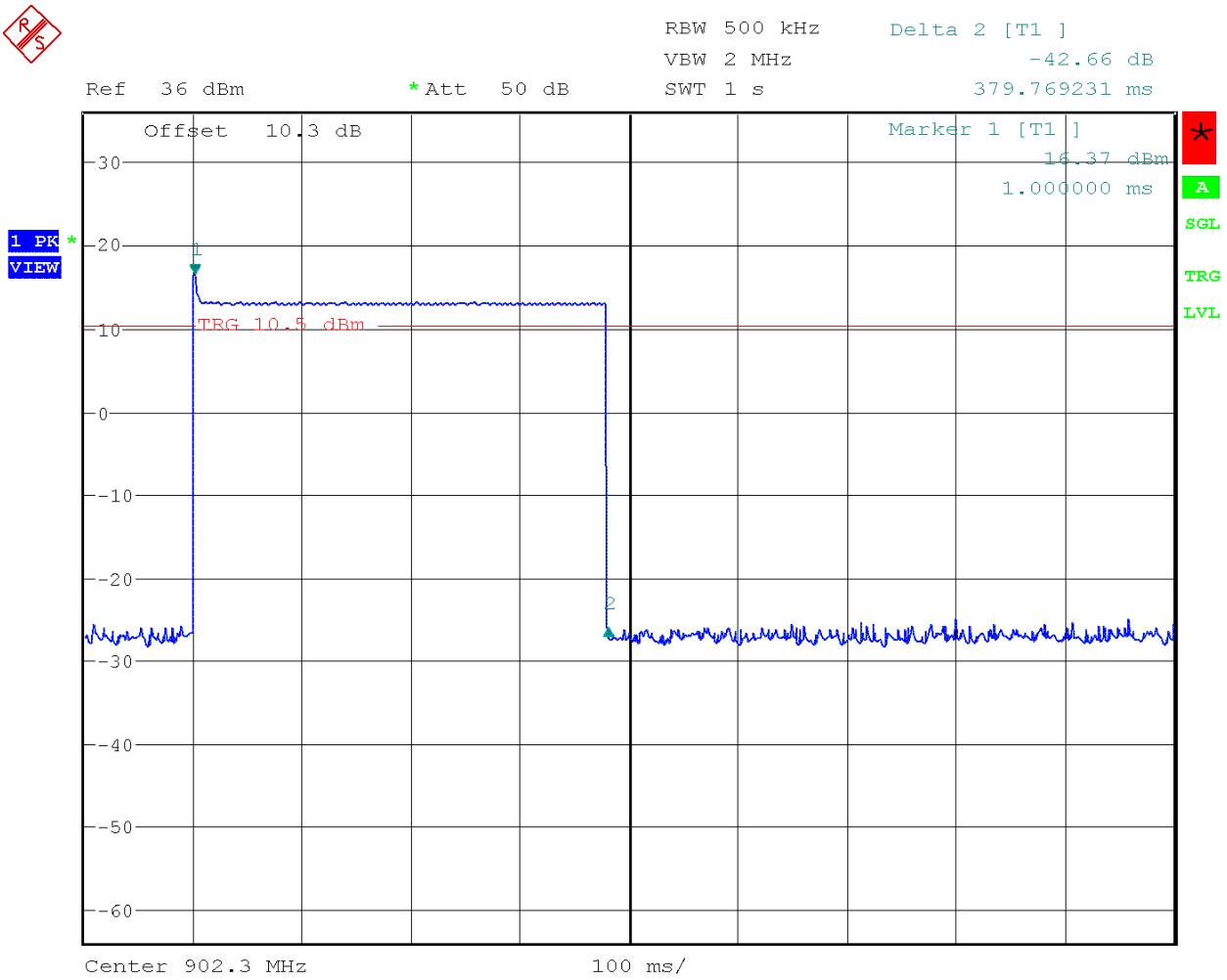
Deviations, Additions, or Exclusions: Frequency hopping sweeps show lower amplitude emissions caused by adjacent channels. The emission of the measured channel is higher amplitude and occupations of this channel are approximately 128 seconds apart.

10.6 Test Data

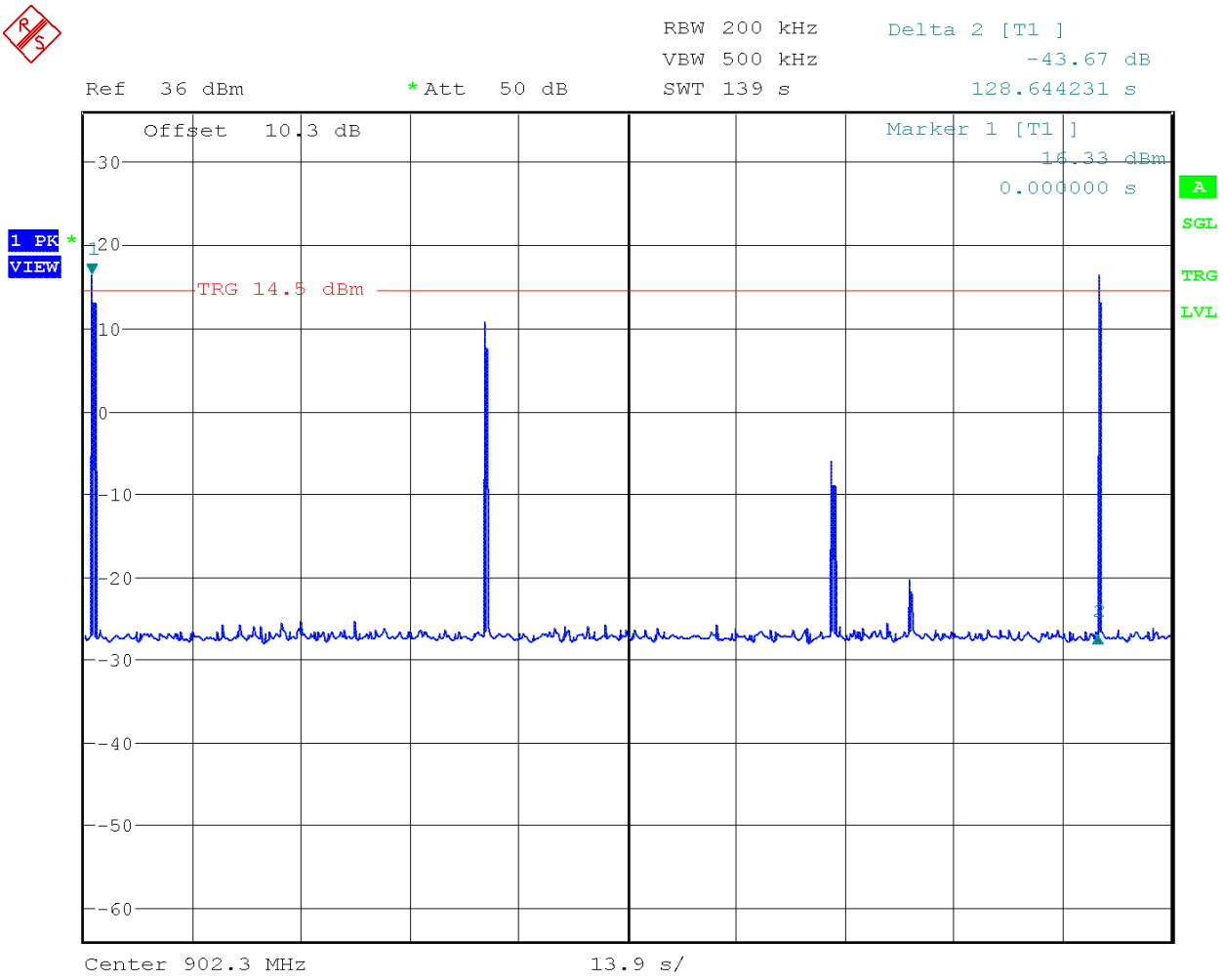
Frequency (MHz)	Pulse Width (ms)	Number of hops per channel in 20 seconds	Time of Occupancy (ms)	Limit (ms)
902.3	379.769231	1	379.769231	≤ 400
908.5	380.769231	1	380.769231	≤ 400
914.5	380.769231	1	380.769231	≤ 400

10.7 Spectrum Plots

10.7.1 902.3 MHz, Pulse Width

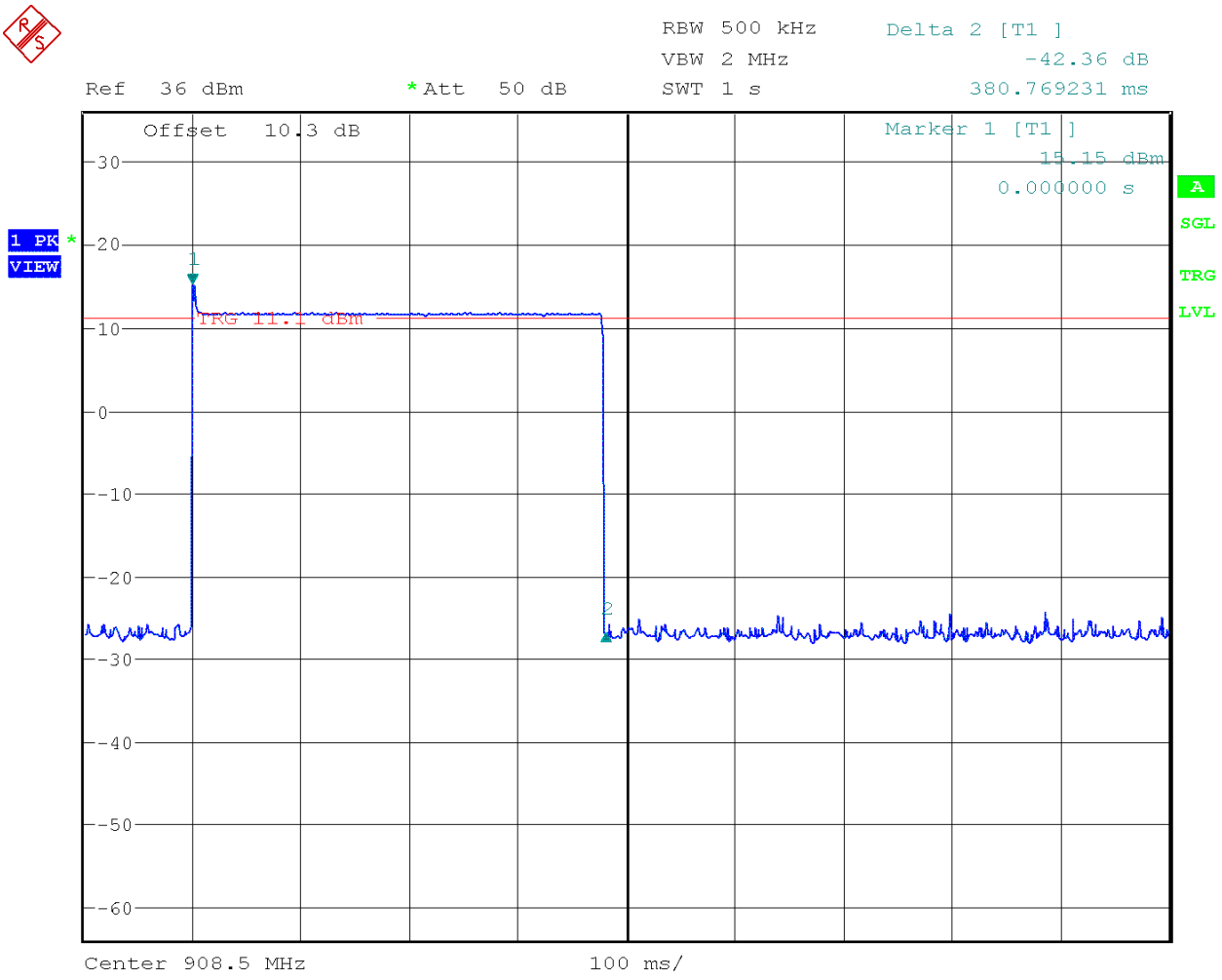


10.7.2 902.3 MHz, Number of Hops in 139s

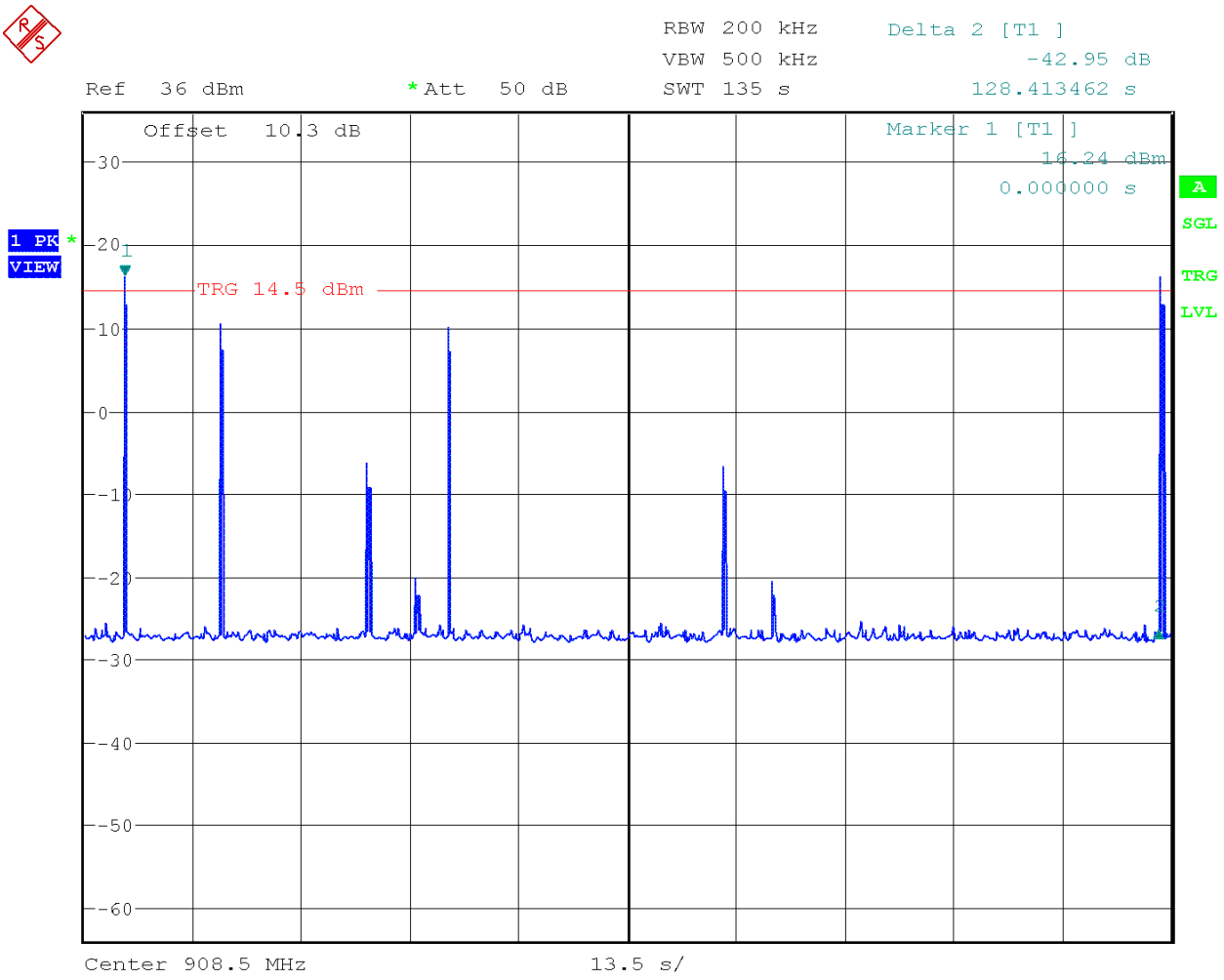


Note: Lower amplitude emissions are cause by adjacent channel leakage and do not represent channels under test.

10.7.3 908.5 MHz, Pulse Width

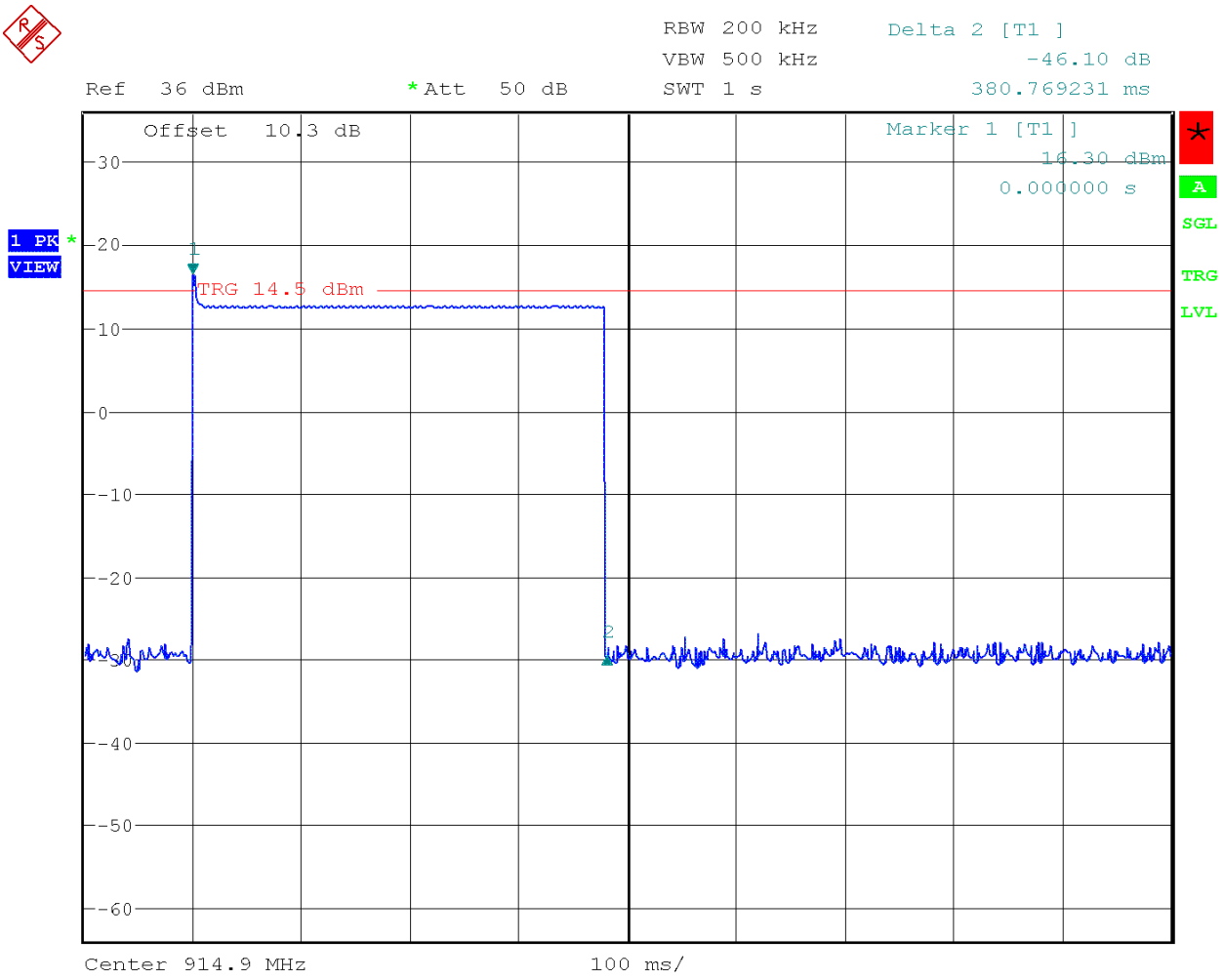


10.7.4 908.5 MHz, Number of Hops in 139

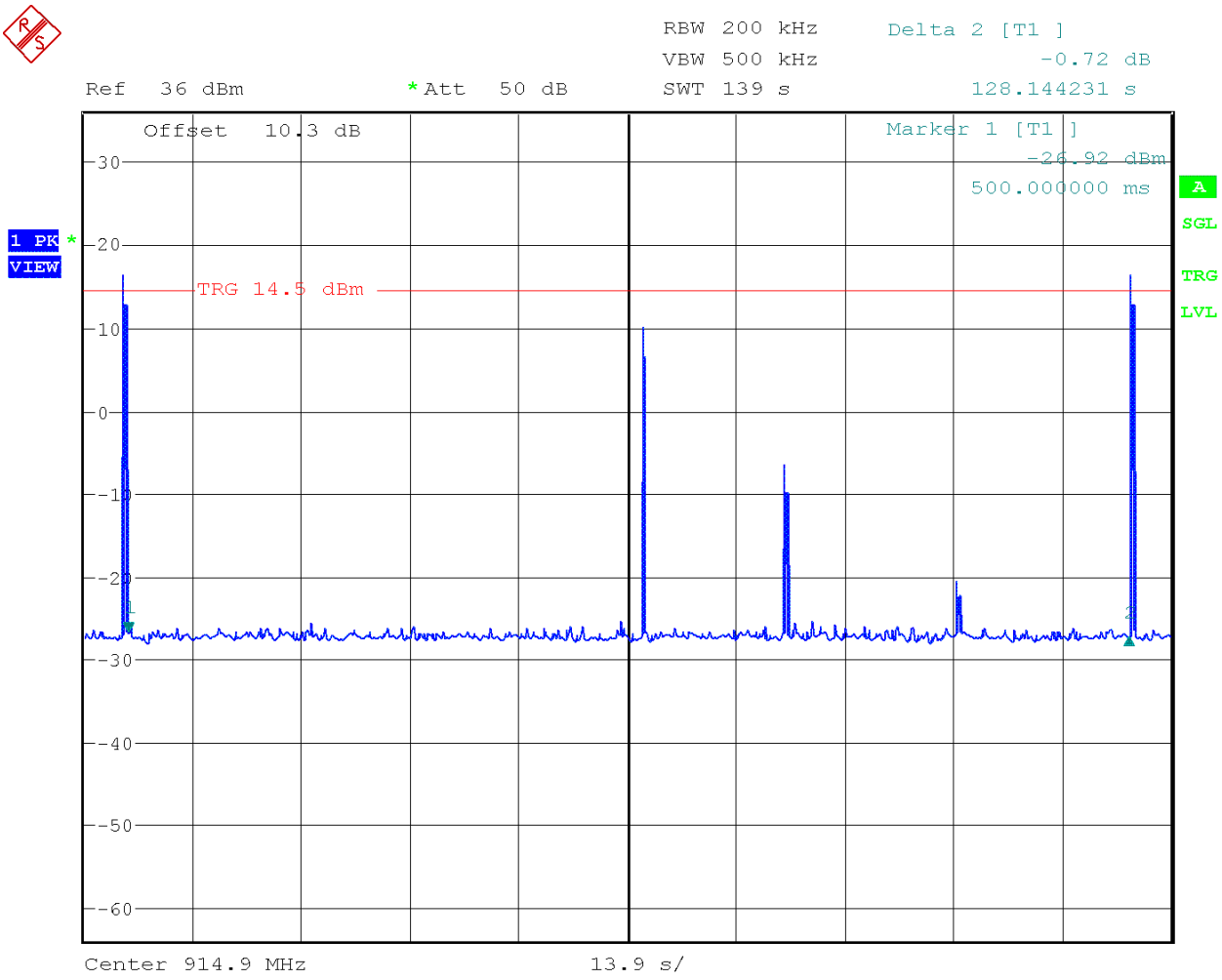


Note: Lower amplitude emissions are cause by adjacent channel leakage and do not represent channels under test.

10.7.5 914.9 MHz, Pulse Width



10.7.6 914.9 MHz, Number of Hops in 139s



Note: Lower amplitude emissions are cause by adjacent channel leakage and do not represent channels under test.

11 Radiated Spurious Emissions & Band Edge

11.1 Test Limits

FCC Part 15.247(d):

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

RSS-247 Issue 2 § 5.5:

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

11.2 Test Method

Tests are performed in accordance with ANSI C63.10:2013 § 11.12.1 Radiated emission measurements.

TEST SITE: 10m ALSE

Site Designation: 10m Chamber

Measurement Uncertainty

Measurement	Frequency Range	Expanded Uncertainty (k=2)	Ucispr
Radiated Emissions, 10m	30-1000 MHz	3.9dB	6.3 dB
Radiated Emissions, 3m	30-1000 MHz	4.0dB	6.3 dB
Radiated Emissions, 3m	1-6 GHz	4.7dB	5.2 dB
Radiated Emissions, 3m	6-15 GHz	4.7dB	5.5 dB
Radiated Emissions, 3m	15-18 GHz	4.7dB	5.5 dB
Radiated Emissions, 3m	18-40 GHz	4.7dB	5.5 dB

As shown in the table above our radiated emissions U_{lab} is less than the corresponding U_{CISPR} reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required.

11.3 Sample Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

FS = RA + AF + CF - AG

Where FS = Field Strength in dBμV/m
RA = Receiver Amplitude (including preamplifier) in dBμV
CF = Cable Attenuation Factor in dB
AF = Antenna Factor in dB
AG = Amplifier Gain in dB

In the following table(s), the reading shown on the data table reflects the preamplifier gain. An example for the calculations in the following table is as follows.

Assume a receiver reading of 52.0 dBμV is obtained. The antenna factor of 7.4 dB and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving a field strength of 32 dBμV/m. This value in dBμV/m was converted to its corresponding level in μV/m.

RA = 52.0 dBμV
AF = 7.4 dB/m
CF = 1.6 dB
AG = 29.0 dB
FS = 32 dBμV/m

To convert from dBμV to μV or mV the following was used:

$UF = 10^{(NF / 20)}$ where UF = Net Reading in μV
NF = Net Reading in dBμV

Example:

FS = RA + AF + CF – AG = 52.0 + 7.4 + 1.6 – 29.0 = 32.0
$UF = 10^{(32\ dB\mu V / 20)}$ = 39.8 μV/m

11.4 Test Equipment Used

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
EMI Test Receiver	8285	Rohde & Schwarz	EW44	12/23/2022	12/23/2023
Bilog Antenna	3133	ETS	3142C	8/10/2022	8/10/2023
Horn Antenna (1-18GHz)	3780	ETS	3117	8/19/2022	8/19/2023
System Controller	4096	ETS Lindgren	2090	Verify at Time of Use	Verify at Time of Use
System Controller	3957	Sunol Sciences	SC99V	Verify at Time of Use	Verify at Time of Use
Preamplifier	3918	Rohde & Schwarz	TS-PR18	1/13/2022	1/13/2023
Coaxial Cable	3074			1/13/2022	1/13/2023
Coaxial Cable	2588			1/13/2022	1/13/2023
Coaxial Cable	2593			1/13/2022	1/13/2023
Coaxial Cable	8185			1/13/2022	1/13/2023
Coaxial Cable	8188			1/13/2022	1/13/2023
Coaxial Cable	3339			1/13/2022	1/13/2023
Preamplifier	3919	Rohde & Schwarz	TS-PR3	1/13/2022	1/13/2023
Coaxial Cable	3172			1/13/2022	1/13/2023
Coaxial Cable	2590			1/13/2022	1/13/2023
Coaxial Cable	8186			1/13/2022	1/13/2023
Coaxial Cable	8187			1/13/2022	1/13/2023
Coaxial Cable	7020			1/13/2022	1/13/2023
Coaxial Cable	7021			1/13/2022	1/13/2023
Magnetic Loop Antenna	2366	ETS	6502	8/22/2022	8/22/2023

11.5 Software Utilized

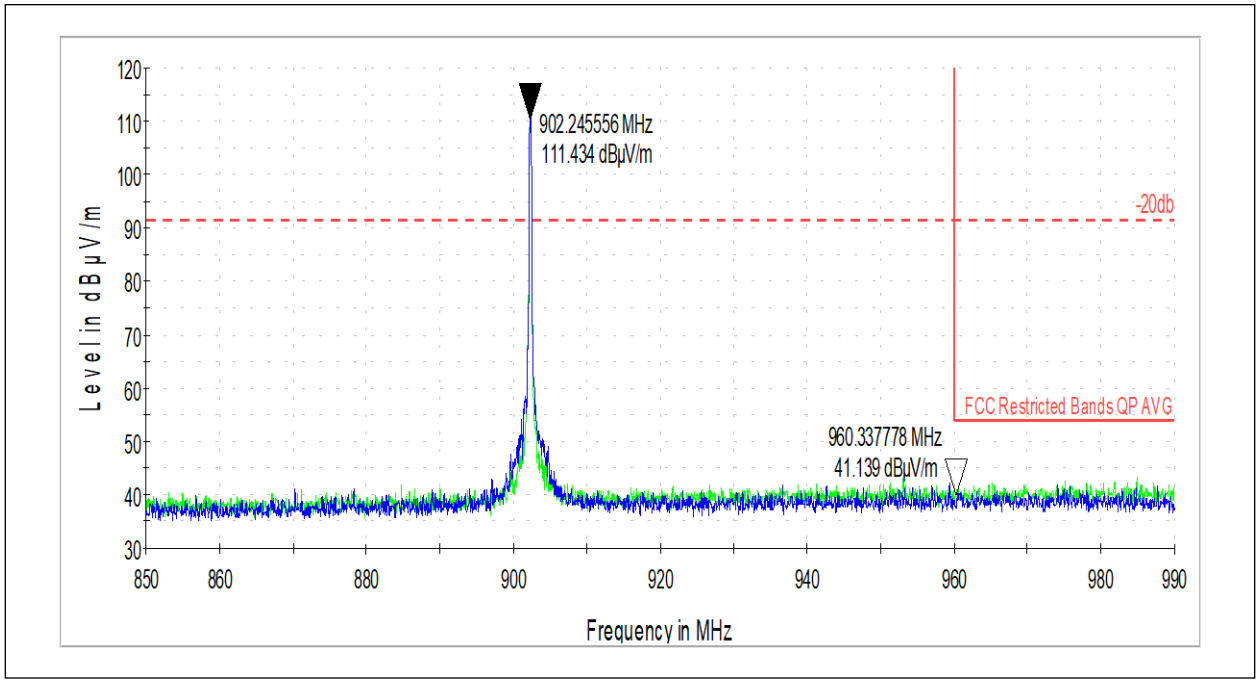
Name	Manufacturer	Version
EMC32	Rohde & Schwarz	Version 10.60.20

11.6 Test Results

The sample tested was found to be **compliant**. The data presented represents the worst-case emissions with the device positioned in three orthogonal positions. All observed emissions outside of the band of operation were attenuated by at least 20dB.

11.7 Test Data: Radiated Band Edge

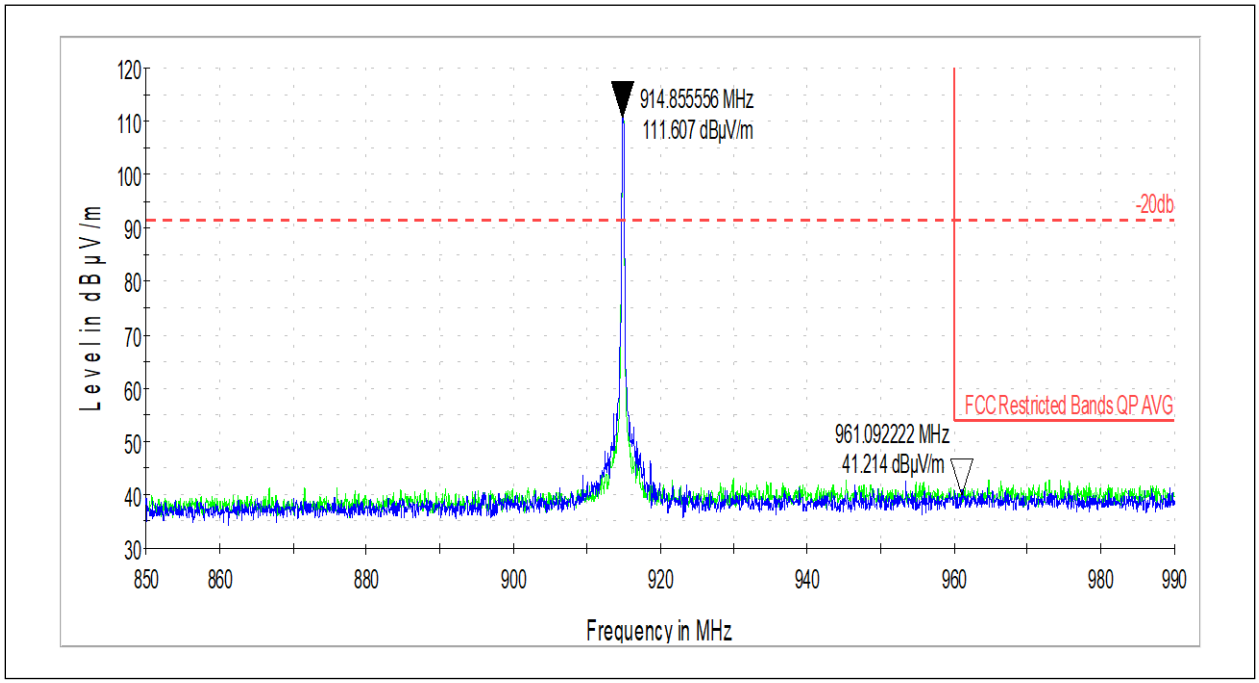
11.7.1 902.3 MHz



Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: EUT is operating at 902.3MHz, marker shows lower frequency due to limited resolution with an RBW of 120KHz.

11.7.2 914.9 MHz

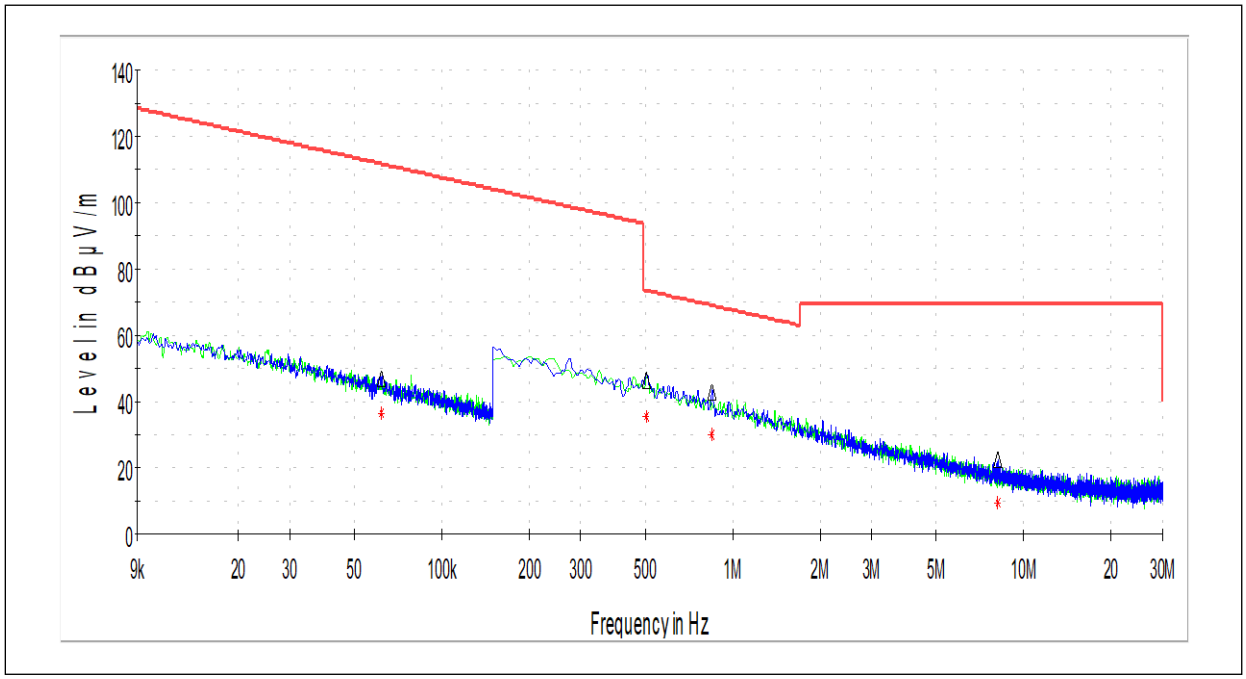


Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: EUT is operating at 914.9MHz, marker shows lower frequency due to limited resolution with an RBW of 120KHz.

11.8 Test Data: 9kHz – 30MHz

11.8.1 908.5MHz



Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Azimuth (deg)	Corr. (dB/m)
0.061875	46.95	131.76	84.81	0.200	0.0	12.5
0.505566	46.39	93.53	47.14	9.000	233.0	11.6
0.847963	42.83	89.05	46.22	9.000	279.0	11.5
8.117316	22.67	89.50	46.22	9.000	0.0	10.7

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Azimuth (deg)	Corr. (dB/m)
0.061875	36.56	111.76	75.20	0.200	0.0	12.5
0.505566	35.47	73.53	38.06	9.000	233.0	11.6
0.847963	30.10	69.05	38.95	9.000	279.0	11.5
8.117316	9.47	69.50	60.03	9.000	0.0	10.7

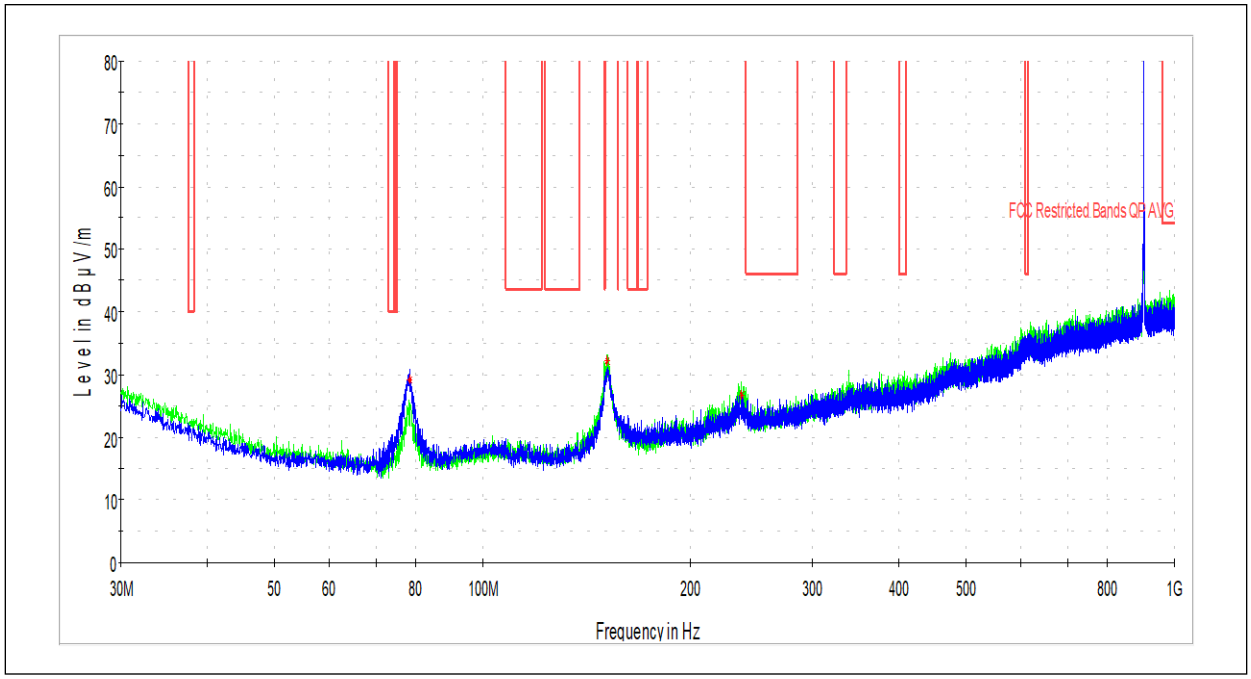
Test Personnel:	David Perry	Test Date:	1/17/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: Measurements with a max peak detector showed compliance with the quasi-peak limit and thereby the device is deemed to comply.

Note: Testing represents worst case of low, middle, and high channels.

11.9 Test Data: 30 MHz – 1 GHz

11.9.1 902.3 MHz

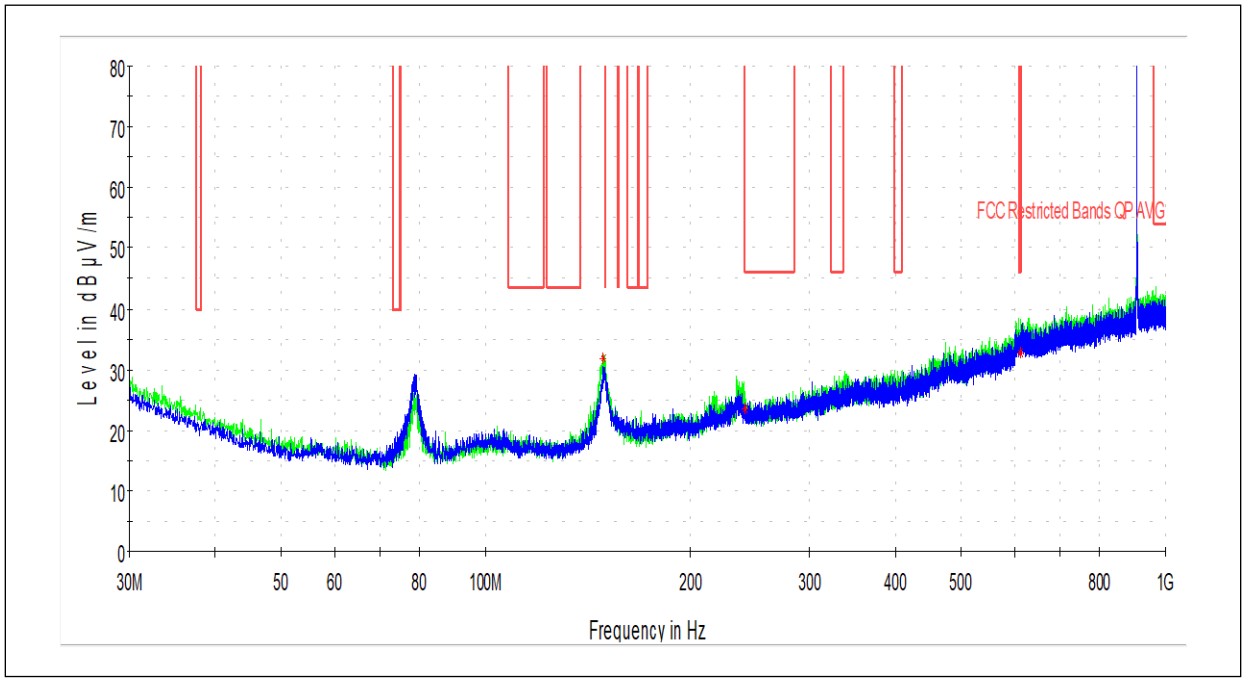


Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
78.446111	29.09	-	-	120.000	105.0	V	209.0	14.0
151.303889	32.16	-	-	120.000	156.0	H	199.0	17.7
236.502222	26.66	-	-	120.000	99.0	H	146.0	21.3

Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: None

11.9.2 908.5 MHz

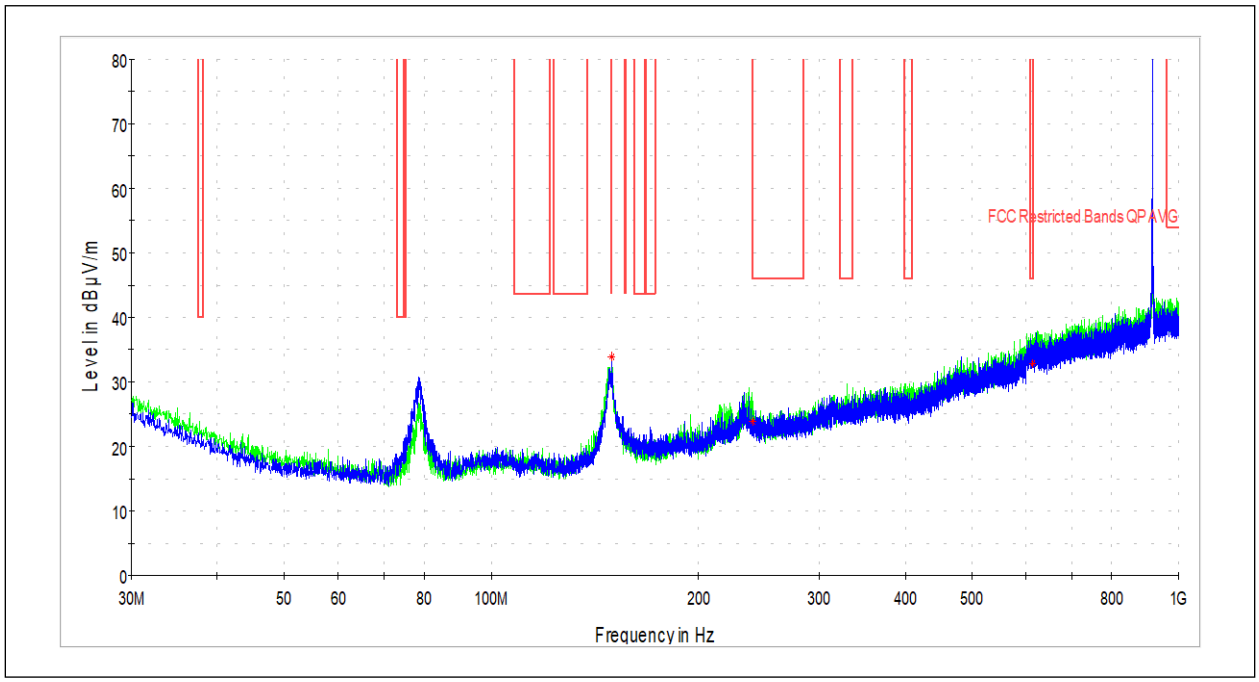


Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
149.040556	31.93	-	-	120.000	171.0	H	208.0	17.5
240.597778	23.58	46.02	22.44	120.000	95.0	H	136.0	21.5
611.946111	32.81	46.02	13.21	120.000	183.0	H	218.0	32.6

Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: None

11.9.3 914.9 MHz



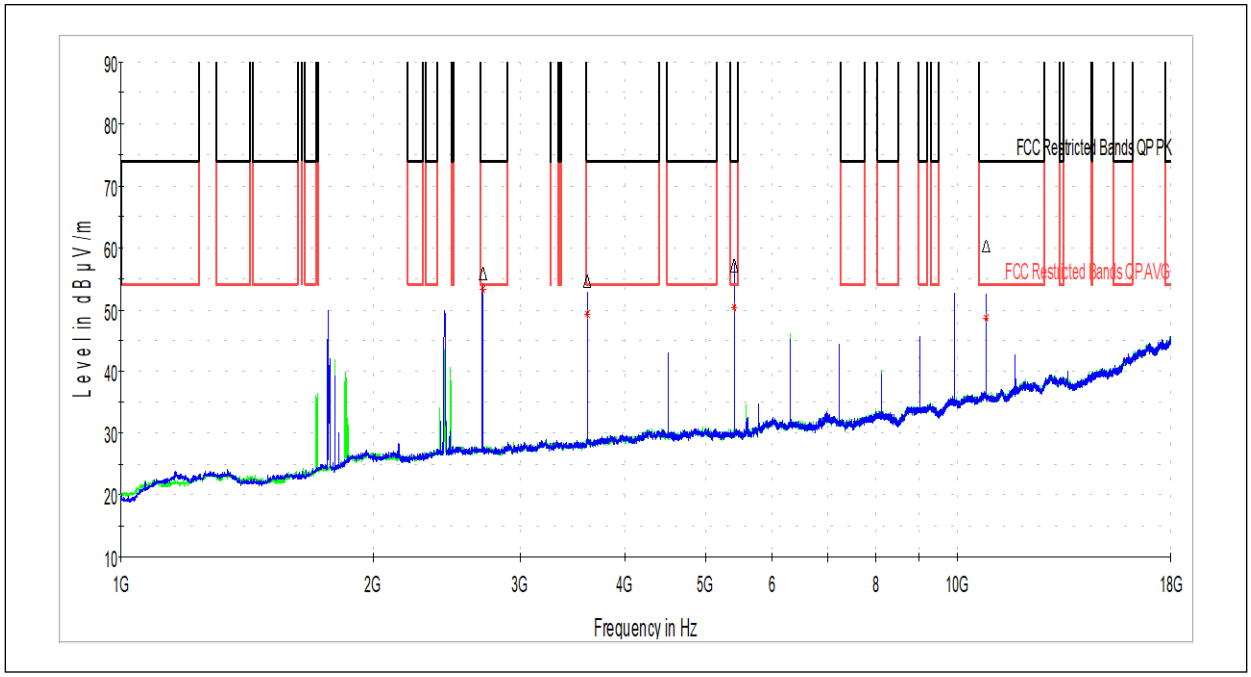
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
150.010556	33.83	43.52	9.69	120.000	143.0	H	210.0	17.6
240.382222	23.91	46.02	22.11	120.000	115.0	H	146.0	21.5
612.538889	32.84	46.02	13.18	120.000	268.0	H	320.0	32.7

Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: None

11.10 Test Data: 1 GHz – 18 GHz

11.10.1 902.3 MHz



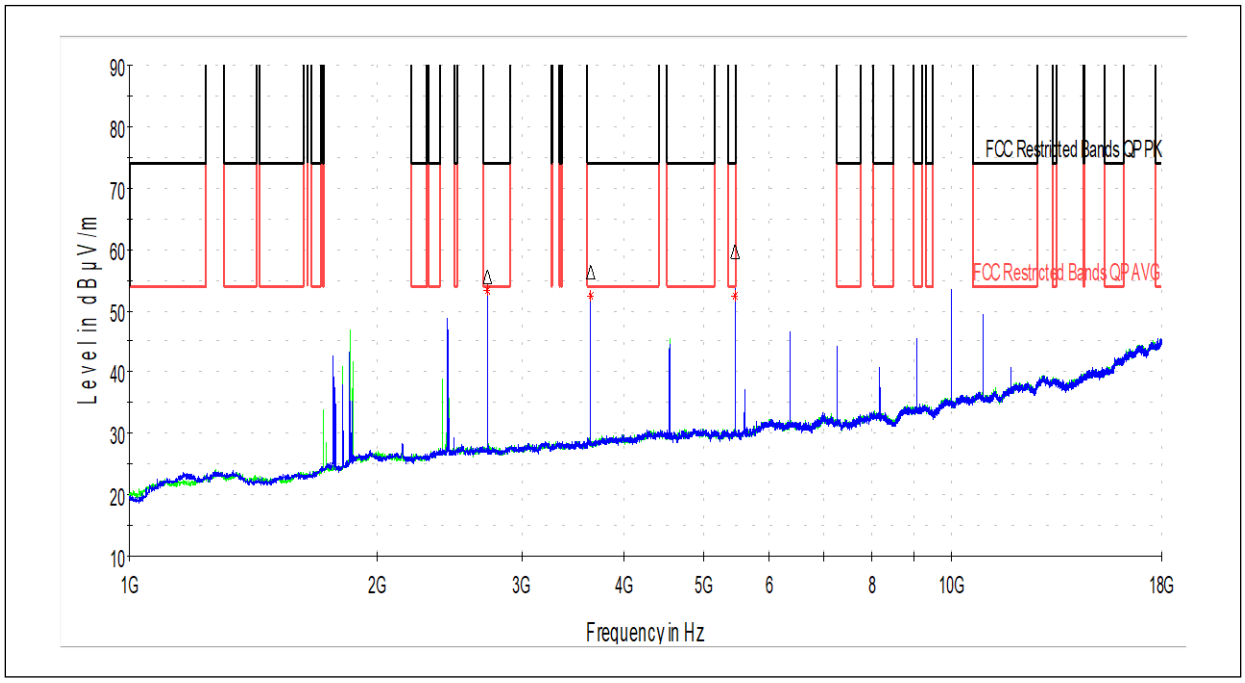
Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2707.000000	55.84	73.98	18.14	1000.000	390.0	V	252.0	4.8
3609.000000	54.65	73.98	19.33	1000.000	209.0	V	162.0	6.6
5414.000000	57.11	73.98	16.87	1000.000	270.0	V	239.0	9.8
10827.500000	60.37	73.98	13.61	1000.000	100.0	V	304.0	18.4

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2707.000000	53.27	53.98	0.71	1000.000	390.0	V	252.0	4.8
3609.000000	49.33	53.98	4.65	1000.000	209.0	V	162.0	6.6
5414.000000	50.32	53.98	3.66	1000.000	270.0	V	239.0	9.8
10827.500000	48.51	53.98	5.47	1000.000	100.0	V	304.0	18.4

Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: None

11.10.2 908.5 MHz



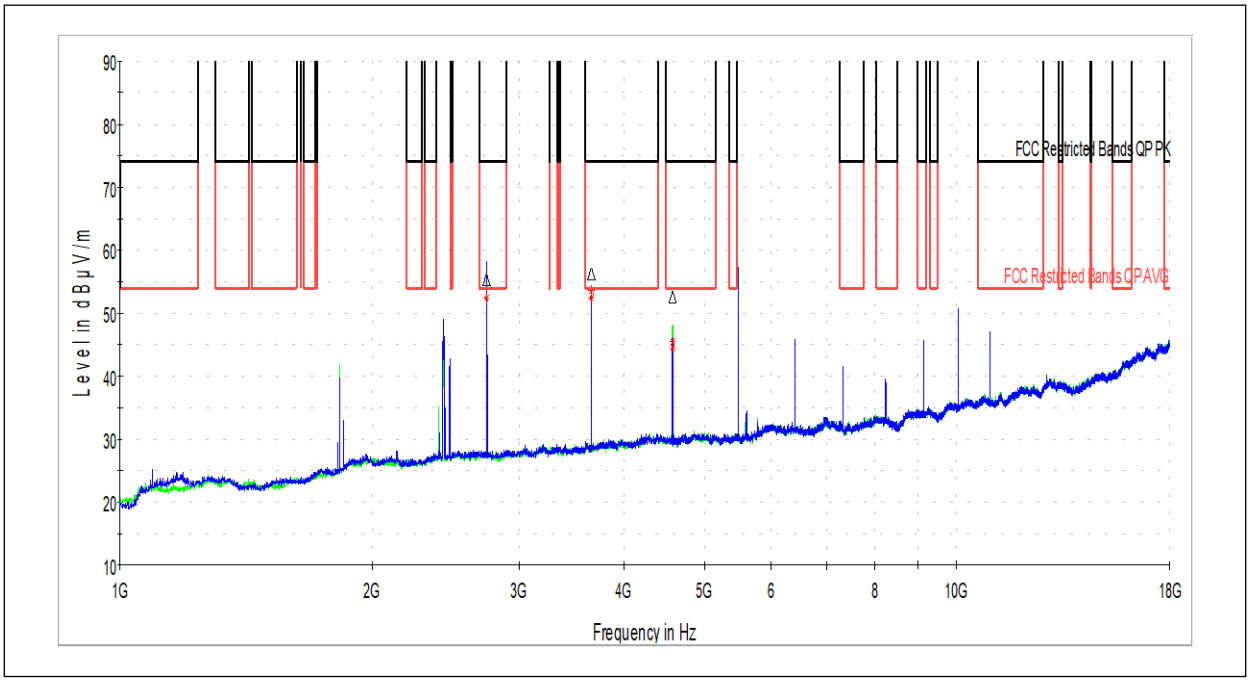
Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2725.500000	55.57	73.98	18.41	1000.000	392.0	V	247.0	4.7
3634.000000	56.28	73.98	17.70	1000.000	252.0	V	184.0	6.5
5450.500000	59.74	73.98	14.24	1000.000	220.0	V	186.0	9.7

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2725.500000	53.36	53.98	0.62	1000.000	392.0	V	247.0	4.7
3634.000000	52.44	53.98	1.54	1000.000	252.0	V	184.0	6.5
5450.500000	52.44	53.98	1.54	1000.000	220.0	V	186.0	9.7

Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: None

11.10.3 914.9 MHz



Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2744.500000	55.38	73.98	18.60	1000.000	382.0	V	257.0	4.7
3659.500000	56.36	73.98	17.62	1000.000	249.0	V	182.0	6.6
4574.500000	52.61	73.98	21.37	1000.000	166.0	H	66.0	9.2

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2744.500000	52.31	53.98	1.67	1000.000	382.0	V	257.0	4.7
3659.500000	52.37	53.98	1.61	1000.000	249.0	V	182.0	6.6
4574.500000	44.46	53.98	9.52	1000.000	166.0	H	66.0	9.2

Test Personnel:	David Perry	Test Date:	12/27/2022
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	Limits from 15.209 in restricted bands from 15.205.
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	22.0C
Input Voltage:	6V DC	Relative Humidity:	21.6%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	992.4mbar

Deviations, Additions, or Exclusions: None

12 Conducted Spurious Emissions

12.1 Test Limits

FCC Part 15.247(d):

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

RSS-247 Issue 2 § 5.5:

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

12.2 Test Method

Tests are performed in accordance with ANSI C63.10:2013 § 11.11 Emissions in nonrestricted frequency bands.

12.3 Test Equipment Used

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
EMI Test Receiver	3900	Rohde & Schwarz	ESU40	10/5/2022	10/5/2023

12.4 Test Results

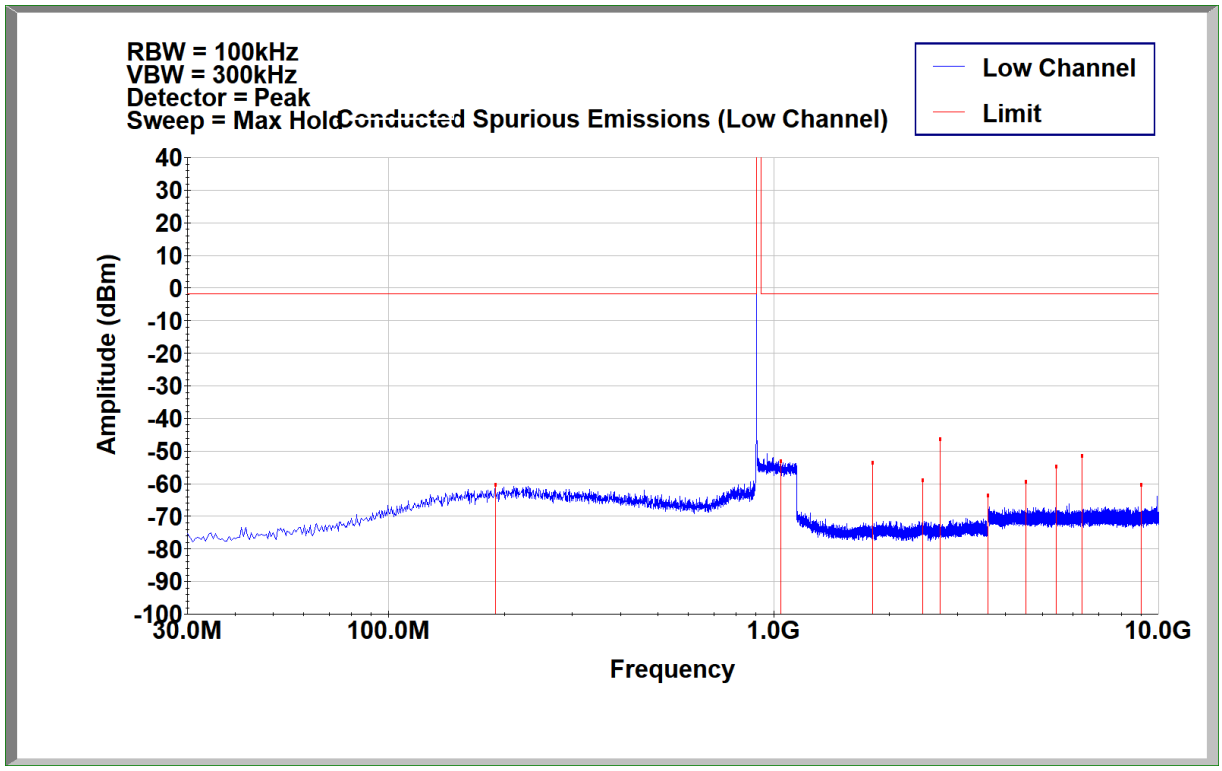
The device was found to be **compliant**. All spurious emissions were found to be attenuated more than 20dB below the level of the fundamental.

Test Personnel:	David Perry	Test Date:	1/5/2023
Supervising/Reviewing Engineer:	Brian Lackey	Limit Applied:	See Above
Product Standard:	FCC Part 15.247 & RSS-247 Issue 2	Ambient Temperature:	25.6C
Input Voltage:	6V DC	Relative Humidity:	52.2%
Pretest Verification w / Ambient Signals or BB Source:	Yes	Atmospheric Pressure:	985.4mbar

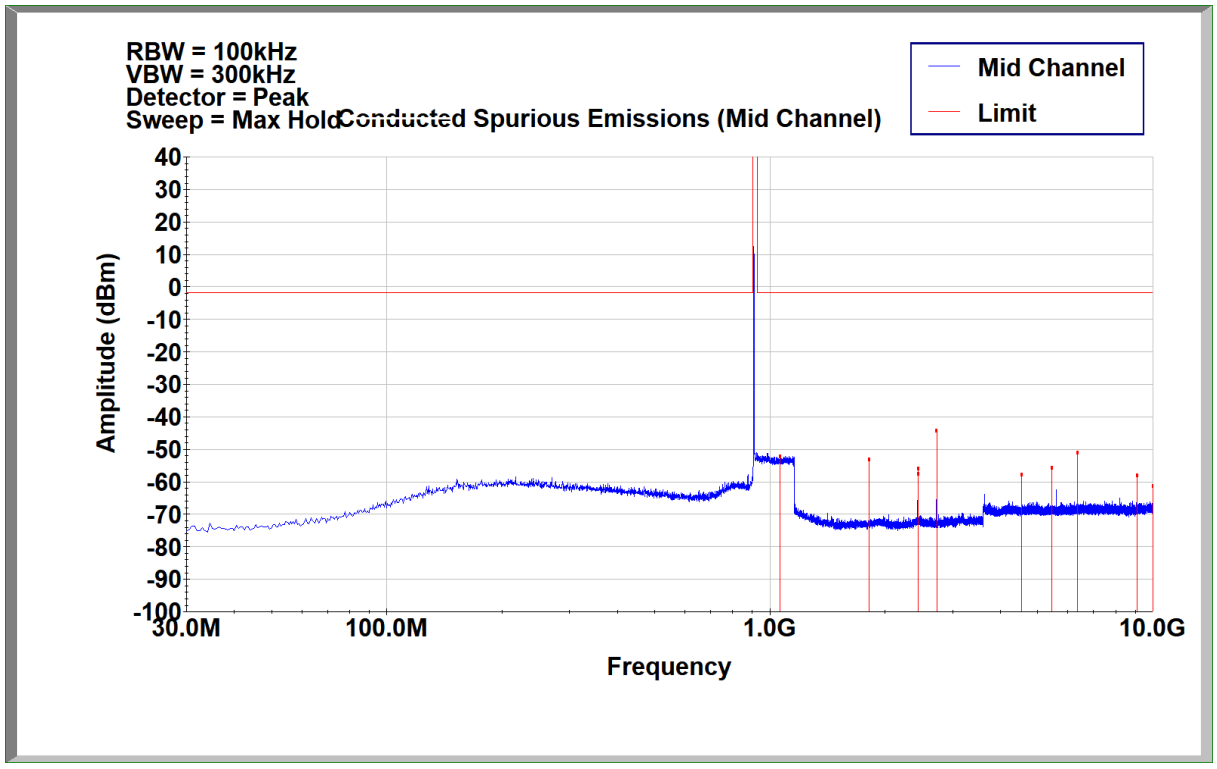
Deviations, Additions, or Exclusions: None

12.5 Test Data

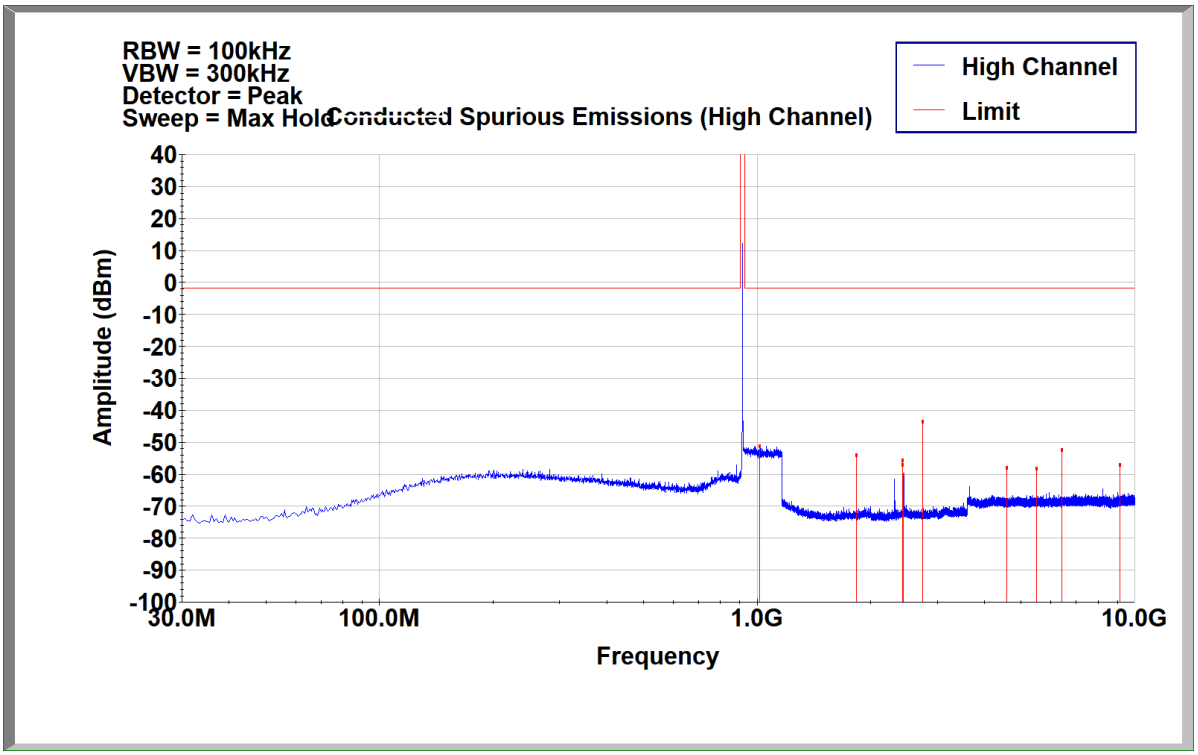
12.5.1 902.3 MHz



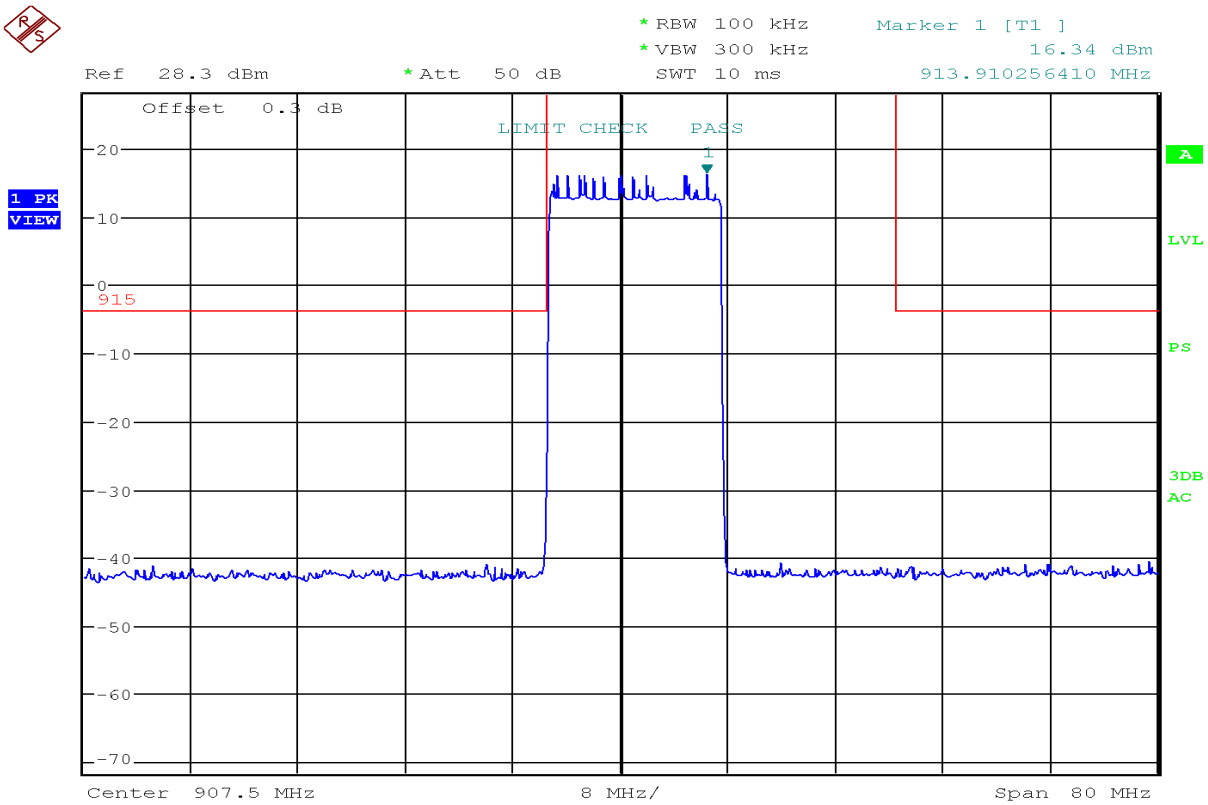
12.5.2 908.5 MHz



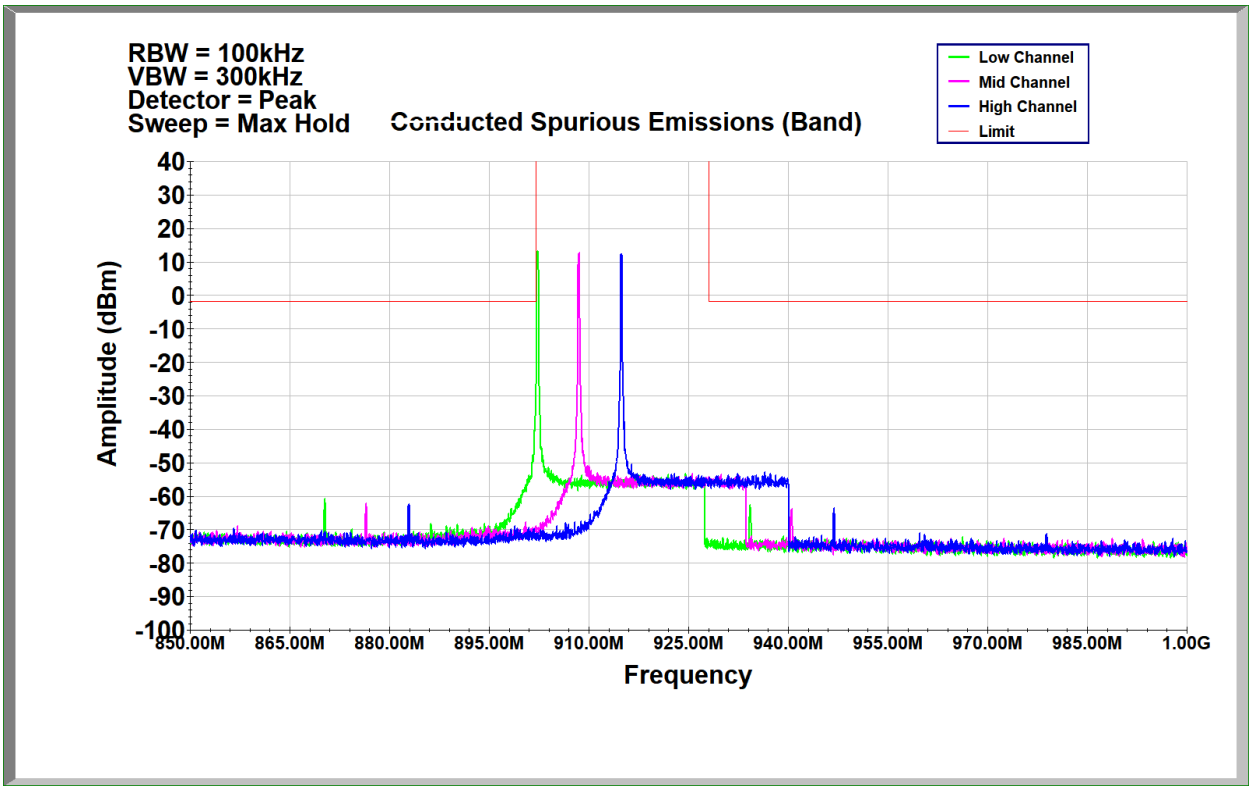
12.5.3 914.5 MHz



12.5.4 FHSS On



12.5.5 Band Edge



13 Antenna Requirement

13.1 Test Limits

FCC Part 15.203:

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of §§15.211, 15.213, 15.217, 15.219, 15.221, or §15.236. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

RSS-Gen Issue 5 § 6.8:

The applicant for equipment certification, as per RSP-100, must provide a list of all antenna types that may be used with the license-exempt transmitter, indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna.

License-exempt transmitters that have received equipment certification may operate with different types of antennas. However, it is not permissible to exceed the maximum equivalent isotopically radiated power (e.i.r.p.) limits specified in the applicable standard (RSS) for the license-exempt apparatus.

Testing shall be performed using the highest gain antenna of each combination of license-exempt transmitter and antenna type, with the transmitter output power set at the maximum level. When a measurement at the antenna connector is used to determine RF output power, the effective gain of the device's antenna shall be stated, based on a measurement or on data from the antenna manufacturer.

User manuals for transmitters equipped with detachable antennas shall also contain the following notice in a conspicuous location:

This radio transmitter (identify the device by certification number) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Immediately following the above notice, the manufacturer shall provide a list of all antenna types approved for use with the transmitter, indicating the maximum permissible antenna gain (in dBi).

13.2 Test Results

The device was found to be **compliant**. The device uses a uFL connector that is permanently attached using MG Chemicals One Part Epoxy General Purpose A, 9310-10ML.

14 Revision History

Revision Level	Date	Report Number	Prepared By	Reviewed By	Notes
0	1/27/2023	105270108LEX-002.1			Original Issue
1	2/13/2023	105270108LEX-002.1			Revisions made per TCB feedback