

TEST REPORT

Reference No..... : WTX23X02010589W001
FCC ID : 2A97W-SPIRIT
Applicant : Radonova Laboratories AB
Address..... : Rapskatan 25, 75450 Uppsala, SWEDEN
Manufacturer : The same as Applicant
Address..... : The same as Applicant
Product Name : SPIRIT Radon Sensor
Model No..... : SPIRIT
Standards : FCC Part 15.247
Date of Receipt sample : 2023-02-01
Date of Test..... : 2023-02-01 to 2023-03-23
Date of Issue : 2023-03-23
Test Report Form No. : WTX_Part 15_247W
Test Result..... : Pass

Remarks:

The results shown in this test report refer only to the sample(s) tested, this test report cannot be reproduced, except in full, without prior written permission of the company. The report would be invalid without specific stamp of test institute and the signatures of approver.

Prepared By:

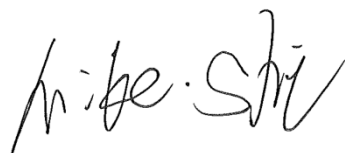
Waltek Testing Group (Shenzhen) Co., Ltd.

Address: 1/F., Room 101, Building 1, Hongwei Industrial Park, Liuxian 2nd Road,
Block 70 Bao'an District, Shenzhen, Guangdong, China

Tel.: +86-755-33663308 Fax.: +86-755-33663309 Email: sem@waltek.com.cn

Tested by:

Approved by:



Mike Shi



Silin Chen

TABLE OF CONTENTS

1. GENERAL INFORMATION	5
1.1 PRODUCT DESCRIPTION FOR EQUIPMENT UNDER TEST (EUT)	5
1.2 TEST STANDARDS.....	6
1.3 TEST METHODOLOGY	6
1.4 TEST FACILITY	6
1.5 EUT SETUP AND TEST MODE	7
1.6 MEASUREMENT UNCERTAINTY	8
1.7 TEST EQUIPMENT LIST AND DETAILS	9
2. SUMMARY OF TEST RESULTS.....	12
3. ANTENNA REQUIREMENT	13
3.1 STANDARD APPLICABLE	13
3.2 EVALUATION INFORMATION	13
4. FREQUENCY HOPPING SYSTEM REQUIREMENTS.....	14
5. QUANTITY OF HOPPING CHANNELS AND CHANNEL SEPARATION.....	16
5.1 STANDARD APPLICABLE	16
5.2 TEST SETUP BLOCK DIAGRAM	16
5.3 TEST PROCEDURE	16
5.4 SUMMARY OF TEST RESULTS/PLOTS.....	17
6. DWELL TIME OF HOPPING CHANNEL	18
6.1 STANDARD APPLICABLE	18
6.2 TEST SETUP BLOCK DIAGRAM	18
6.3 TEST PROCEDURE	18
6.4 SUMMARY OF TEST RESULTS/PLOTS.....	19
7. 20DB BANDWIDTH.....	20
7.1 STANDARD APPLICABLE	20
7.2 TEST SETUP BLOCK DIAGRAM	20
7.3 TEST PROCEDURE	20
7.4 SUMMARY OF TEST RESULTS/PLOTS.....	21
8. RF OUTPUT POWER.....	22
8.1 STANDARD APPLICABLE	22
8.2 TEST SETUP BLOCK DIAGRAM	22
8.3 TEST PROCEDURE	22
8.4 SUMMARY OF TEST RESULTS/PLOTS.....	22
9. FIELD STRENGTH OF SPURIOUS EMISSIONS.....	23
9.1 STANDARD APPLICABLE	23
9.2 TEST PROCEDURE	23
9.3 CORRECTED AMPLITUDE & MARGIN CALCULATION.....	25
9.4 SUMMARY OF TEST RESULTS/PLOTS.....	25
10. OUT OF BAND EMISSIONS.....	33
10.1 STANDARD APPLICABLE	33
10.2 TEST PROCEDURE	33
10.3 SUMMARY OF TEST RESULTS/PLOTS	34
11. CONDUCTED EMISSIONS	35
11.1 TEST PROCEDURE.....	35
11.2 BASIC TEST SETUP BLOCK DIAGRAM.....	35
11.3 TEST RECEIVER SETUP.....	35
11.4 SUMMARY OF TEST RESULTS/PLOTS	35
APPENDIX SUMMARY	38
APPENDIX A.....	39

APPENDIX B.....43

APPENDIX C.....46

APPENDIX D.....48

APPENDIX E.....50

APPENDIX PHOTOGRAPHS.....53

Report version

Version No.	Date of issue	Description
Rev.00	2023-03-23	Original
/	/	/

1. GENERAL INFORMATION

1.1 Product Description for Equipment Under Test (EUT)

General Description of EUT	
Product Name:	SPIRIT Radon Sensor
Trade Name:	/
Model No.:	SPIRIT
Adding Model(s):	/
Rated Voltage:	Battery:DC3.6V USB Port:DC5V
Battery Capacity:	6700mAh
Power Adapter:	/
<i>Note: The test data is gathered from a production sample, provided by the manufacturer.</i>	

Technical Characteristics of EUT	
Frequency Range:	902.3-914.9MHz
RF Output Power:	19.22dBm (Conducted)
Modulation:	GFSK
Quantity of Channels:	64
Channel Separation:	200kHz
Type of Antenna:	Stamped metal antenna
Antenna Gain:	2.4dBi
<i>Note: The Antenna Gain is provided by the customer.</i>	

1.2 Test Standards

The tests were performed according to following standards:

FCC Rules Part 15.247: Frequency Hopping, Direct Spread Spectrum and Hybrid Systems that are in operation within the bands of 902-928MHz, 2400-2483.5MHz, and 5725-5850MHz.

558074 D01 15.247 Meas Guidance v05r02: Guidance for Compliance Measurements on Digital Transmission System, Frequency Hopping Spread Spectrum System, and Hybrid System Devices Operating under section 15.247 of the FCC rules.

ANSI C63.10-2013: American National Standard for Testing Unlicensed Wireless Devices.

Maintenance of compliance is the responsibility of the manufacturer. Any modification of the product, which result in lowering the emission, should be checked to ensure compliance has been maintained.

1.3 Test Methodology

All measurements contained in this report were conducted with ANSI C63.10-2013, the equipment under test (EUT) was configured to measure its highest possible emission level. The test modes were adapted accordingly in reference to the Operating Instructions.

1.4 Test Facility

Address of the test laboratory

Laboratory: Waltek Testing Group (Shenzhen) Co., Ltd.

Address: 1/F., Room 101, Building 1, Hongwei Industrial Park, Liuxian 2nd Road, Block 70 Bao'an District, Shenzhen, Guangdong, China

FCC – Registration No.: 125990

Waltek Testing Group (Shenzhen) Co., Ltd. EMC Laboratory has been registered and fully described in a report filed with the FCC (Federal Communications Commission). The acceptance letter from the FCC is maintained in our files. The Designation Number is CN5010, and Test Firm Registration Number is 125990.

Industry Canada (IC) Registration No.: 11464A

The 3m Semi-anechoic chamber of Waltek Testing Group (Shenzhen) Co., Ltd. has been registered by Certification and Engineering Bureau of Industry Canada for radio equipment testing with Registration No.: 11464A and the CAB identifier is CN0057.

1.5 EUT Setup and Test Mode

The EUT was operated in the engineering mode to fix the Tx frequency that was for the purpose of the measurements. All testing shall be performed under maximum output power condition, and to measure its highest possible emissions level, more detailed description as follows:

Test Mode List		
Test Mode	Description	Remark
TM1	Low Channel	902.3MHz
TM2	Middle Channel	908.7MHz
TM3	High Channel	914.9MHz
TM4	Hopping	902.3-914.9MHz

Test Conditions	
Temperature:	22~25 °C
Relative Humidity:	45~55 %.
ATM Pressure:	1019 mbar

EUT Cable List and Details			
Cable Description	Length (m)	Shielded/Unshielded	With / Without Ferrite
/	/	/	/

Special Cable List and Details			
Cable Description	Length (m)	Shielded/Unshielded	With / Without Ferrite
USB CABLE	1.0	Shielded	Without Ferrite

Auxiliary Equipment List and Details			
Description	Manufacturer	Model	Serial Number
Computer	Lenovo	L13 Yoga	/
Adapter	/	VEL05US050-US-BB	/

1.6 Measurement Uncertainty

Measurement uncertainty		
Parameter	Conditions	Uncertainty
RF Output Power	Conducted	$\pm 0.42\text{dB}$
Occupied Bandwidth	Conducted	$\pm 1.5\%$
Conducted Spurious Emission	Conducted	$\pm 2.17\text{dB}$
Conducted Emissions	Conducted	9-150kHz $\pm 3.74\text{dB}$
		0.15-30MHz $\pm 3.34\text{dB}$
Transmitter Spurious Emissions	Radiated	30-200MHz $\pm 4.52\text{dB}$
		0.2-1GHz $\pm 5.56\text{dB}$
		1-6GHz $\pm 3.84\text{dB}$
		6-18GHz $\pm 3.92\text{dB}$

1.7 Test Equipment List and Details

Fixed asset Number	Description	Manufacturer	Model	Serial No.	Cal Date	Due. Date
WTXE1041A 1001	Communication Tester	Rohde & Schwarz	CMW500	148650	2023-02-25	2024-02-24
WTXE1022A 1002	GSM Tester	Rohde & Schwarz	CMU200	114403	2023-02-25	2024-02-24
WTXE1005A 1005	Spectrum Analyzer	Agilent	N9020A	US471401 02	2023-02-25	2024-02-24
WTXE1084A 1001	Spectrum Analyzer	Agilent	N9020A	MY543205 48	2023-02-25	2024-02-24
WTXE1044A 1001	Signal Generator	Agilent	83752A	3610A014 53	2023-02-25	2024-02-24
WTXE1045A 1001	Vector Signal Generator	Agilent	N5182A	MY470702 02	2023-02-25	2024-02-24
WTXE1018A 1001	Power Divider	Weinschel	1506A	PM204	2023-02-25	2024-02-24
WTXE1045A 1001	Power Divider	RF-Lambda	RFLT4W5M18G	14110400 027	2023-02-25	2024-02-24
☒ Chamber A: Below 1GHz						
WTXE1005A 1003	Spectrum Analyzer	Rohde & Schwarz	FSP30	836079/03 5	2023-02-25	2024-02-24
WTXE1007A 1001	EMI Test Receiver	Rohde & Schwarz	ESVB	825471/00 5	2023-02-25	2024-02-24
WTXE1007A 1001	Amplifier	HP	8447F	2805A034 75	2023-02-25	2024-02-24
WTXE1010A 1007	Loop Antenna	Schwarz beck	FMZB 1516	9773	2021-03-20	2024-03-19
WTXE1010A 1006	Broadband Antenna	Schwarz beck	VULB9163	9163-333	2023-03-20	2026-03-19
☒ Chamber A: Above 1GHz						
WTXE1005A 1003	Spectrum Analyzer	Rohde & Schwarz	FSP30	836079/03 5	2023-02-25	2024-02-24
WTXE1007A 1001	EMI Test Receiver	Rohde & Schwarz	ESVB	825471/00 5	2023-02-25	2024-02-24
WTXE1065A 1001	Amplifier	C&D	PAP-1G18	14918	2023-02-25	2024-02-24
WTXE1010A 1005	Horn Antenna	ETS	3117	00086197	2021-03-19	2024-03-18
WTXE1010A 1010	DRG Horn Antenna	A.H. SYSTEMS	SAS-574	571	2021-03-19	2024-03-18

WTXE1003A 1001	Pre-amplifier	Schwarzbeck	BBV 9721	9721-031	2023-02-25	2024-02-24
☐ Chamber B:Below 1GHz						
WTXE1010A 1006	Trilog Broadband Antenna	Schwarz beck	VULB9163(B)	9163-635	2021-04-09	2024-04-08
WTXE1038A 1001	Amplifier	Agilent	8447D	2944A101 79	2023-02-25	2024-02-24
WTXE1001A 1002	EMI Test Receiver	Rohde & Schwarz	ESPI	101391	2023-02-25	2024-02-24
☐ Chamber C:Below 1GHz						
WTXE1093A 1001	EMI Test Receiver	Rohde & Schwarz	ESIB 26	100401	2023-02-25	2024-02-24
WTXE1010A 1013-1	Trilog Broadband Antenna	Schwarz beck	VULB 9168	1194	2021-05-28	2024-05-27
WTXE1007A 1002	Amplifier	HP	8447F	2944A038 69	2023-02-25	2024-02-24
☐ Chamber C: Above 1GHz						
WTXE1093A 1001	EMI Test Receiver	Rohde & Schwarz	ESIB 26	100401	2023-02-25	2024-02-24
WTXE1103A 1005	Horn Antenna	POAM	RTF-11A	LP228060 221	2023-03-10	2026-03-09
WTXE1103A 1006	Amplifier	Tonscend	TAP01018050	AP22E806 235	2023-02-25	2024-02-24
☒ Conducted Room 1#						
WTXE1001A 1001	EMI Test Receiver	Rohde & Schwarz	ESPI	101611	2023-02-25	2024-02-24
WTXE1002A 1001	Pulse Limiter	Rohde & Schwarz	ESH3-Z2	100911	2023-02-25	2024-02-24
WTXE1003A 1001	AC LISN	Schwarz beck	NSLK8126	8126-224	2023-02-25	2024-02-24
☐ Conducted Room 2#						
WTXE1001A 1004	EMI Test Receiver	Rohde & Schwarz	ESPI	101259	2023-02-25	2024-02-24
WTXE1003A 1003	LISN	Rohde & Schwarz	ENV 216	100097	2023-02-25	2024-02-24

Software List			
Description	Manufacturer	Model	Version
EMI Test Software (Radiated Emission)*	Farad	EZ-EMC	RA-03A1
EMI Test Software (Conducted Emission)*	Farad	EZ-EMC	RA-03A1

*Remark: indicates software version used in the compliance certification testing.

2. SUMMARY OF TEST RESULTS

FCC Rules	Description of Test Item	Result
§15.203; §15.247(b)(4)(i)	Antenna Requirement	Compliant
§15.205	Restricted Band of Operation	Compliant
§15.207(a)	Conducted Emission	Compliant
§15.209(a)	Radiated Spurious Emissions	Compliant
§15.247(a)(1)(i)	Quantity of Hopping Channel	Compliant
§15.247(a)(1) (i)	Channel Separation	Compliant
§15.247(a)(1) (i)	Time of Occupancy (Dwell time)	Compliant
§15.247(a)	20dB Bandwidth	Compliant
§15.247(b)(2)	RF Power Output	Compliant
§15.247(d)	Band Edge (Out of Band Emissions)	Compliant
§15.247(a)(1)	Frequency Hopping Sequence	Compliant
§15.247(g), (h)	Frequency Hopping System	Compliant

N/A: Not applicable.

3. Antenna Requirement

3.1 Standard Applicable

According to 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.

3.2 Evaluation Information

This product has a Stamped metal antenna, fulfill the requirement of this section.

4. Frequency Hopping System Requirements

4.1 Standard Applicable

According to FCC Part 15.247(a)(1), 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.

(g) Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

(h) The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.

4.2 Frequency Hopping System

This transmitter device is frequency hopping device, and complies with FCC part 15.247 rule.

This device uses transmitter radio which operates in 902-928MHz band. It uses a radio technology called frequency-hopping spread spectrum, which chops up the data being sent and transmits chunks of it on up to 64 bands (0.2MHz each; centred from 902.3 to 914.9MHz) in the range 902-928MHz.

This device was tested with a system receiver to check that the device maintained hopping synchronization, and the device complied with these requirements for 558074 D01 15.247 Meas Guidance v05r02 and FCC Part 15.247 rule.

4.3 EUT Pseudorandom Frequency Hopping Sequence

Pseudorandom Frequency Hopping Sequence Table as below:

Channel:

40,56,48,41,44,0,10,24,31,55,25,62,39,53,32,22,8,4,58,16,61,46,19,33,42,59,34,38,30,21,1,60,15,43,17,18,51,45,7,12,49,35,63,5,50,29,14,13,28,47,6,26,2,11,37,9,20,3,57,52,23,36,54,27 etc.

Reference No.: WTX23X02010589W001

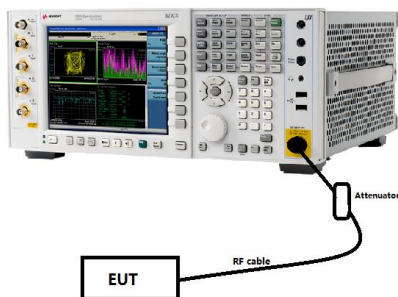
The system receiver have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shift frequencies in synchronization with the transmitted signals.

5. Quantity of Hopping Channels and Channel Separation

5.1 Standard Applicable

According to FCC 15.247(a)(i), for frequency hopping systems operating in the 902-928MHz band: if the 20dB bandwidth of the hopping channel is less than 250kHz, 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 20dB bandwidth of the hopping channel is 250kHz 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 20dB bandwidth of the hopping channel is 500kHz.

5.2 Test Setup Block Diagram



5.3 Test Procedure

According to KDB 558074 D01 v05r02 Sub clause 9 and ANSI C63.10-2013 section 7.8.3, the number of hopping frequencies test method as follows.

- Span: The frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans, to allow the individual channels to be clearly seen.
- RBW: To identify clearly the individual channels, set the RBW to less than 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller.
- VBW $\geq$ RBW.
- Sweep: Auto.
- Detector function: Peak.
- Trace: Max hold.
- Allow the trace to stabilize.

According to KDB 558074 D01 v05r02 Sub clause 9 and ANSI C63.10-2013 section 7.8.2, the EUT shall have its hopping function enabled, the Carrier frequency separation test method as follows:

- Span: Wide enough to capture the peaks of two adjacent channels.
- RBW: Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best

Reference No.: WTX23X02010589W001

identify the center of each individual channel.

c) Video (or average) bandwidth (VBW) $\geq$ RBW.

d) Sweep: Auto.

e) Detector function: Peak.

f) Trace: Max hold.

g) Allow the trace to stabilize.

Use the marker-delta function to determine the separation between the peaks of the adjacent channels.

5.4 Summary of Test Results/Plots

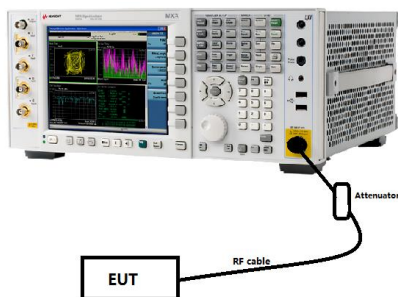
Please refer to Appendix A

6. Dwell Time of Hopping Channel

6.1 Standard Applicable

According to FCC 15.247(a)(i), For frequency hopping systems operating in the 902-928MHz band: if the 20dB bandwidth of the hopping channel is less than 250kHz, 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 20dB bandwidth of the hopping channel is 250kHz 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 20dB bandwidth of the hopping channel is 500kHz.

6.2 Test Setup Block Diagram



6.3 Test Procedure

According to KDB 558074 D01 v05r02 Sub clause 9 and ANSI C63.10-2013 section 7.8.4, the dwell time of a hopping channel test method as follows.

- Span: Zero span, centered on a hopping channel.
- RBW shall be $\leq$ channel spacing and where possible RBW should be set $\gg 1/T$, where T is the expected dwell time per channel.
- Sweep: As necessary to capture the entire dwell time per hopping channel; where possible use a video trigger and trigger delay so that the transmitted signal starts a little to the right of the start of the plot. The trigger level might need slight adjustment to prevent triggering when the system hops on an adjacent channel; a second plot might be needed with a longer sweep time to show two successive hops on a channel.
- Detector function: Peak.
- Trace: Max hold.

Use the marker-delta function to determine the transmit time per hop. If this value varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation in transmit time.

Repeat the measurement using a longer sweep time to determine the number of hops over the period specified in the requirements. The sweep time shall be equal to, or less than, the period specified in the requirements. Determine the number of hops over the sweep time and calculate the total number of hops in

the period specified in the requirements, using the following equation:

$$(\text{Number of hops in the period specified in the requirements}) = (\text{number of hops on spectrum analyzer}) \times (\text{period specified in the requirements} / \text{analyzer sweep time})$$

The average time of occupancy is calculated from the transmit time per hop multiplied by the number of hops in the period specified in the requirements. If the number of hops in a specific time varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation.

The measured transmit time and time between hops shall be consistent with the values described in the operational description for the EUT.

6.4 Summary of Test Results/Plots

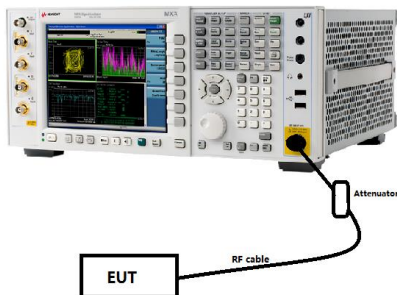
Please refer to Appendix B

7. 20dB Bandwidth

7.1 Standard Applicable

According to 15.247(a) and 15.215(c), 20dB bandwidth 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.

7.2 Test Setup Block Diagram



7.3 Test Procedure

According to KDB 558074 D01 v05r02 Sub clause 9 and ANSI C63.10-2013 section 6.9.2, the 20dB bandwidth test method as follows.

- The spectrum analyzer center frequency is set to the nominal EUT channel center frequency. The span range for the EMI receiver or spectrum analyzer shall be between two times and five times the OBW.
- The nominal IF filter bandwidth (3dB RBW) shall be in the range of 1% to 5% of the OBW and video bandwidth (VBW) shall be approximately three times RBW, unless otherwise specified by the applicable requirement.
- Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than $[10 \log (OBW/RBW)]$ below the reference level.
- Steps a) through c) might require iteration to adjust within the specified tolerances.
- The dynamic range of the instrument at the selected RBW shall be more than 10 dB below the target “-xx dB down” requirement; that is, if the requirement calls for measuring the -20dB OBW, the instrument noise floor at the selected RBW shall be at least 30dB below the reference value.
- Set detection mode to peak and trace mode to max hold.
- Determine the reference value: Set the EUT to transmit an unmodulated carrier or modulated signal, as applicable. Allow the trace to stabilize. Set the spectrum analyzer marker to the highest level of the displayed trace (this is the reference value).
- Determine the “-xx dB down amplitude” using $[(\text{reference value}) - xx]$. Alternatively, this calculation may be made by using the marker-delta function of the instrument.
- If the reference value is determined by an unmodulated carrier, then turn the EUT modulation ON, and either clear the existing trace or start a new trace on the spectrum analyzer and allow the new trace to

stabilize. Otherwise, the trace from step g) shall be used for step j).

j) Place two markers, one at the lowest frequency and the other at the highest frequency of the envelope of the spectral display, such that each marker is at or slightly below the “-xx dB down amplitude” determined in step h). If a marker is below this “-xx dB down amplitude” value, then it shall be as close as possible to this value. The occupied bandwidth is the frequency difference between the two markers. Alternatively, set a marker at the lowest frequency of the envelope of the spectral display, such that the marker is at or slightly below the “-xx dB down amplitude” determined in step h). Reset the marker-delta function and move the marker to the other side of the emission until the delta marker amplitude is at the same level as the reference marker amplitude. The marker-delta frequency reading at this point is the specified emission bandwidth.

k) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

7.4 Summary of Test Results/Plots

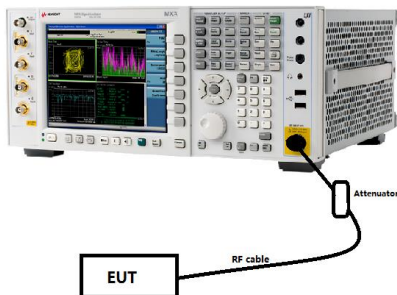
Please refer to Appendix C

8. RF Output Power

8.1 Standard Applicable

According to 15.247(b)(2), for frequency hopping systems operating in the 902-928MHz 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.

8.2 Test Setup Block Diagram



8.3 Test Procedure

According to KDB 558074 D01 v05r02 Sub clause 9 and ANSI C63.10-2013 section 7.8.5, the output power test method as follows.

Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the spectrum analyzer.

This is an RF-conducted test to evaluate maximum peak output power. Use a direct connection between the antenna port of the unlicensed wireless device and the spectrum analyzer, through suitable attenuation. The hopping shall be disabled for this test:

a) Use the following spectrum analyzer settings:

- 1) Span: Approximately five times the 20dB bandwidth, centered on a hopping channel.
- 2) RBW > 20dB bandwidth of the emission being measured.
- 3) VBW $\geq$ RBW.
- 4) Sweep: Auto.
- 5) Detector function: Peak.
- 6) Trace: Max hold.

b) Allow trace to stabilize.

c) Use the marker-to-peak function to set the marker to the peak of the emission.

d) The indicated level is the peak output power, after any corrections for external attenuators and cables.

e) A plot of the test results and setup description shall be included in the test report.

8.4 Summary of Test Results/Plots

Please refer to Appendix D

9. Field Strength of Spurious Emissions

9.1 Standard Applicable

According to §15.247(d), in any 100kHz 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 20dB below that in the 100kHz 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 30dB instead of 20dB. 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).

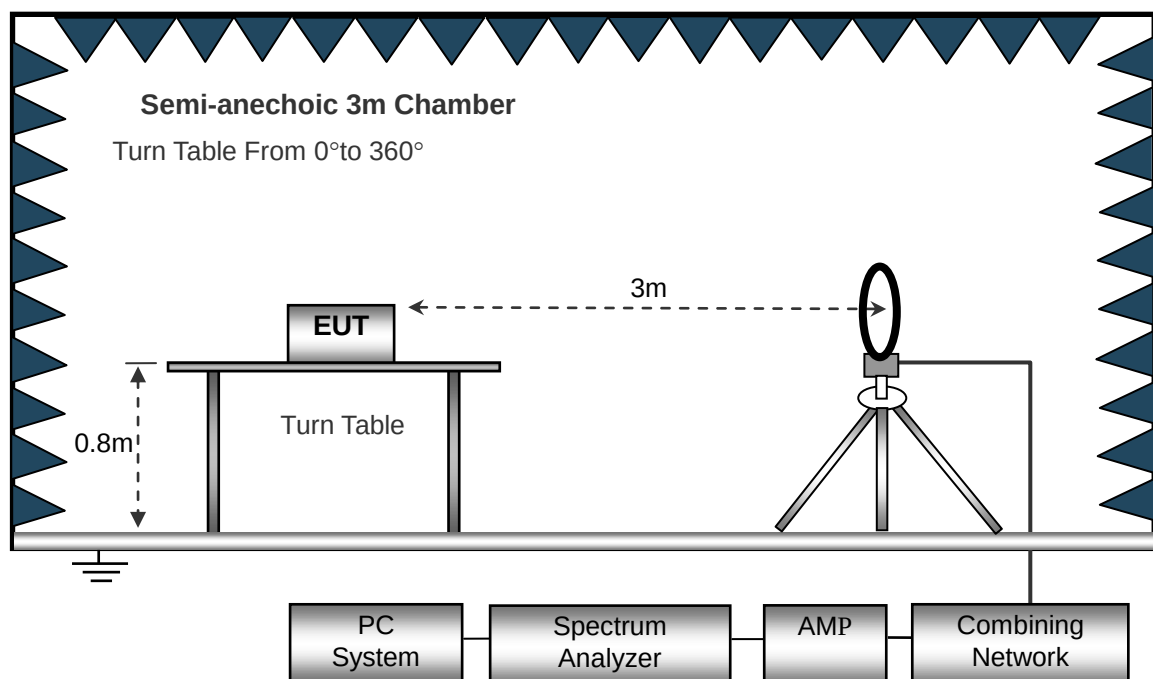
The emission limit in this paragraph is based on measurement instrumentation employing an average detector. The provisions in §15.35 for limiting peak emissions apply. Spurious Radiated Emissions measurements starting below or at the lowest crystal frequency.

9.2 Test Procedure

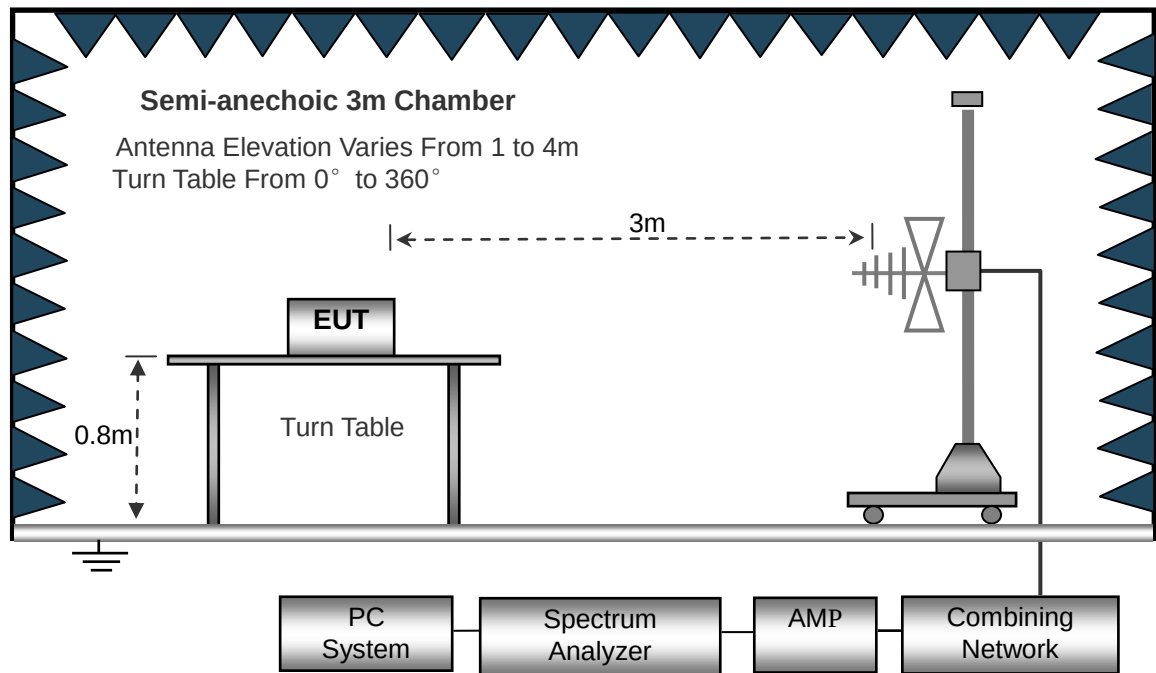
The setup of EUT is according with per ANSI C63.10-2013 measurement procedure. The specification used was with the FCC Part 15.205 15.247(a) and FCC Part 15.209 Limit.

The external I/O cables were draped along the test table and formed a bundle 30 to 40cm long in the middle. The spacing between the peripherals was 10cm.

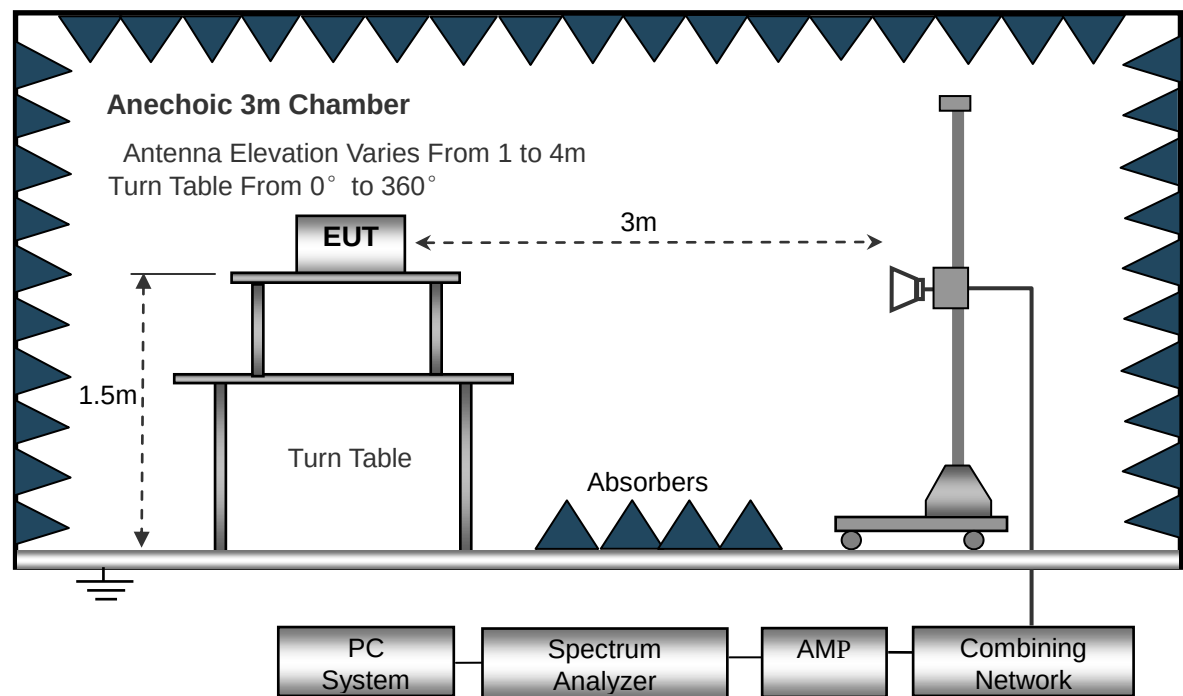
The test setup for emission measurement below 30MHz.



The test setup for emission measurement from 30MHz to 1GHz.



The test setup for emission measurement above 1GHz.



Frequency :9kHz-30MHz
RBW=10KHz,
VBW =30KHz
Sweep time= Auto
Trace = max hold

Frequency :30MHz-1GHz
RBW=120KHz,
VBW=300KHz
Sweep time= Auto
Trace = max hold

Frequency :Above 1GHz
RBW=1MHz,
VBW=3MHz(Peak), 10Hz(AV)
Sweep time= Auto
Trace = max hold

Detector function = peak

Detector function = peak, QP

Detector function = peak, AV

9.3 Corrected Amplitude & Margin Calculation

The Corrected Amplitude is calculated by adding the Antenna Factor and the Cable Factor, and subtracting the Amplifier Gain from the Amplitude reading. The basic equation is as follows:

$$\begin{aligned}\text{Corr. Ampl.} &= \text{Indicated Reading} + \text{Correct} \\ \text{Correct} &= \text{Ant. Factor} + \text{Cable Loss} - \text{Ampl. Gain}\end{aligned}$$

The “**Margin**” column of the following data tables indicates the degree of compliance with the applicable limit. For example, a margin of -6dB μ V means the emission is 6dB μ V below the maximum limit. The equation for margin calculation is as follows:

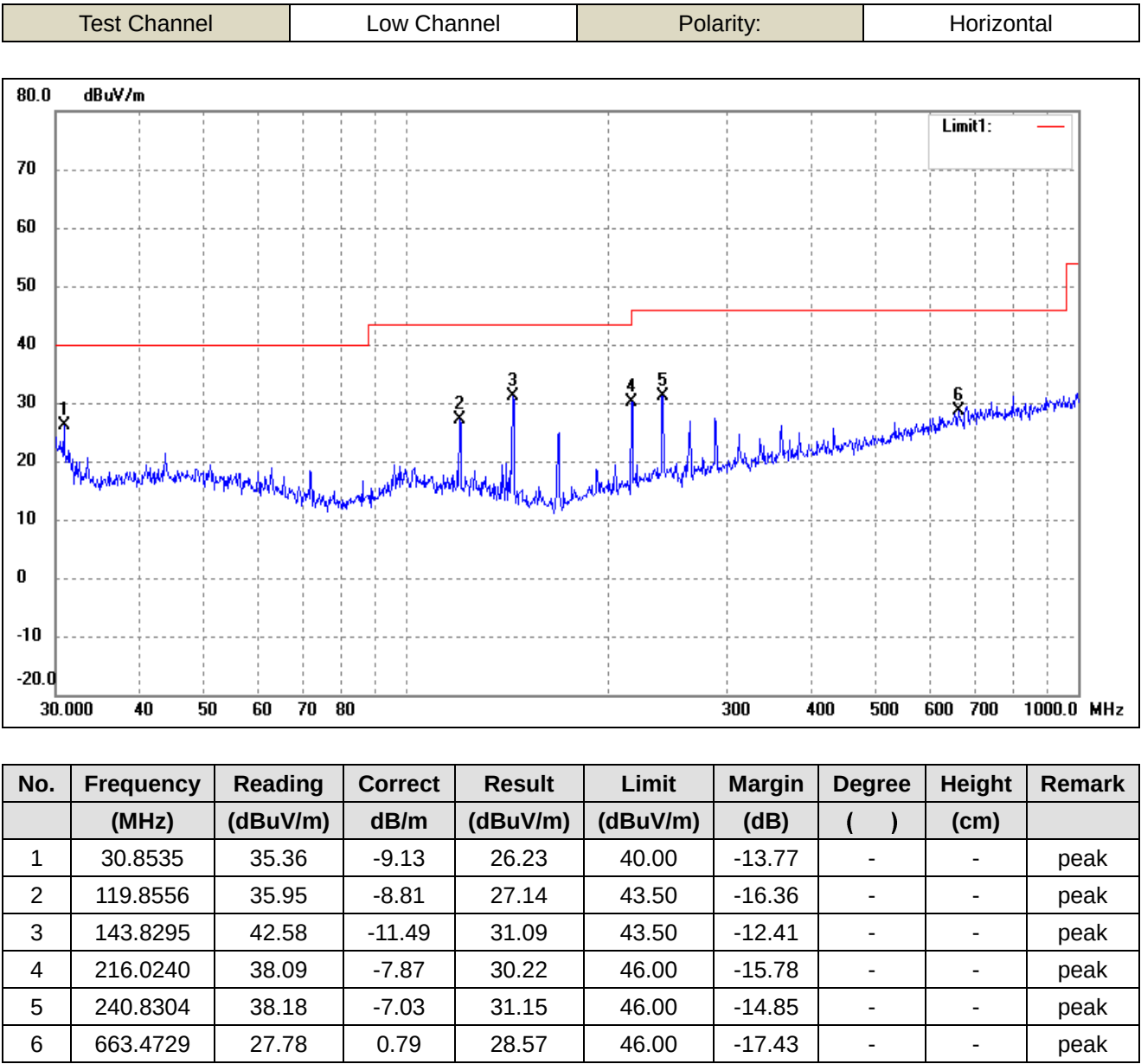
$$\text{Margin} = \text{Corr. Ampl.} - \text{FCC Part 15 Limit}$$

9.4 Summary of Test Results/Plots

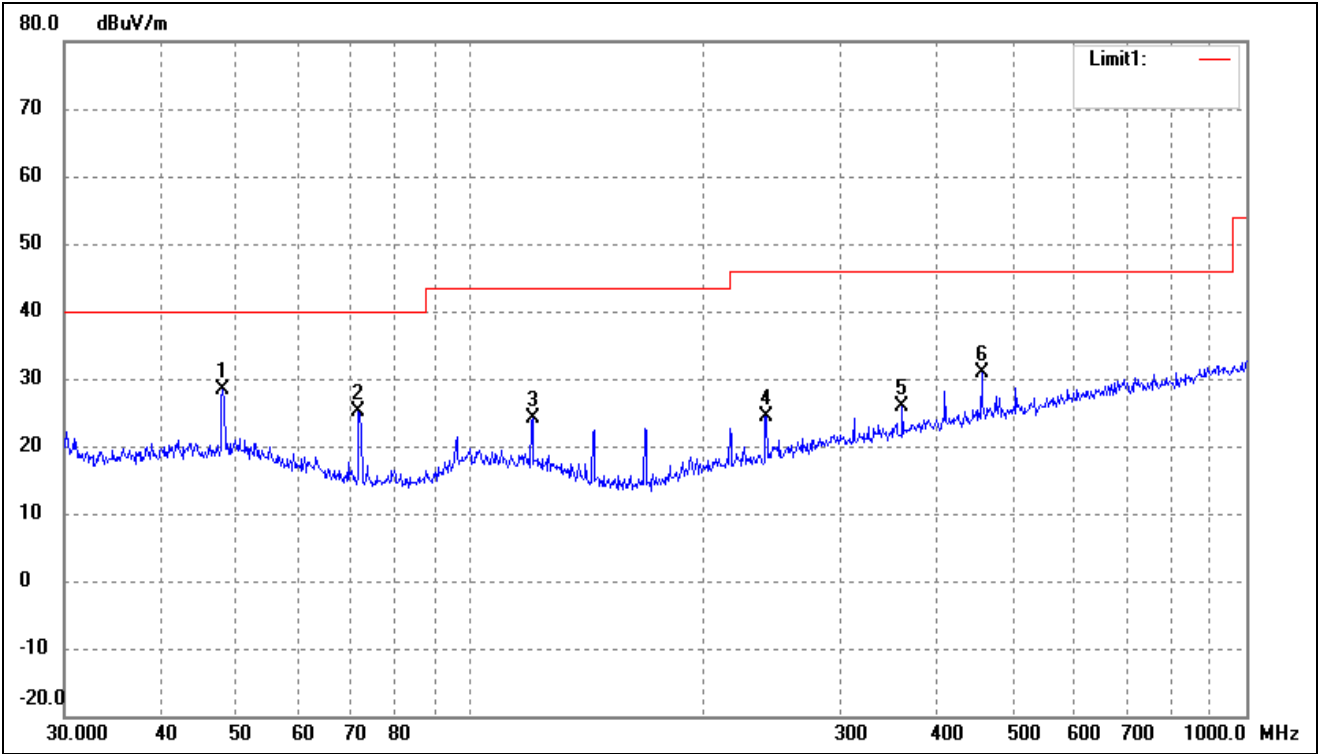
Note: this EUT was tested in 3 orthogonal positions and the worst case position data was reported.

All test modes (different data rate and different modulation) are performed, but only the worst case (GFSK) is recorded in this report.

➤ Spurious Emissions Below 1GHz

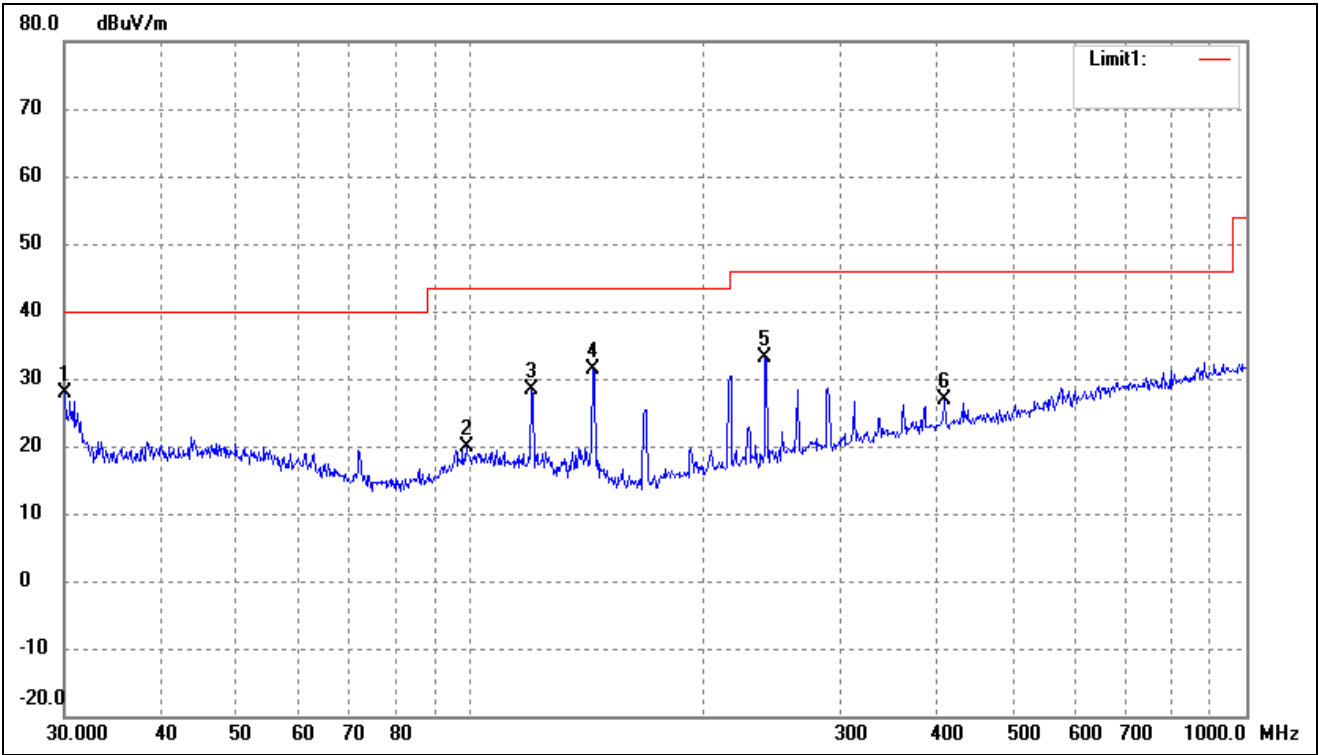


Test Channel	Low Channel	Polarity:	Vertical
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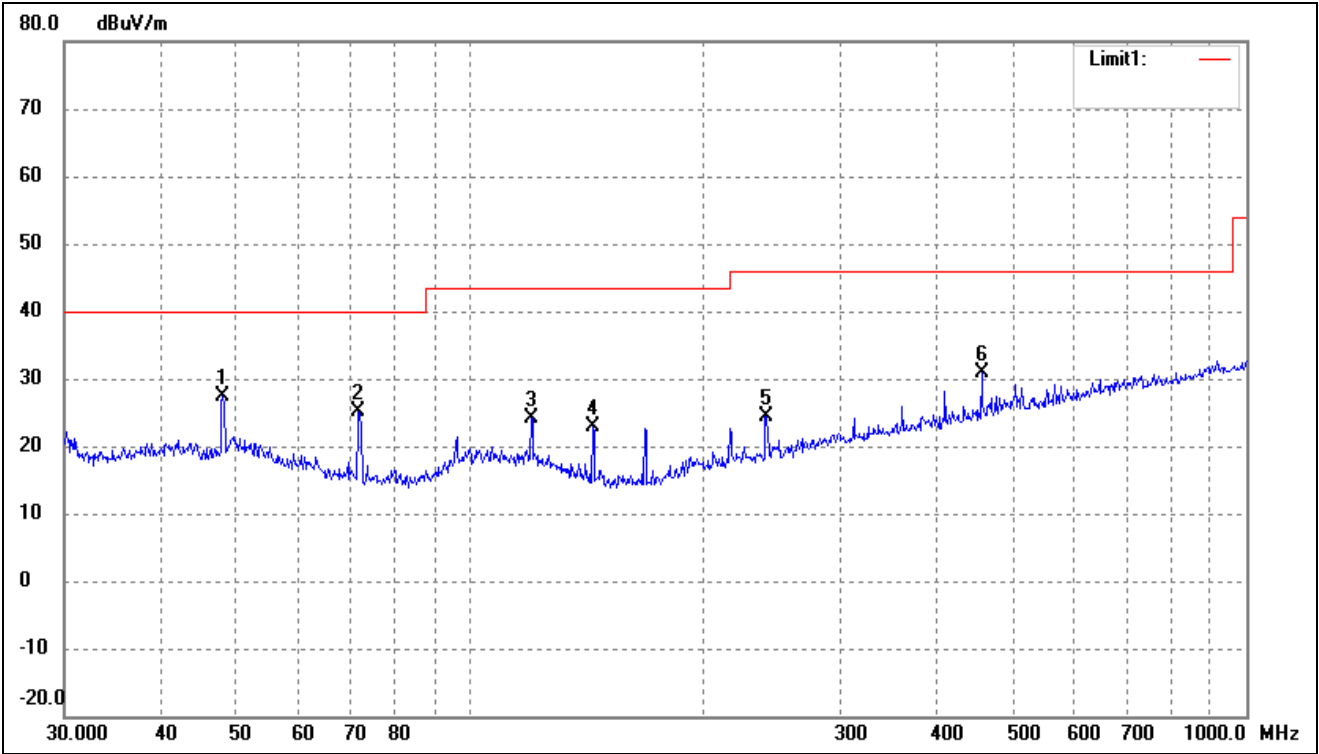
No.	Frequency (MHz)	Reading (dBuV/m)	Correct dB/m	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Degree ()	Height (cm)	Remark
1	47.9940	35.56	-7.27	28.29	40.00	-11.71	-	-	peak
2	71.8320	36.30	-11.23	25.07	40.00	-14.93	-	-	peak
3	120.2766	32.88	-8.87	24.01	43.50	-19.49	-	-	peak
4	240.8304	31.35	-7.03	24.32	46.00	-21.68	-	-	peak
5	360.4477	29.76	-3.97	25.79	46.00	-20.21	-	-	peak
6	455.9058	33.48	-2.71	30.77	46.00	-15.23	-	-	peak

Test Channel	Middle Channel	Polarity:	Horizontal
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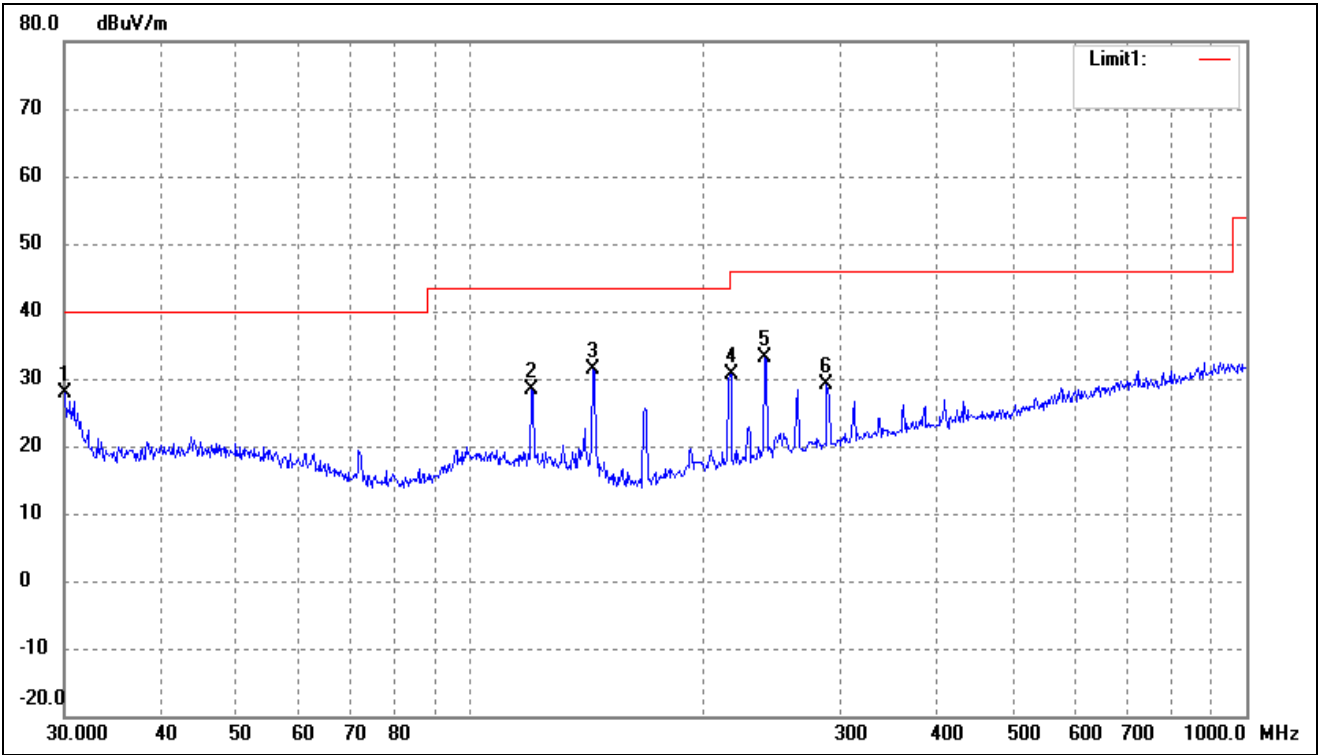
No.	Frequency (MHz)	Reading (dBuV/m)	Correct dB/m	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Degree ()	Height (cm)	Remark
1	30.0000	37.18	-9.32	27.86	40.00	-12.14	-	-	peak
2	98.8326	28.31	-8.38	19.93	43.50	-23.57	-	-	peak
3	119.8556	37.14	-8.81	28.33	43.50	-15.17	-	-	peak
4	143.8295	42.81	-11.49	31.32	43.50	-12.18	-	-	peak
5	239.9874	40.06	-7.05	33.01	46.00	-12.99	-	-	peak
6	408.9460	30.08	-3.22	26.86	46.00	-19.14	-	-	peak

Test Channel	Middle Channel	Polarity:	Vertical
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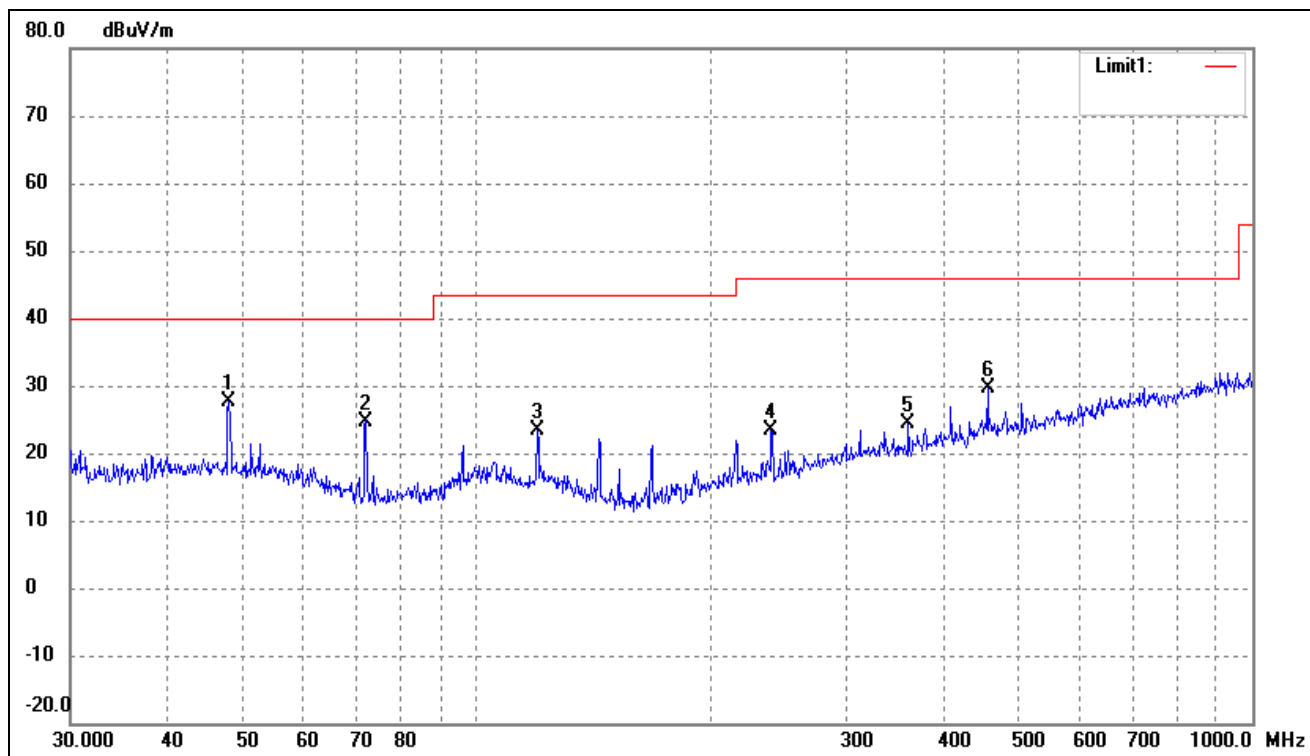
No.	Frequency (MHz)	Reading (dBuV/m)	Correct dB/m	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Degree ()	Height (cm)	Remark
1	47.9940	34.56	-7.27	27.29	40.00	-12.71	-	-	peak
2	71.8320	36.43	-11.23	25.20	40.00	-14.80	-	-	peak
3	119.8556	33.01	-8.81	24.20	43.50	-19.30	-	-	peak
4	143.8295	34.27	-11.49	22.78	43.50	-20.72	-	-	peak
5	240.8304	31.35	-7.03	24.32	46.00	-21.68	-	-	peak
6	455.9058	33.48	-2.71	30.77	46.00	-15.23	-	-	peak

Test Channel	High Channel	Polarity:	Horizontal
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No.	Frequency (MHz)	Reading (dBuV/m)	Correct dB/m	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Degree ()	Height (cm)	Remark
1	30.0000	37.18	-9.32	27.86	40.00	-12.14	-	-	peak
2	119.8556	37.14	-8.81	28.33	43.50	-15.17	-	-	peak
3	143.8295	42.86	-11.49	31.37	43.50	-12.13	-	-	peak
4	216.7828	38.60	-7.85	30.75	46.00	-15.25	-	-	peak
5	239.9874	40.06	-7.05	33.01	46.00	-12.99	-	-	peak
6	287.9904	34.62	-5.42	29.20	46.00	-16.80	-	-	peak

Test Channel	High Channel	Polarity:	Vertical
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No.	Frequency (MHz)	Reading (dBuV/m)	Correct dB/m	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Degree ()	Height (cm)	Remark
1	47.9940	35.02	-7.27	27.75	40.00	-12.25	-	-	peak
2	72.0843	36.00	-11.25	24.75	40.00	-15.25	-	-	peak
3	119.8556	32.12	-8.81	23.31	43.50	-20.19	-	-	peak
4	239.9874	30.40	-7.05	23.35	46.00	-22.65	-	-	peak
5	360.4477	28.45	-3.97	24.48	46.00	-21.52	-	-	peak
6	455.9058	32.41	-2.71	29.70	46.00	-16.30	-	-	peak

Remark: '-'Means' the test Degree and Height are not recorded by the test software and only show the worst case in the test report.

➤ Spurious Emissions Above 1GHz

Frequency	Reading	Correct	Result	Limit	Margin	Polar	Detector
(MHz)	(dBuV/m)	dB	(dBuV/m)	(dBuV/m)	(dB)	H/V	
Low Channel-902.3MHz							
1258.925	54.99	-12.64	42.35	74.00	-31.65	H	PK
1803.018	52.40	-10.56	41.84	74.00	-32.16	H	PK
3605.786	55.28	-5.65	49.63	74.00	-24.37	H	PK
1803.018	50.73	-10.56	40.17	74.00	-33.83	V	PK
4159.106	51.90	-4.98	46.92	74.00	-27.08	V	PK
Middle Channel-908.7MHz							
1815.516	49.81	-10.53	39.28	74.00	-34.72	H	PK
3639.150	57.05	-5.66	51.39	74.00	-22.61	H	PK
4159.106	53.30	-4.98	48.32	74.00	-25.68	H	PK
1815.516	51.85	-10.53	41.32	74.00	-32.68	V	PK
3639.150	50.31	-5.66	44.65	74.00	-29.35	V	PK
4159.106	52.45	-4.98	47.47	74.00	-26.53	V	PK
High Channel-914.9MHz							
1710.015	51.79	-10.87	40.92	74.00	-33.08	H	PK
3664.376	56.59	-5.67	50.92	74.00	-23.08	H	PK
4159.106	51.44	-4.98	46.46	74.00	-27.54	H	PK
1828.100	50.45	-10.48	39.97	74.00	-34.03	V	PK
3664.376	49.26	-5.67	43.59	74.00	-30.41	V	PK
4159.106	52.38	-4.98	47.40	74.00	-26.60	V	PK

Note: Testing is carried out with frequency rang 9kHz to the tenth harmonics, other than listed in the table above are attenuated more than 20dB below the permissible limits or the field strength is too small to be measured.

10. Out of Band Emissions

10.1 Standard Applicable

According to §15.247 (d), in any 100kHz 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 20dB below that in the 100kHz 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 30dB instead of 20dB. 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).

10.2 Test Procedure

According to ANSI C63.10-2013 section 7.8.6, the Band-edge measurements for RF conducted emissions test method as follows.

- a) Connect the EMI receiver or spectrum analyzer to the EUT using an appropriate RF cable connected to the EUT output. Configure the spectrum analyzer settings as described in step e) (be sure to enter all losses between the unlicensed wireless device output and the spectrum analyzer).
- b) Set the EUT to the lowest frequency channel (for the hopping on test, the hopping sequence shall include the lowest frequency channel).
- c) Set the EUT to operate at maximum output power and 100% duty cycle, or equivalent “normal mode of operation” as specified in 6.10.3.
- d) If using the radiated method, then use the applicable procedure(s) of 6.4, 6.5, or 6.6, and orient the EUT and measurement antenna positions to produce the highest emission level.
- e) Perform the test as follows:
 - 1) Span: Wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products that fall outside of the authorized band of operation.
 - 2) Reference level: As required to keep the signal from exceeding the maximum instrument input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than $[10 \log (OBW/RBW)]$ below the reference level. Specific guidance is given in 4.1.5.2.
 - 3) Attenuation: Auto (at least 10 dB preferred).
 - 4) Sweep time: Coupled.
 - 5) Resolution bandwidth: 100kHz.
 - 6) Video bandwidth: 300kHz.
 - 7) Detector: Peak.
 - 8) Trace: Max hold.
- f) Allow the trace to stabilize. For the test with the hopping function turned ON, this can take several minutes

to achieve a reasonable probability of intercepting any emissions due to oscillator overshoot.

g) Set the marker on the emission at the band edge, or on the highest modulation product outside of the band, if this level is greater than that at the band edge. Enable the marker-delta function, and then use the marker-to-peak function to move the marker to the peak of the in-band emission.

h) Repeat step c) through step e) for every applicable modulation.

i) Set the EUT to the highest frequency channel (for the hopping on test, the hopping sequence shall include the highest frequency channel) and repeat step c) through step d).

j) The band-edge measurement shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

Restricted-band band-edge test method please refers to ANSI C63.10-2013 section 6.10.5. The emission must comply with the 15.209 limit for fall in the restricted bands listed in section 15.205. Note that the method of measurement KDB publication number: 913591 may be used for the radiated band-edge measurements.

According to ANSI C63.10-2013 section 7.8.8, Conducted spurious emissions shall be measured for the transmit frequency, per 5.5 and 5.6, and at the maximum transmit powers.

Connect the primary antenna port through an attenuator to the spectrum analyzer input; in the results, account for all losses between the unlicensed wireless device output and the spectrum analyzer. The instrument shall span 30MHz to 10 times the operating frequency in GHz, with a resolution bandwidth of 100kHz, video bandwidth of 300kHz, and a coupled sweep time with a peak detector. The band 30MHz to the highest frequency may be split into smaller spans, as long as the entire spectrum is covered.

10.3 Summary of Test Results/Plots

Please refer to Appendix E

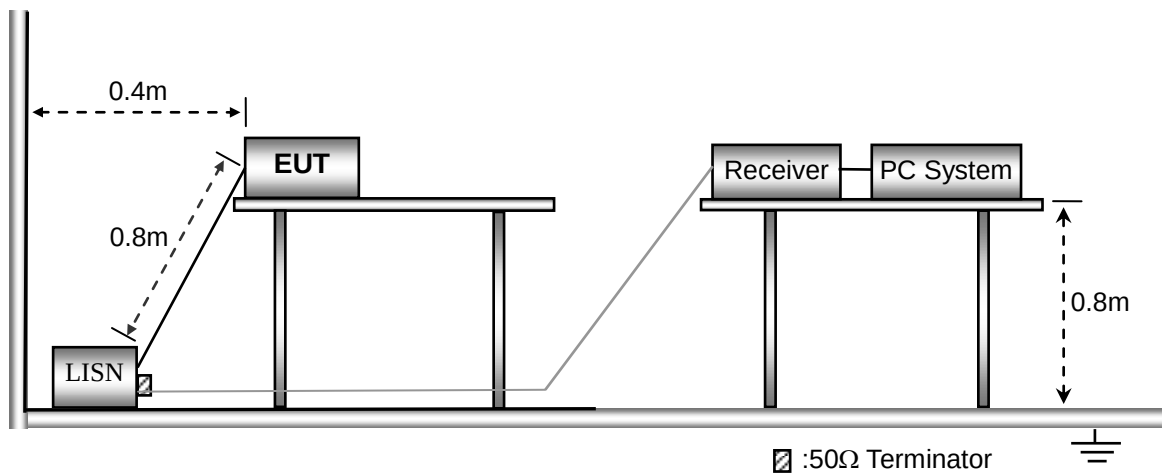
11. Conducted Emissions

11.1 Test Procedure

The setup of EUT is according with per ANSI C63.10-2013 measurement procedure. The specification used was with the FCC Part 15.207 Limit.

The external I/O cables were draped along the test table and formed a bundle 30 to 40cm long in the middle. The spacing between the peripherals was 10cm.

11.2 Basic Test Setup Block Diagram



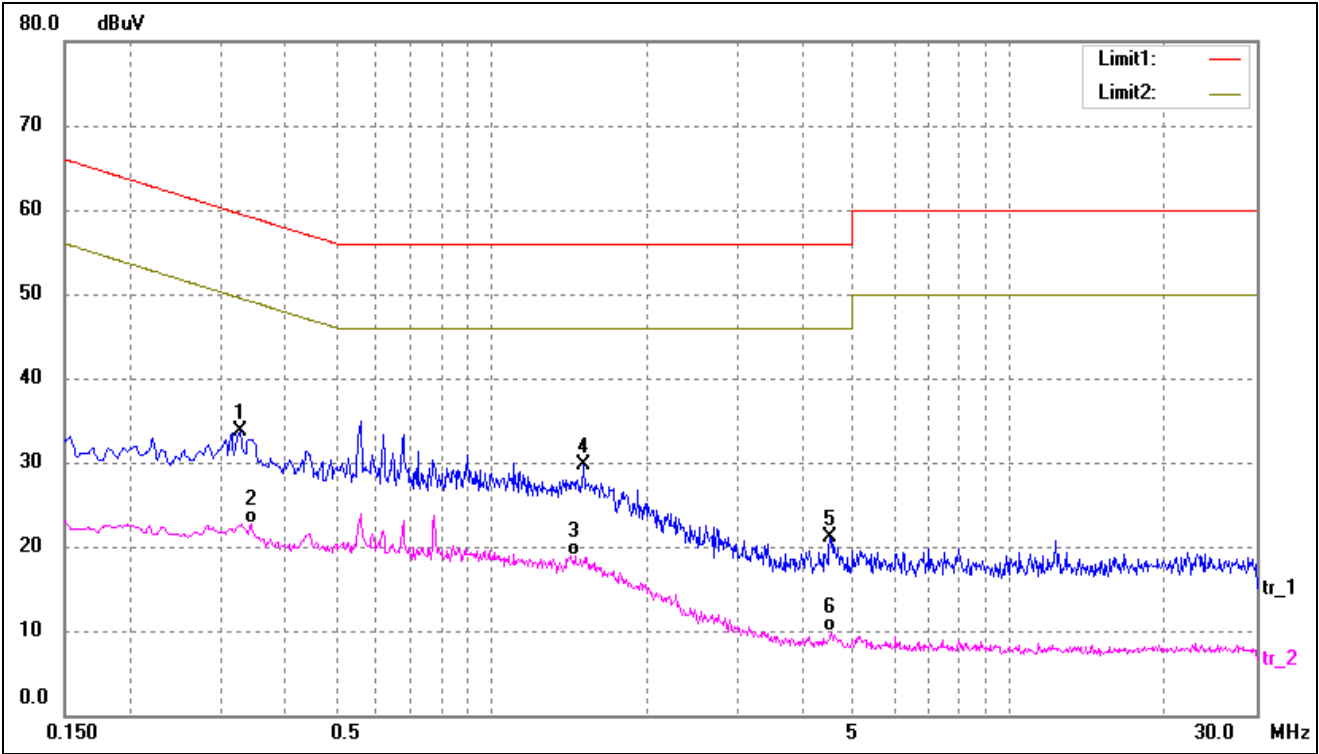
11.3 Test Receiver Setup

During the conducted emission test, the test receiver was set with the following configurations:

Start Frequency	150kHz
Stop Frequency	30MHz
Sweep Speed	Auto
IF Bandwidth	10kHz
Quasi-Peak Adapter Bandwidth	9kHz
Quasi-Peak Adapter Mode	Normal

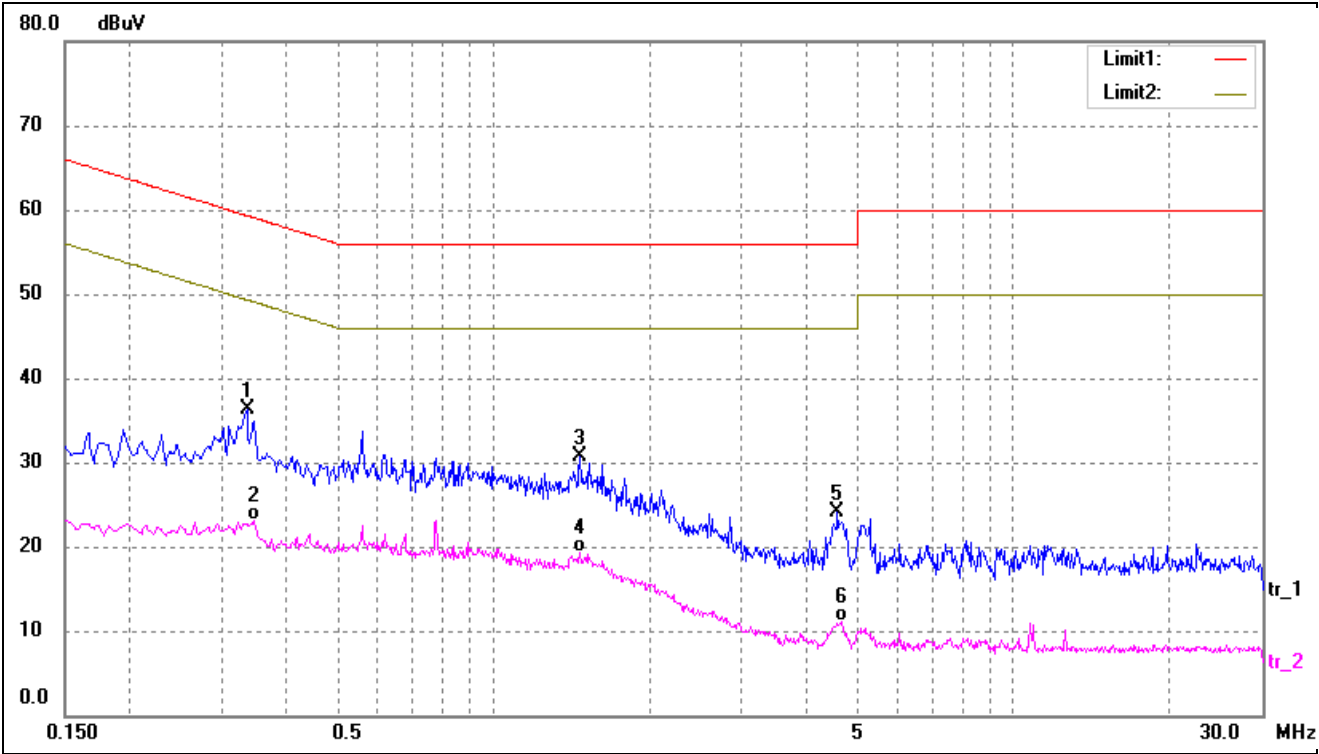
11.4 Summary of Test Results/Plots

Test Mode	Communication	AC120V 60Hz	Polarity:	Line
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No.	Frequency (MHz)	Reading (dBuV)	Correct (dB/m)	Result (dBuV)	Limit (dBuV)	Margin (dB)	Detector
1*	0.3260	23.46	10.24	33.70	59.55	-25.85	peak
2	0.3420	12.57	10.23	22.80	49.15	-26.35	AVG
3	1.4500	8.77	10.18	18.95	46.00	-27.05	AVG
4	1.5060	19.47	10.20	29.67	56.00	-26.33	peak
5	4.5060	10.77	10.32	21.09	56.00	-34.91	peak
6	4.5420	-0.36	10.32	9.96	46.00	-36.04	AVG

Test Mode	Communication	AC120V 60Hz	Polarity:	Neutral
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No.	Frequency (MHz)	Reading (dBuV)	Correct (dB/m)	Result (dBuV)	Limit (dBuV)	Margin (dB)	Detector
1*	0.3339	25.99	10.24	36.23	59.35	-23.12	peak
2	0.3460	12.88	10.23	23.11	49.06	-25.95	AVG
3	1.4660	20.43	10.19	30.62	56.00	-25.38	peak
4	1.4660	9.02	10.19	19.21	46.00	-26.79	AVG
5	4.5739	13.75	10.32	24.07	56.00	-31.93	peak
6	4.6820	0.71	10.32	11.03	46.00	-34.97	AVG

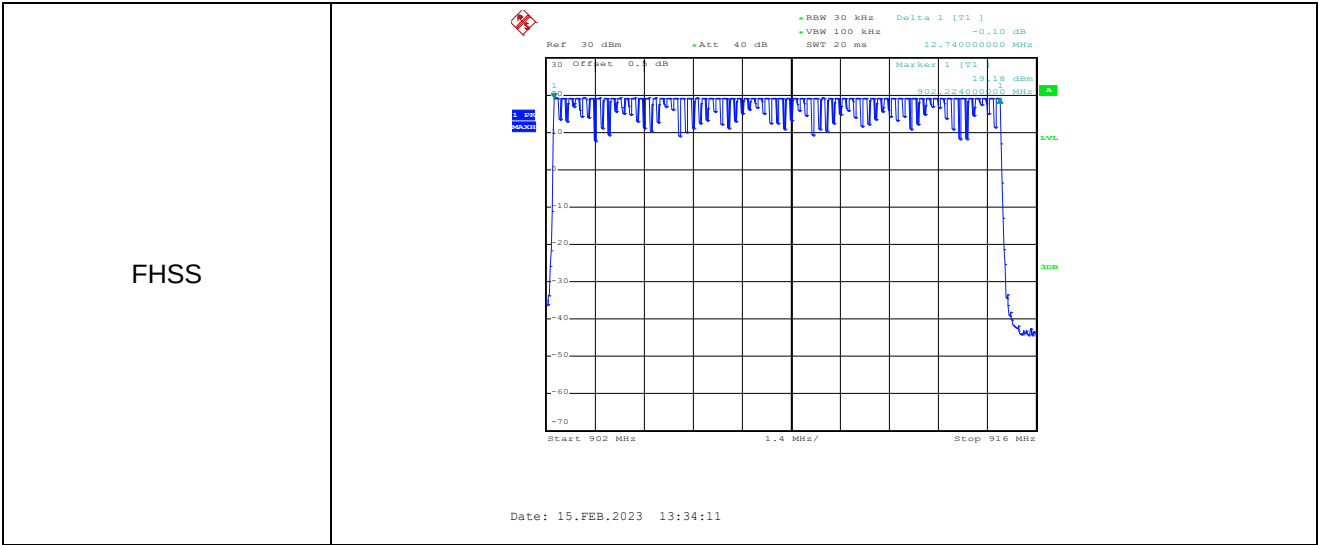
APPENDIX SUMMARY

Project No.	WTX23X02010589W	Test Engineer	Timi Huang
Start date	2023/2/15	Finish date	2023/2/15
Temperature	23℃	Humidity	45%
RF specifications	900MHz-FHSS		

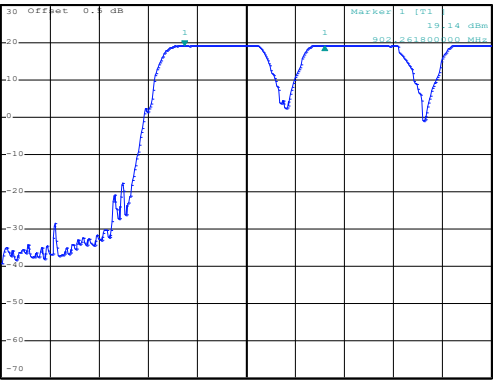
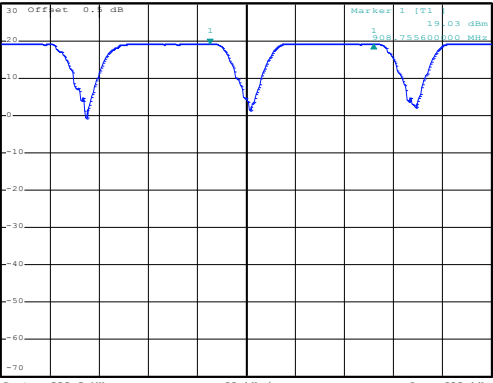
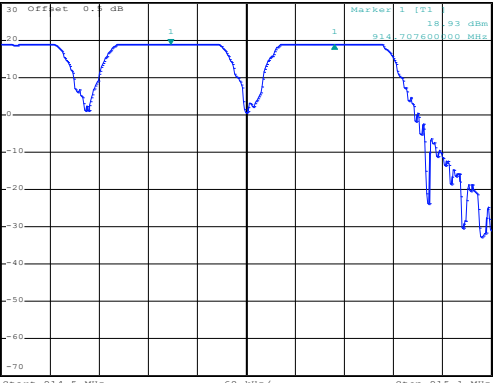
APPENDIX	Description of Test Item	Result
A	Hopping Channels and Channel Separation	Compliant
B	Dwell Time of Hopping Channel	Compliant
C	20dB Bandwidth	Compliant
D	RF Output Power	Compliant
E	Conducted Out of Band Emissions	Compliant

APPENDIX A

Hopping Channels Number			
Mode	Test Result	Limit	Result
FHSS	64	≥50	Pass



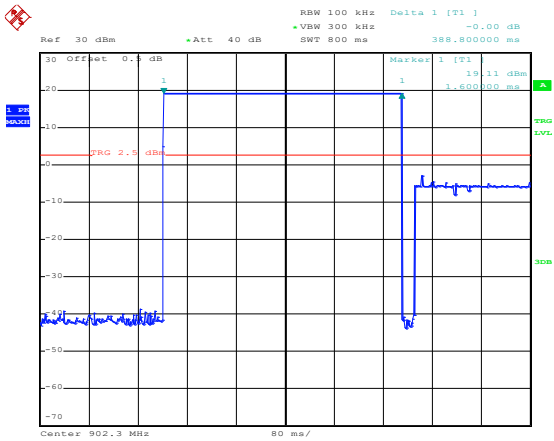
Channel Separation			
Mode	Channel	Carrier Frequencies Separation (kHz)	Result
FHSS	Low	200.20	Pass
	Middle	200.40	Pass
	High	200.40	Pass

Low	 The spectrum plot for the Low band shows a signal level around -19.14 dBm. The plot includes parameters: Ref 30 dBm, Offset 0.1 dB, Att 40 dB, RBW 30 kHz, VSW 100 kHz, and SWT 2.5 ms. The frequency range is from 902 MHz to 902.7 MHz with a 70 kHz span. A marker at 902.251800000 MHz indicates the signal level. Date: 15.FEB.2023 13:28:24
Middle	 The spectrum plot for the Middle band shows a signal level around -19.03 dBm. The plot includes parameters: Ref 30 dBm, Offset 0.1 dB, Att 40 dB, RBW 30 kHz, VSW 100 kHz, and SWT 2.5 ms. The frequency range is centered at 908.8 MHz with a 60 kHz span. A marker at 908.753600000 MHz indicates the signal level. Date: 15.FEB.2023 14:01:54
High	 The spectrum plot for the High band shows a signal level around -18.93 dBm. The plot includes parameters: Ref 30 dBm, Offset 0.1 dB, Att 40 dB, RBW 30 kHz, VSW 100 kHz, and SWT 2.5 ms. The frequency range is from 914.5 MHz to 915.1 MHz with a 60 kHz span. A marker at 914.797600000 MHz indicates the signal level. Date: 15.FEB.2023 13:31:23

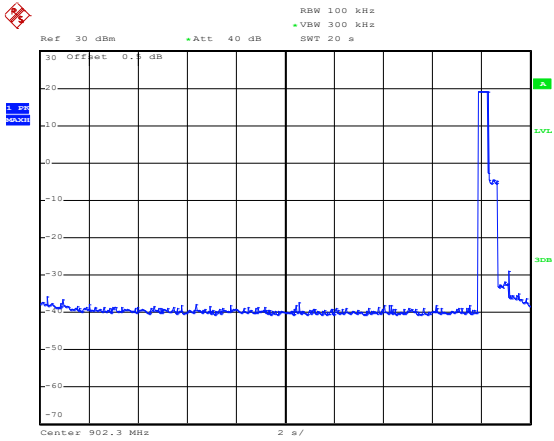
APPENDIX B

Test Channel	Test period (s)	Number of Bursts per Hopping Period	Burst Duration (ms)	Dwell time (ms)	Limit (ms)
Low	20	1	388.80	388.80	400
Middle	20	1	390.40	390.40	400
High	20	1	390.40	390.40	400

Low

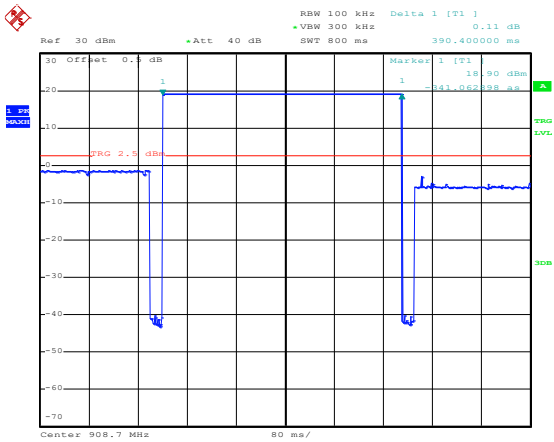


Date: 15.FEB.2023 14:23:54

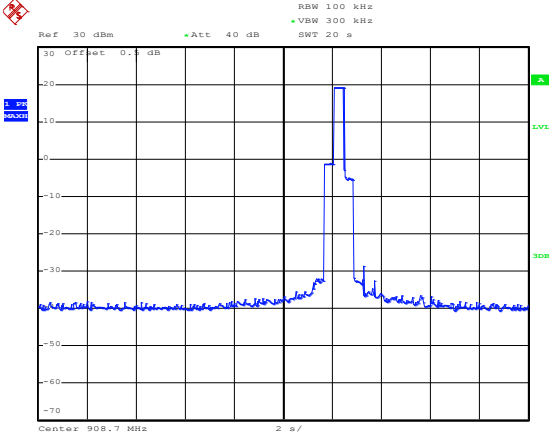
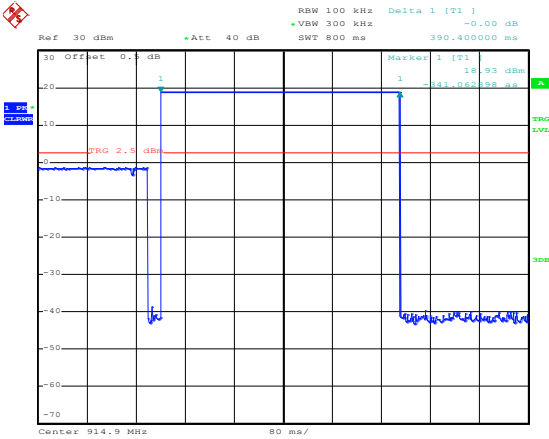
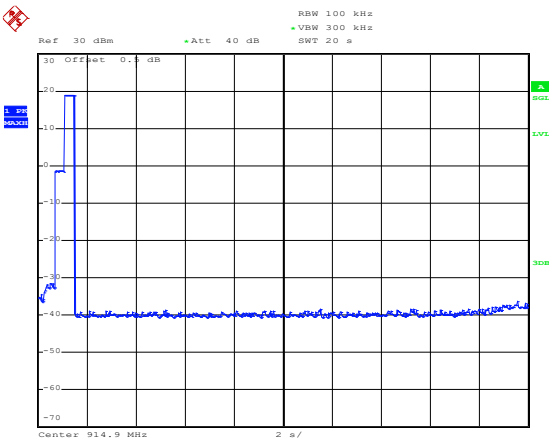


Date: 15.FEB.2023 14:24:48

Middle



Date: 15.FEB.2023 14:29:45

	 Date: 15.FEB.2023 14:26:20
High	 Date: 15.FEB.2023 14:29:20
	 Date: 15.FEB.2023 14:28:19

APPENDIX C

20 dB Bandwidth			
Test Mode	Channel	20 dB Bandwidth MHz	Result
FHSS	Low	0.142	Pass
	Middle	0.143	Pass
	High	0.139	Pass

20 dB Bandwidth Low	Ref 30 dBm Att 40 dB RBW 3 kHz VBW 10 kHz Marker 1 [T1] 16.46 dBm SWT 60 ms 902.325000000 MHz ndB [T1] 20.00 dB BW 142.000000000 kHz Temp 1 [T1] ndB 902.233000000 MHz -4.01 dBm Temp 2 [T2] ndB 902.375000000 MHz -3.85 dBm Center 902.3 MHz 50 kHz/ Span 500 kHz Date: 15.FEB.2023 13:36:15
Middle	Ref 30 dBm Att 40 dB RBW 3 kHz VBW 10 kHz Marker 1 [T1] 16.30 dBm SWT 60 ms 908.739000000 MHz ndB [T1] 20.00 dB BW 143.000000000 kHz Temp 1 [T1] ndB 908.633000000 MHz -3.76 dBm Temp 2 [T2] ndB 908.776000000 MHz -3.68 dBm Center 908.7 MHz 50 kHz/ Span 500 kHz Date: 15.FEB.2023 13:47:56
High	Ref 30 dBm Att 40 dB RBW 3 kHz VBW 10 kHz Marker 1 [T1] 16.48 dBm SWT 60 ms 914.865000000 MHz ndB [T1] 20.00 dB BW 139.000000000 kHz Temp 1 [T1] ndB 914.835000000 MHz -2.63 dBm Temp 2 [T2] ndB 914.974000000 MHz -3.43 dBm Center 914.9 MHz 50 kHz/ Span 500 kHz Date: 15.FEB.2023 13:51:19

APPENDIX D

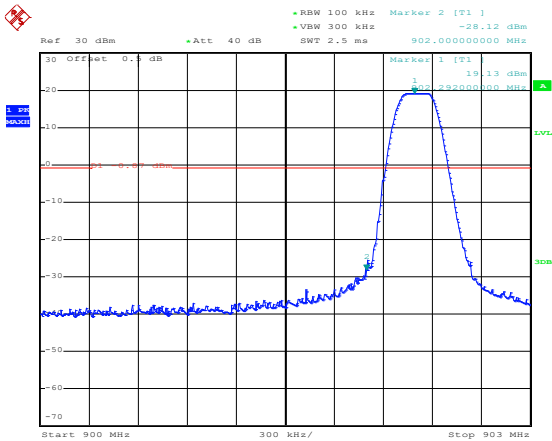
RF Output Power				
Modulation type	Channel	Output power (dBm)	Limit (dBm)	Result
FHSS	Low	19.22	30.00	Pass
	Middle	19.14		
	High	19.06		

Low	Date: 15.FEB.2023 14:03:24
Middle	Date: 15.FEB.2023 14:03:56
High	Date: 15.FEB.2023 14:04:21

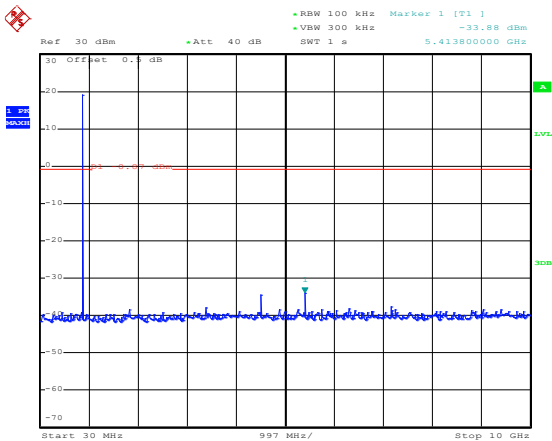
APPENDIX E

Conducted Out of Band Emissions

Low

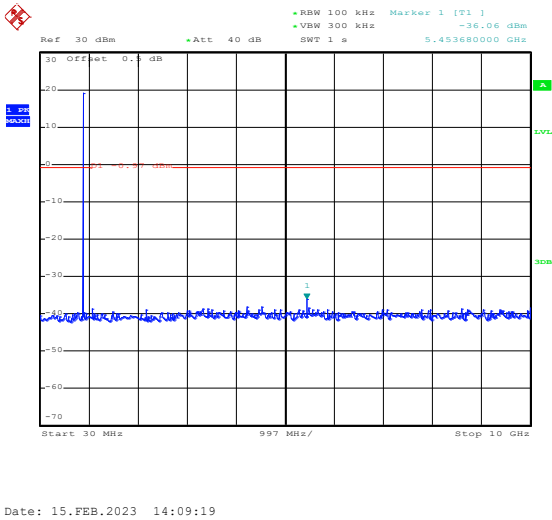
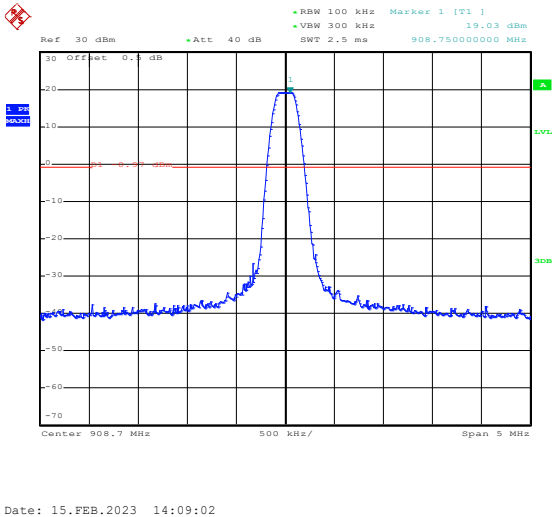


Date: 15.FEB.2023 14:06:30

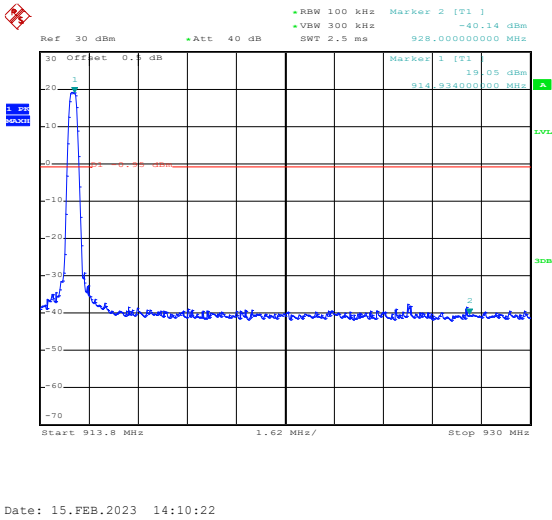


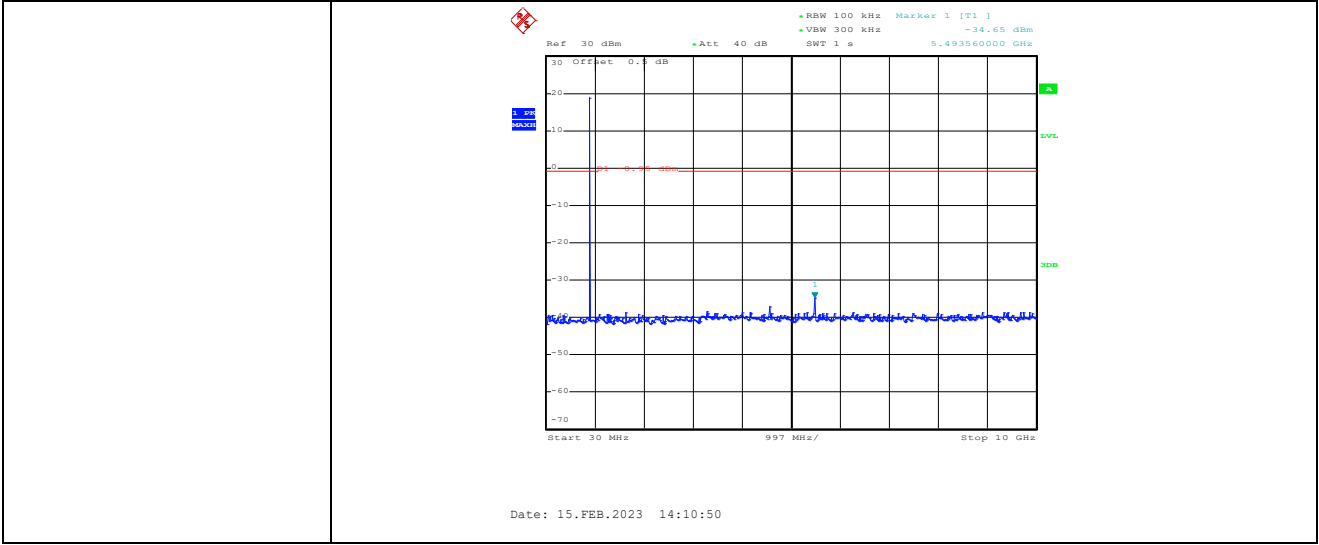
Date: 15.FEB.2023 14:06:56

Middle



High





APPENDIX PHOTOGRAPHS

Please refer to “ANNEX”

***** END OF REPORT *****