FCC RF Test Report
As per

RSS-247 Issue 2

FCC Part 15.247 Subpart C

on the

LudwigHook

IC: 26059-LHREG; FCC ID:2AWA9-LHREG
Prepared to:

Ludwig System GmbH & Co KG
Reichenhaller Straße 109
D - 83435 Bad Reichenhall

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RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Test Specialist	Abdoulaye Ndiaye	8-12-2020	
Authorised Signatory	Scott Drysdale	8-12-2020	Drysdale

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD Product Service document control rules.

EXECUTIVE SUMMARY
A sample of this product was tested and found to be in compliance with FCC Part 15 Subpart 15.247/ RSS-247 Issue 2.
(See Justifications and deviations section)

A2LA Cert. No. 2955.20

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is a trading name of TUV SUD Ltd
2972 Joseph-A-Bombardier
Laval, QC H7P 6E3 Canada

TUV SUD Ltd is a
TÜV SÜD Group Company

Phone: +450-687-4976
www.tuv-sud.ca

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1 Report Summary

Report Modification Record

Document revision history. Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	June 19, 2020
2	Minor revisions as per TCB Request – Kept on file	June 28. 2020
3	Minor revisions as per TCB Request – Kept on file	July 28, 2020
4	Minor revisions as per TCB Request – Kept on file	August 12, 2020

Table 1 – Modification Records

Acronyms & Definitions

The following definitions and acronyms are applicable in this report. See also ANSI C63.14.

Acronyms

AM	Amplitude Modulation
ASCE	Antenna Spurious Conducted Emissions
DTS	Digital Transmission System
EIRP	Equivalent Isotropical Radiated Power
ETSI	European Telecommunications Standards Institute
EUT	Equipment Under Test
FHSS	Frequency Hopping Spread Spectrum
OOB	Out of Band
PKPSD	Peak Power Spectrum Density
RBW	Resolution Bandwidth
RF	Radio Frequency of oscillation rate of electromagnetic fields (e.g. radio waves: 9kHz to 300GHz)
RMS	Root mean square, i.e., $V_p/\sqrt{2}$
Rx	Referred as antennae for receiving RF signals
SD	Spurious Domain
TR	Technical Report

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Tx	Referred as antenna for transmitting RF signals
VBW	Video Bandwidth
Vp	Peak Voltage

EMC – Electro-Magnetic Compatibility. The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

EMI – Electro-Magnetic Immunity. The ability to maintain a specified performance when the equipment is subjected to disturbance (unwanted) signals of specified levels.

EUT – Equipment Under Test. A device or system being evaluated for compliance that is representative of a product to be marketed.

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2 Introduction

Applicant:	Ludwig System GmbH & Co KG
Manufacturer:	Ludwig System GmbH & Co KG
Number of Samples Tested:	2
Test Specification/Issue/Date:	RSS-247 Issue 2: February 2017 FCC Part 15 Subpart C.247:2019
Test Plan/Issue/Date:	N/A
Project Number: **Date:**	7169007823 2020-03-11
Date of Receipt of EUT:	2020-04-24
Start of Test:	2020-04-27
Finish of Test:	2020-05-01
Name of Tester(s):	Abdoulaye Ndiaye
Related Documents:	ANSI C63.10:2013

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Brief Summary of Results

A brief summary of the tests carried out in accordance with RSS-247 Issue 2, FCC Part 15 Subpart 15.247, FCC Part 15 Subpart 15.209 is summarized in Table 2.

Report Section	FCC Rule	IC Rule	Description	Class/Limit	Result
6	FCC 15.247(a)(1)	RSS-247.5.1	OBW	N/A	N/A
7	15.247(a)(2)	RSS-247.5.2(a)	6 dB Bandwidth	>500kHz	Pass
8	§15.247(b)(3)	RSS-247.5.4(d)	Maximum Peak Output Power (DTS)	< 1W	Pass
9	15.247(f)	RSS-247 5.2(b)	Power Spectral Density	<8dBm in any 3kHz Band	Pass
10	§15.247(d)	RSS-247 5.5	Band Edge	≤ 20dBc	Pass
11	§15.209(a)	RSS-247 5.5	Tx Spurious Radiated Emission	Quasi-Peak Average	Pass
	15.247 (i)	RSS-102	RF Exposure	Note 3	Pass
	15.247(b)(4)	RSS 247 5.4 (3)	Antenna Gain	<6dBi <Note 2>	Pass

Continue on next page

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	15.203 & 15.247(b)	RSS-210	Antenna Requirement	Note 1	Not Applicable

Note 1: Manufacture uses a BNC antenna and is considered professional use/installation as per attestation
Note 2: For the Antenna requirement specified in FCC 15.203 (RSS-247 section 5.5), the unit uses a rubber monopole antenna with a gain of less than 6 dBi.

Note 3: For maximum permissible exposure, this device operates at less than 1 Watt at 902 - 928MHz It is designed to operate less than 5 cm from any personnel during normal operation. No testing is required; however, it complies with SAR exemption evaluation as determined the RF Exposure exhibits

Table 2 – Test Summary Table

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Declaration of Build Status

This report addresses the EMC verification testing and test results of the LudwigHook and is herein referred to as EUT (Equipment Under Test). The EUT was tested for compliance against the following standards:

RSS-247 Issue 2:2017
FCC Part 15 Subpart C 15.247:2019

Test procedures, results, justifications, and engineering considerations, if any, follow later in this report.

This report does not imply product endorsement by any government, accreditation agency, or TÜV SÜD Canada Inc.

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For a more detailed list of the standards and the revision used, see the "Applicable Standards, Specifications and Methods" section of this report.

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Notes, Justifications and Deviations

The following notes, justifications for tests not performed or deviations from the above listed specifications apply:

For the Antenna requirement specified in FCC 15.203 (RSS-247 section 5.5), the unit uses an external stub antenna with a gain of less than 6 dBi, which is 3dBi. This antenna is connected with a standard BNC connection that is considered professionally installed/use as per manufacturer specification

For the Restricted Bands of operation, the EUT is designed to only operate between 913.7 and 919MHz on a single channel

For maximum permissible exposure, this device operates at less than 1 Watt at 913.7 and 919MHz It is designed to operate less than 30 mm from any personnel during normal operation. No testing is required; however, it complies with SAR exemption evaluation as determined the RF Exposure exhibits.

For the scope of this test report, the EUT was mounted in three orthogonal axes to maximize emissions. Worst case results are presented

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3 EUT Information: LudwigHook

3.1 Specifications:

PRODUCT NAME:	LudwigHook
MANUFACTURER:	Ludwig System GmbH & Co KG
MODEL	Hook (Receiver only)
TUV NUMBER:	489540
SERIAL NUMBER	1217
SOFTWARE VERSION	V5
HARDWARE VERSION	0.1
FREQUENCY RANGE (MHz)	913.7 - 919
CHANNEL BANDWIDTH	5.4MHz
VOLTAGE RANGE:	3.3Vdc – 6Vdc

Table 3 – EUT – LudwigHook-Red

Photo 1: – LudwigHook Red - S/N# 1217

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PRODUCT NAME:	LudwigHook
MANUFACTURER:	Ludwig System GmbH & Co KG
MODEL	Hook (Receiver only)
TUV NUMBER:	489539
SERIAL NUMBER	1218
SOFTWARE VERSION	V5
HARDWARE VERSION	0.1
FREQUENCY RANGE (MHz)	913.7 - 919
CHANNEL BANDWIDTH	5.4MHz
VOLTAGE RANGE:	3.3Vdc – 6Vdc

Table 4 – EUT – LudwigHook-Blue

Photo 2: – LudwigHook Red - S/N# 1218

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PRODUCT NAME:	LudwigHook XL
MANUFACTURER:	Ludwig System GmbH & Co KG
MODEL	Hook XL (Receiver only)
TUV NUMBER:	489535
SERIAL NUMBER	0246
SOFTWARE VERSION	V5
HARDWARE VERSION	0.1
FREQUENCY RANGE (MHz)	913.7 - 919
CHANNEL BANDWIDTH	5.4MHz
VOLTAGE RANGE	3.3Vdc – 6Vdc

Table 5 – EUT – LudwigHook XL Red

Photo 3: – LudwigHook XL Red - S/N# 0246

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PRODUCT NAME:	LudwigHook XL
MANUFACTURER:	Ludwig System GmbH & Co KG
MODEL	Hook XL (Receiver only)
TUV NUMBER:	489535
SERIAL NUMBER	0247
SOFTWARE VERSION	V5
HARDWARE VERSION	0.1
FREQUENCY RANGE (MHz)	913.7 - 919
CHANNEL BANDWIDTH	5.4MHz
VOLTAGE RANGE	3.3Vdc – 6Vdc

Table 6 – EUT – LudwigHook XL Blue

Photo 4: – LudwigHook XL Blue - S/N# 0247

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PRODUCT NAME:	LudwigHook Remote Control
MANUFACTURER:	Ludwig System GmbH & Co KG
MODEL	SLH
TUV NUMBER:	489772
SERIAL NUMBER	US S2071
SOFTWARE VERSION	V5
HARDWARE VERSION	4^{+}
FREQUENCY RANGE (MHz)	913.7 - 919
CHANNEL BANDWIDTH	5.4MHz
VOLTAGE RATING	4.8 Vdc

Table 7 – EUT – LudwigHook Radio Remote Control

Photo 5: – LudwigHook Radio Remote Control - S/N# US S2071

Frequency (MHz)
913.7 - 919

Table 8 Frequency of operation

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3.2 Modes of Operation

The LudwigHook is operating in the 902 to 928 MHz band. For operation it uses the digital modulation to transmit data from the sender (Remote Control) .

For each transmission, the signal is digitally modulated with two carriers, one at 913.7 MHz and another one at 919 MHz
For more details refer to operation manual

3.3 Setup Diagram

During the EUT was exercised by powering to the rated voltage and connecting according to Figure 1.

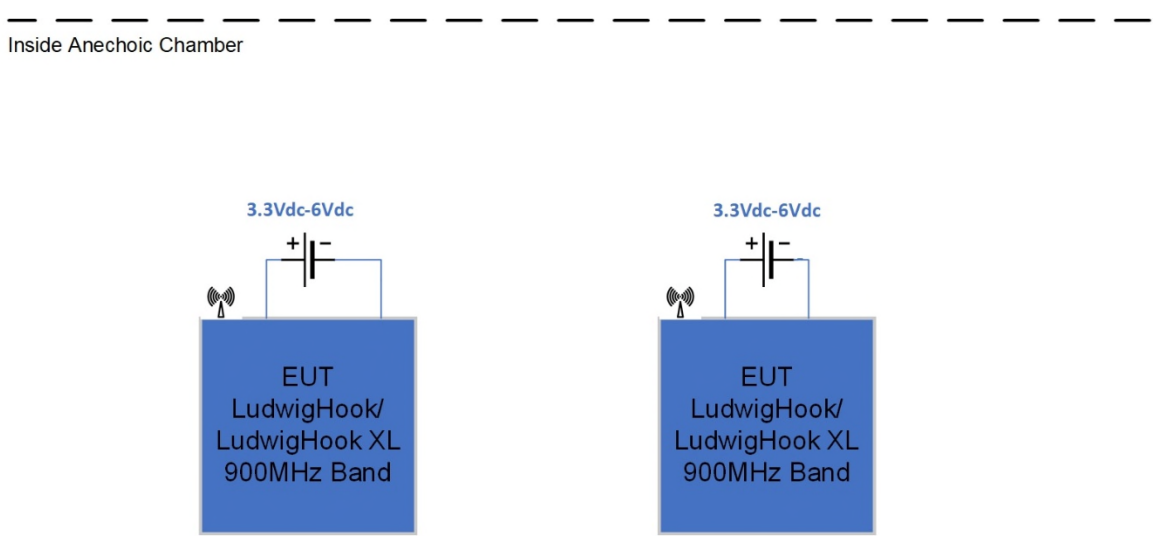

Figure 1: EUT Setup Diagram – LudwigHook – Spurious emissions

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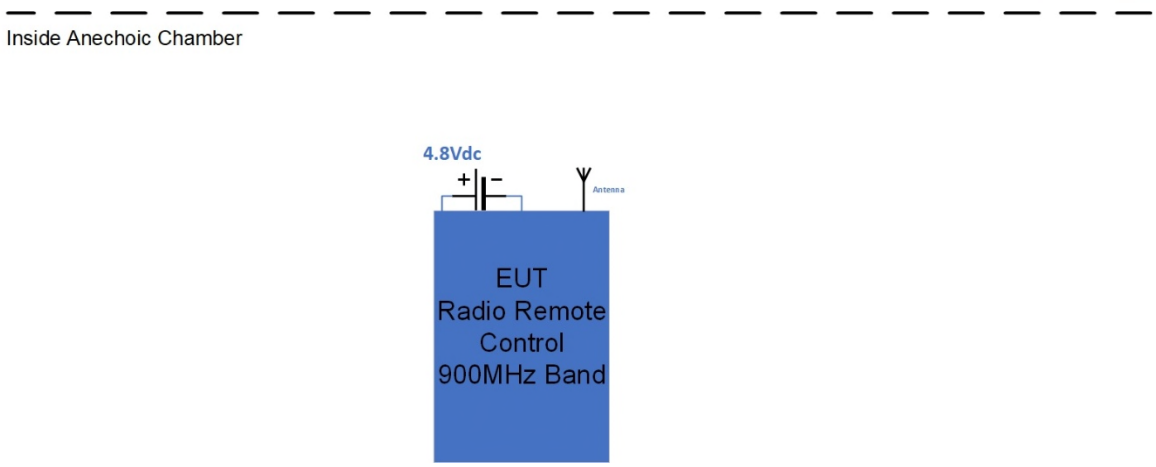

Figure 2: EUT Setup Diagram – LudwigHook Radio Remote Control – Spurious emissions

4 Justifications and Deviations

No deviations from the applicable test standard were made during testing. It is noted that this report is subject to further to review from the TCB, FCC and ISED. All emissions on the hooks (receivers) are provided for information purposes only and are not part of transmitter certification

5 Measurement Uncertainty

The expanded measurement uncertainty is calculated in accordance with CISPR 16-4-2. For instance, for the range of 0.15MHz-30MHz, 30MHz – 1GHz and 1GHz – 18GHz is ±3.3 dB, ±4.25dB and ±4.93dB, respectively with a 'k=2' coverage factor and a 95% confidence level.

Parameter	Uncertainty
Occupied channel Bandwidth	± 5%
RF output power, conducted	± 1.5dB
Power Spectral Density, conducted	± 3dB
Unwanted Emission, conducted	± 3dB
All emission, radiated	± 6dB
Temperature	± 3°C

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Table 9 Acceptable Uncertainties

6 99% Bandwidth

6.1 Purpose & Methods

The Purpose & Methods of this test is to ensure that the bandwidth occupied exceeds a stated minimum. This helps ensure the utilization of the frequency allocation is sufficiently wide. This also helps prevent corruption of data by ensuring adequate data separation to distinguish the reception of the intended information. The test method is a defined in ANSI C63.10.

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6.2 Test Specifications

REFERENCE STANDARD	FCC 15.247(a)(1) ANSI C63.10-2013 Clause 6.9 RSS-247.5.1
SPECIFICATIONS	
Frequency range (MHz)	913.7 919
RBW (kHz):	Set to 1% to 3% of the 99% bandwidth
VBW (kHz)	3xRBW
EUT	
Identification	Radio Remote Control
Voltage Input	4.8Vdc
ENVIROMENTAL & TEST INFO	
Test Date (YYYY-MM-DD)	2020-05-01
Temperature (°C)	25.2 ± 2
Humidity (%)	23.4 ± 5
Atmospheric Pressure kPa (For Info Only)	103.39
Tester	Abdoulaye Ndiaye
Client Witness	No Witness

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6.3 Test Setup

The setup for 99% Bandwidth measurements is depicted in photo 6

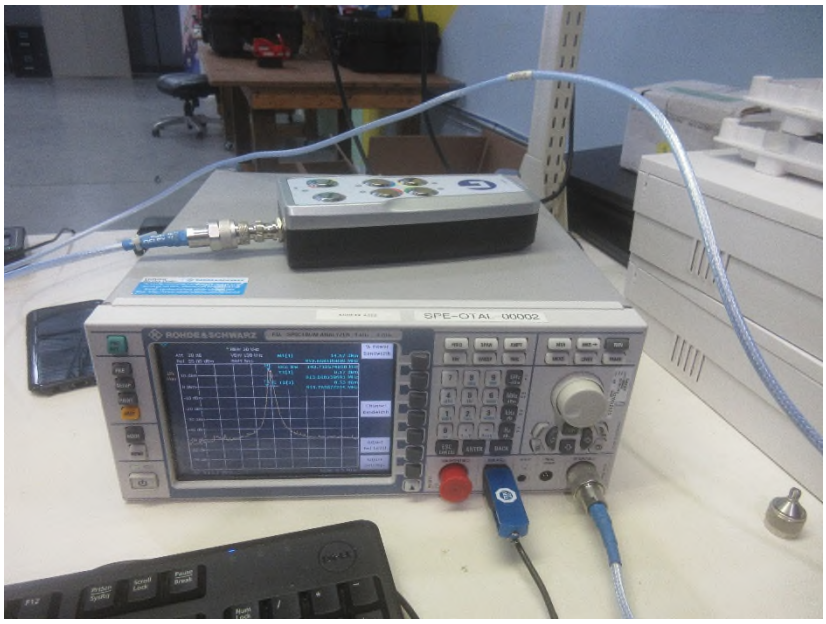

Photo 6: – Radio Remote Control

6.4 Test Results

The carrier gave a maximum of 5.57 MHz for 99% BW. Details are depicted in Table 10

Frequency Carrier (MHz)	99% Bandwidth (MHz)	Results
913.7-919	5.57	Pass
Note 1: No Limit is applicable, but according to RSS GEN 5 the RBW has to be set to 1% to 3% of the 99% bandwidth		

Table 10 – 99% Bandwidth Results

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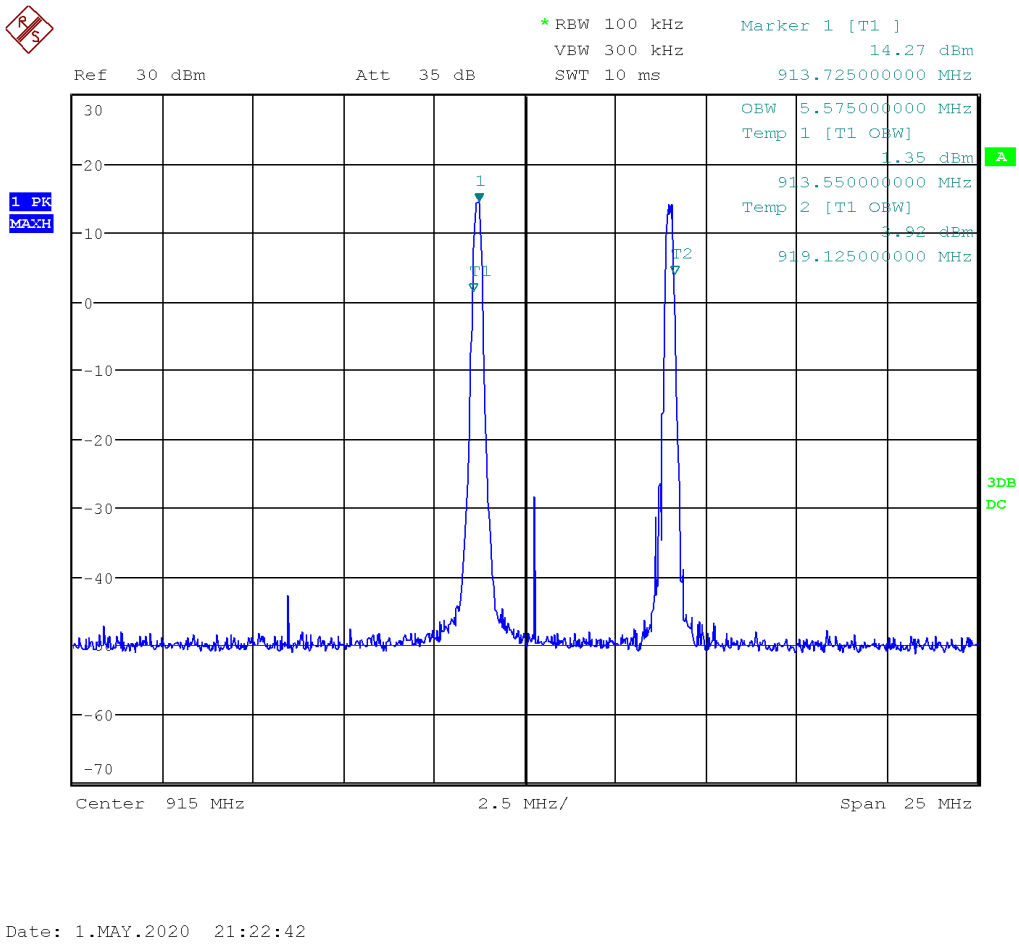
6.5 Graphs

The graphs showed below show the OBW during the operation of the device. This is measured by a max hold on the spectrum analyzer and the highest resolution bandwidth that is sufficiently low to exhibit the 99% bandwidth of a channel during operation of the EUT. Max hold is performed for a duration of not less than 1 minute. No attenuator was used between the EUT and the Spectrum Analyzer.



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Graph 1 Test Results – 99% Bandwidth Results – Radio Remote Control

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6.6 Test Instruments

This test was carried out in Laval test location

Equipment	Model No.	Manufacturer	Calibration Period (months)	Calibration Due (YYY-MM-DD)	Asset No: LAVE
Spectrum Analyzer	ESU-40	Rohde & Schwarz	24	2021-04-20	4092
Attenuator 10 dB	4779-10	Narda	NCR	NCR	4096
Cable 254mm SMA	Minibend-10	Huber+ Suhner	NCR	NCR	4080
Signal generator	SMU100A	Rohde & Schwarz	24	2020-08-23	4135
Signal generator	FSL 6	Rohde & Schwarz	24	2020-09-02	4095

Table 11: 99% dB Bandwidth Test Equipment

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7 6dB Bandwidth of Digitally Modulated Systems

7.1 Purpose & Methods

The Purpose & Methods of this test is to ensure that the bandwidth occupied exceeds a stated minimum. This helps ensure the utilization of the frequency allocation is sufficiently wide. This also helps prevent corruption of data by ensuring adequate data separation to distinguish the reception of the intended information. The test method is a defined in ANSI C63.10.

7.2 Test Specifications

REFERENCE STANDARD	FCC Part 15.247(a)2 RSS-247 5.2(a)
SPECIFICATIONS	
Limit – 6dB Bandwidth	≥500kHz
Frequency range (MHz)	913.7 919
RBW (kHz):	100
VBW (kHz)	300
EUT	
Identification	Ludwig Remote Control
Voltage Input	4.8 Vdc
Test Date (YYYY-MM-DD)	2020-04-30
Temperature (°C)	22.8 ± 2
Humidity (%)	19.4± 5
Atmospheric Pressure kPa (For Info Only)	101.98
Tester	Abdoulaye Ndiaye Scott Drysdale
Client Witness	No Witness

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7.3 Test Setup

The Setup for the 6dB Bandwidth testing is identical to the 99% Bandwidth setup. For more details refer to photo 6

7.4 Test Results

This carrier gave a maximum of 5.528 MHz for 6dB BW. Details are depicted in Table 12

Frequency Carrier (MHz)	6dB Bandwidth (kHz)	Limit (kHz)	Results
913.7-919	5528	≥500	Pass

Table 12 – 6dB Bandwidth Results

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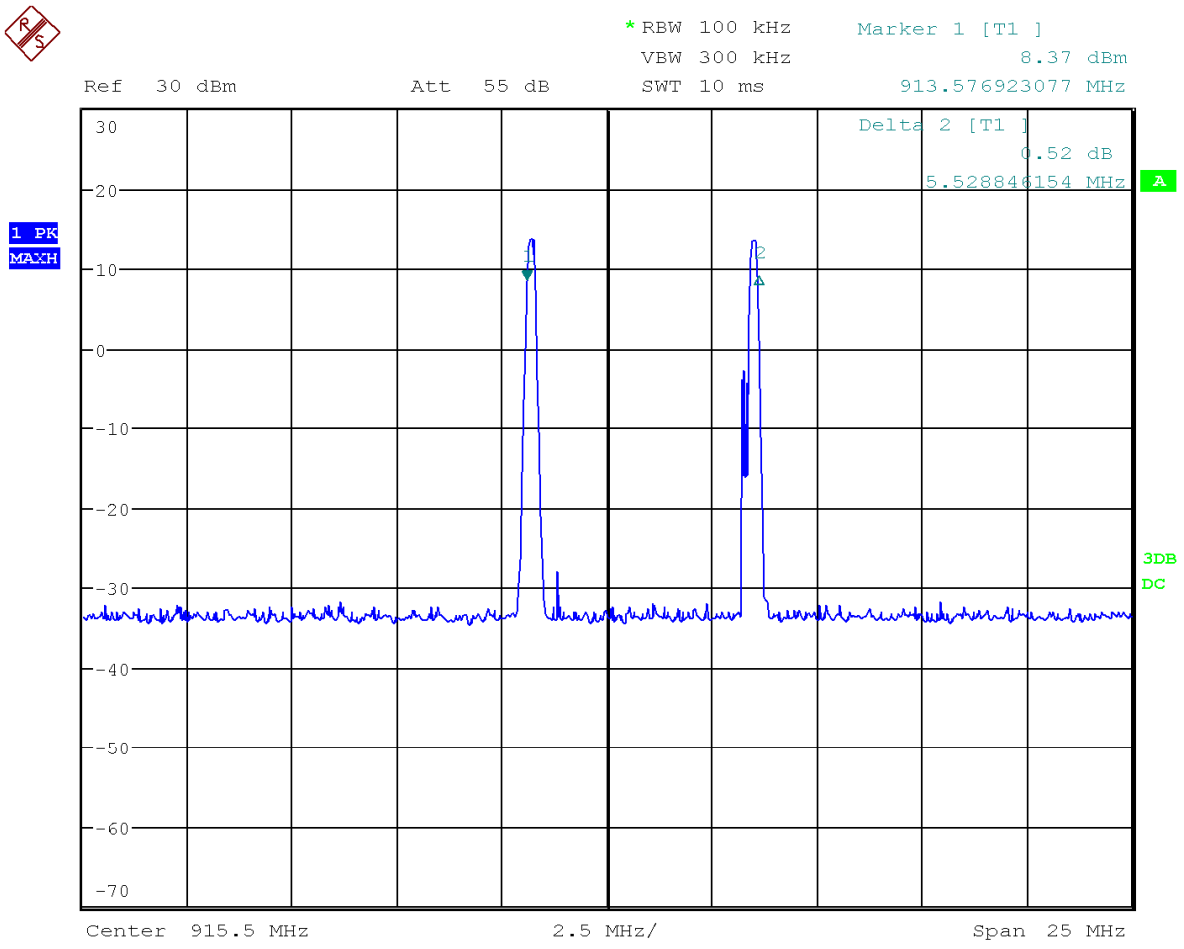
7.5 Graphs

The graphs showed below show the OBW during the operation of the device. This is measured by a max hold on the spectrum analyzer and the highest resolution bandwidth that is sufficiently low to exhibit the 6dB of the 99% bandwidth of a channel during operation of the EUT. Max hold is performed for a duration of not less than 1 minute. No attenuator was used between the EUT and the Spectrum Analyzer.



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Graph 2 Test Results – 6dB Bandwidth Results –

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7.6 Test Instruments

This test was carried out in Laval test location

Equipment	Model No.	Manufacturer	Calibration Period (months)	Calibration Due (YYY-MM-DD)	Asset No: LAVE
Spectrum Analyzer	ESU-40	Rohde & Schwarz	24	2021-04-20	4092
Cable 254mm SMA	Minibend-10	Huber+ Suhner	NCR	NCR	4080
Spectrum Analyzer	FSL 6	Rohde & Schwarz	24	2020-09-02	4095

Table 13: 6 dB OBW Test Equipment

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8 Maximum Peak Envelope Conducted Power – Digital Modulated

8.1 Purpose & Methods

The purpose of this test is to ensure that the maximum power conducted to the radiating element does not exceed the limits specified. The test method is a defined in ANSI C63.10.

This Test must be performed on normal temperature (23°C - 35°C)

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8.2 Test Specifications

REFERENCE STANDARD	FCC Part 15.247(b)(3) RSS-247.5.4(d) ANSI C63.10. Clause 11.9.1
SPECIFICATIONS	
Limit – Power (W)	<1
Frequencies (MHz)	913.7 to 919
RBW (MHz):	Greater then OBW
VBW (MHz)	Greater then OBW
Span (MHz)	8
EUT	
Identification	Ludwig Remote Control
Voltage Input	4.8 Vdc
ENVIROMENTAL	**Normal Conditions**
Test Date (YYYY-MM-DD)	2020-04-28
Temperature (°C)	23.4 ± 2
Humidity (%)	23.4± 5
Atmospheric Pressure kPa (For Info Only)	99.95
Tester	Abdoulaye Ndiaye
Client Witness	No Witness

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8.3 Limits

The limits are defined in 15.247(b)(3).

The maximum peak conducted output power of the intentional radiator shall not exceed 1 Watt for systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands

8.4 Test Setup

The Setup for the Maximum Peak Power testing is identical to the 99% Bandwidth setup. For more details refer to photo 6

8.5 Tests Results

The EUT only operates on one channel. The power levels is as shown below. The peak power measurements of channel tested are depicted in Table 14.

Frequency (MHz)	Measured Peak Power (dBm)	External Attenuation +Cable (dB) <Note 1>	Corrected Peak Power (dBm)	Peak Power (mW)	Limit (W)	Result
913.7	14.28	0	14.28	26.79	1	Pass
919	13.99	0	13.99	25.06	1	Pass
Total			17.15	51.85	1	Pass
Note 1: attenuation was taken into consideration with reference level offset.						

Table 14 – Test Results Peak-Power Measurements

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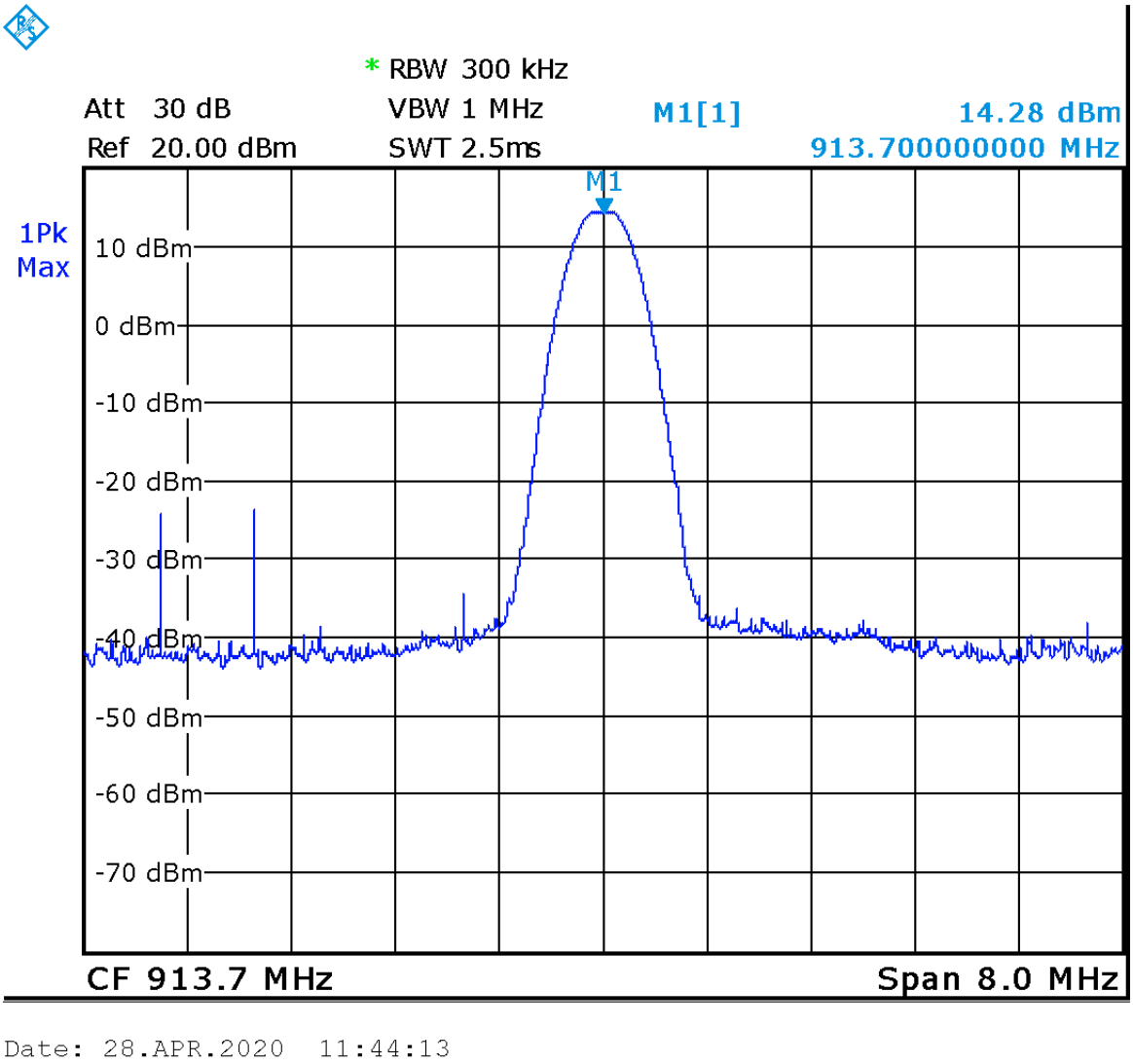
8.6 Graphs

The plots shown below show the Peak Power Output of the device during the antenna conducted measurements during transmit operation of the EUT. Note that no attenuator was used between the EUT and the Spectrum Analyzer.



Graph 3 Test Results – Conducted Peak Power Measurements – at 913.7MHz

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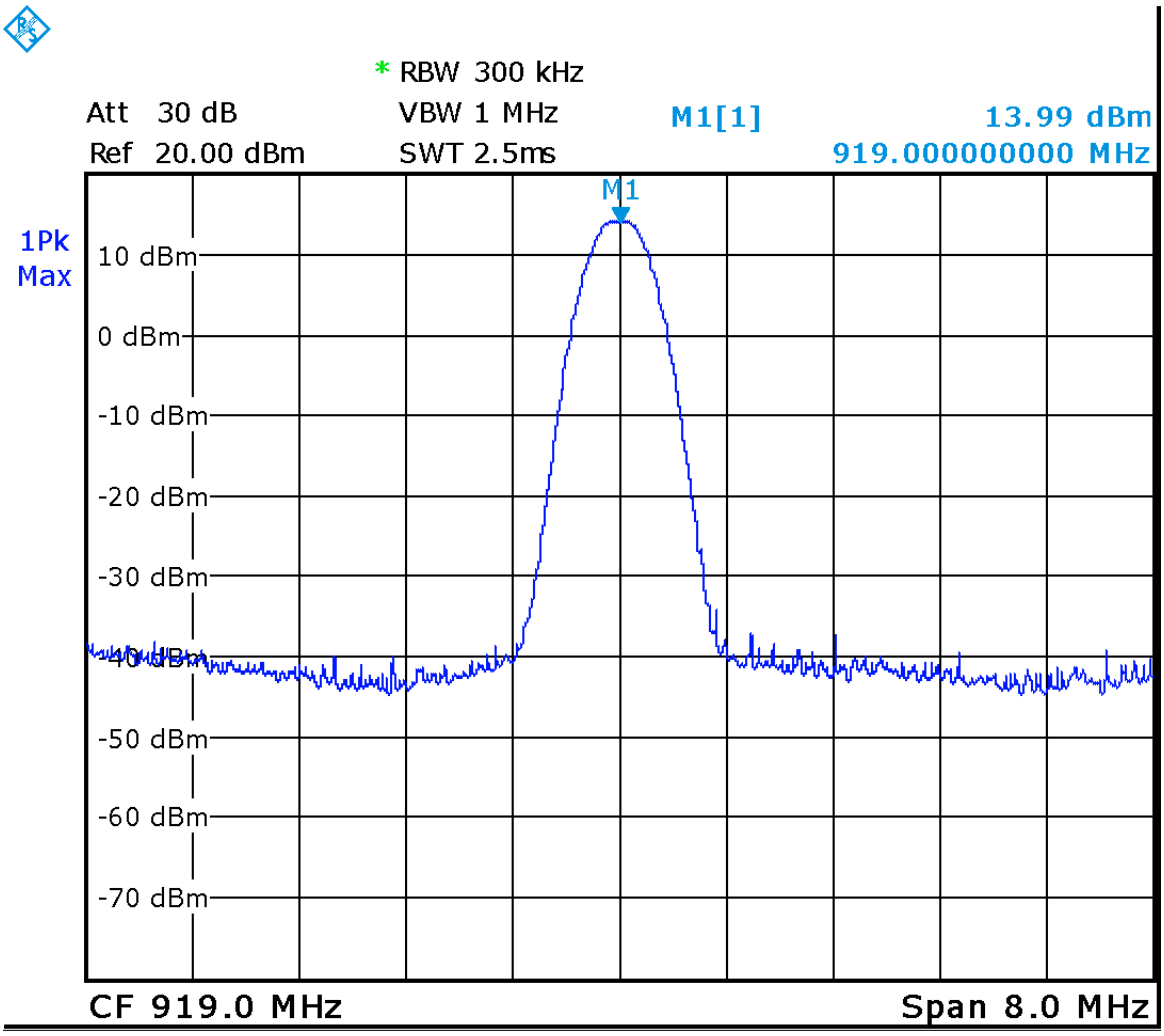

Date: 28.APR.2020 11:44:54

Graph 4 Test Results – Conducted Peak Power Measurements – at 919MHz

Note: For reference the markers are shown on the two carriers. Measurement was performed as a peak measurement.

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8.7 Test Instruments

This test was carried out in Laval test location

Equipment	Model No.	Manufacturer	Calibration Period (months)	Calibration Due (YYY-MM-DD)	Asset No: LAVE
Spectrum Analyzer	ESU-40	Rohde & Schwarz	24	2021-04-20	4092
Spectrum Analyzer	FSL 6	Rohde & Schwarz	24	2020-09-02	4095

Table 15: Conducted Peak Power Test Equipment

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9 Peak Power Spectral Density

9.1 Purpose & Methods

The Purpose & Methods of this test is to ensure that the maximum power spectral density to the radiating element does not exceed the limits specified. This ensures that the modulation is significantly wide enough, or low enough in power that it will allow for co-operation of other wireless devices operating within this frequency allocation. The method applied is the PKPSD described in ANSI C63.10-2013 in Clause 11.10.

9.2 Test Specifications

REFERENCE STANDARD	FCC Part 15.247(e) RSS-247 5.2(b) ANSI C63.10. Clause 11.10
SPECIFICATIONS	
Limit (dBm)	<8
Frequencies (MHz)	913.7 919
RBW (kHz):	3
VBW (kHz)	10
Span (MHz)	4
EUT	
Identification	Ludwig Remote Control
Voltage Input	4.8 Vdc
ENVIROMENTAL & TEST INFO	
Test Date (YYYY-MM-DD)	2020-04-28
Temperature (°C)	23.4 ± 2
Humidity (%)	23.4 ± 5
Atmospheric Pressure kPa (For Info Only)	99.95
Tester	Abdoulaye Ndiaye
Client Witness	No Witness

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9.3 Limits

The limits are defined in 15.247(e)

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission

9.4 Test Setup

The Setup for the Peak Power Spectral Density testing is identical to the 99% Bandwidth setup. For more details refer to photo 6

9.5 Test Results

The EUT was tested on both channels. The worst-case value is –8.43 dBm at 913.7MHz as measured with a 3 kHz resolution bandwidth. The results of the peak power of channels tested are depicted in Table 16

Frequency (MHz)	Measured PSD (dBm)	External Attenuation +Cable (dB)	Corrected Peak Power (dBm)	Result
913.7	2.88	0	2.88	Pass
919	1.1	0	1.1	Pass

Table 16- Results – PKPSD

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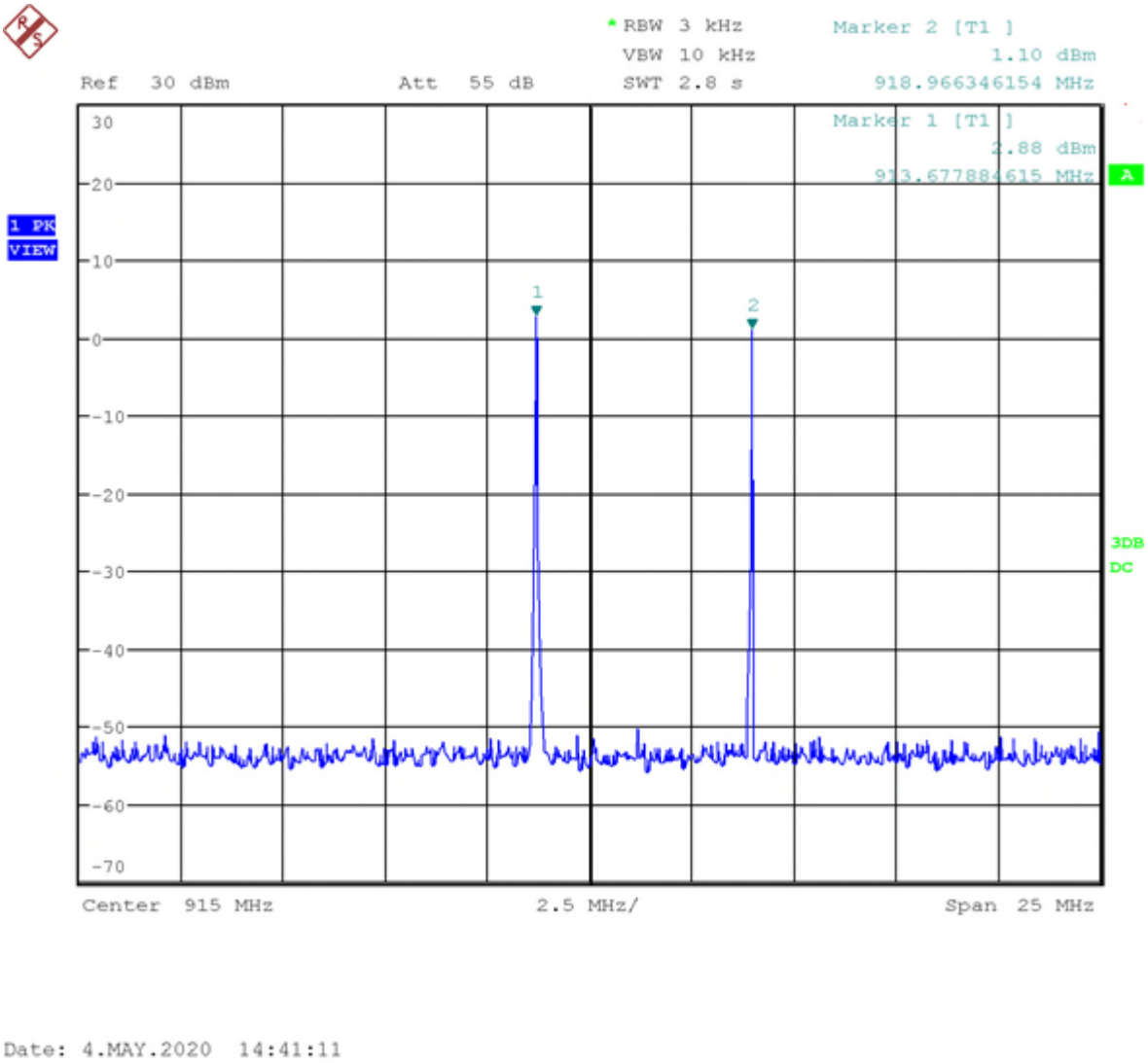
9.6 Graphs

The graphs shown below show the power spectral density of the device during the conducted measurement operation of the EUT. Low, middle, and high channel was investigated. No attenuator was used between the EUT and the Spectrum Analyzer



Graph 5 Test Results – PKPSD – at 913.7MHz

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9.7 Test Instruments

This test was carried out in Laval test location

Equipment	Model No.	Manufacturer	Calibration Period (months)	Calibration Due (YYY-MM-DD)	Asset No: LAVE
Spectrum Analyzer	ESU-40	Rohde & Schwarz	24	2021-04-20	4092
Spectrum Analyzer	FSL 6	Rohde & Schwarz	24	2020-09-02	4095

Table 17 – Test Instrumentation – Power Spectral Density

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10 Band Edge (-20 dBc Requirement)

10.1 Purpose & Methods

The Purpose of this test is to ensure that the maximum power conducted to the radiating element at frequencies outside of the authorized spectrum does not exceed the limits specified. This ensures that the only the intended signal is delivered to the radiating element. The method applied is described in ANSI C63.10-2013 in Clause 11.11.1

10.2 Test Specifications

REFERENCE STANDARD	FCC Part 15.247(d) RSS-247 5.5 ANSI C63.10 Clause 11.11.1
SPECIFICATIONS	
Limit (dBc)	<-20
Frequencies (MHz)	913.7 919
EUT	
Identification	Ludwig Remote Control
Voltage Input	4.8Vdc
ENVIROMENTAL & TEST INFO	
Test Date (YYYY-MM-DD)	2020-04-28
Temperature (°C)	23.4 ± 2
Humidity (%)	23.4 ± 5
Atmospheric Pressure kPa (For Info Only)	99.95
Tester	Abdoulaye Ndiaye Scott Drysdale
Client Witness	No Witness

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10.3 Limits

The limits are defined in 15.247(d). In any 100 kHz band, the peak spurious harmonics emissions must be at least 20 dB below the fundamental. Band Edge is to be evaluated up to the 10th harmonic. This -20 dBc requirement also applies at the 'band edge' of 902MHz and 928MHz.

10.4 Test Setup

The Setup for the Band Edge testing is identical to the 99% Bandwidth setup. For more details refer to photo 6

10.5 Test Results

The EUT was tested on the frequency carrier (913.7MHz-919MHz). The worst-case value is -22.63 dBm with 36.94 dBc from the fundamental. The peak of Spurious Conducted of channels tested are depicted in Table 18.

Frequency carrier (MHz)	Frequency (MHz)	Measured Spurious Conducted (dBm)	Fundamental Level <Note 2>	dBc	Results
913.7-919	0.009-0.15	-37.74	14.4	52.1	Pass
	0.15-30	-30.60	14.4	45.0	Pass
	30-902	-45.64	14.4	60.0	Pass
	902-928	-22.63	14.4	36.94	Pass
	928-1000	-38.02	14.4	52.4	Pass
	1000-6000	-25.5	14.4	39.9	Pass
Note 2. The highest level of the fundamental is 14.4 dBm based on RF output Power results (Table 14)					

Table 18- Results – Band Edge

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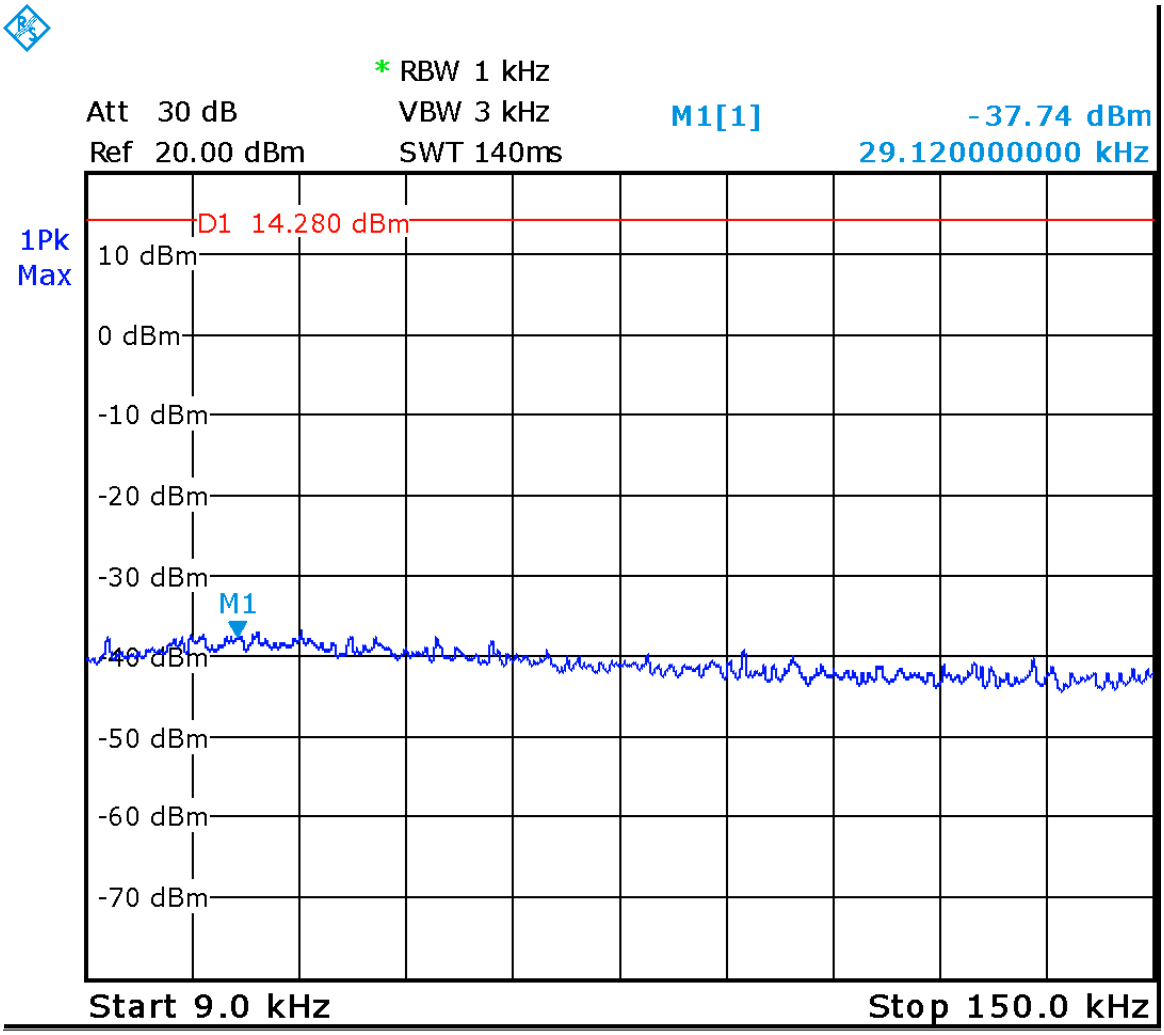
10.6 Graphs

The graphs below show the worst-case peak power output of the device with conducted measurement during transmit operation of the EUT. No attenuator was used between the EUT and the Spectrum Analyzer



D1=Fundamental Level

Date: 28.APR.2020 15:35:27

Graph 6 Test Results – Band Edge – 9kHz to 150kHz

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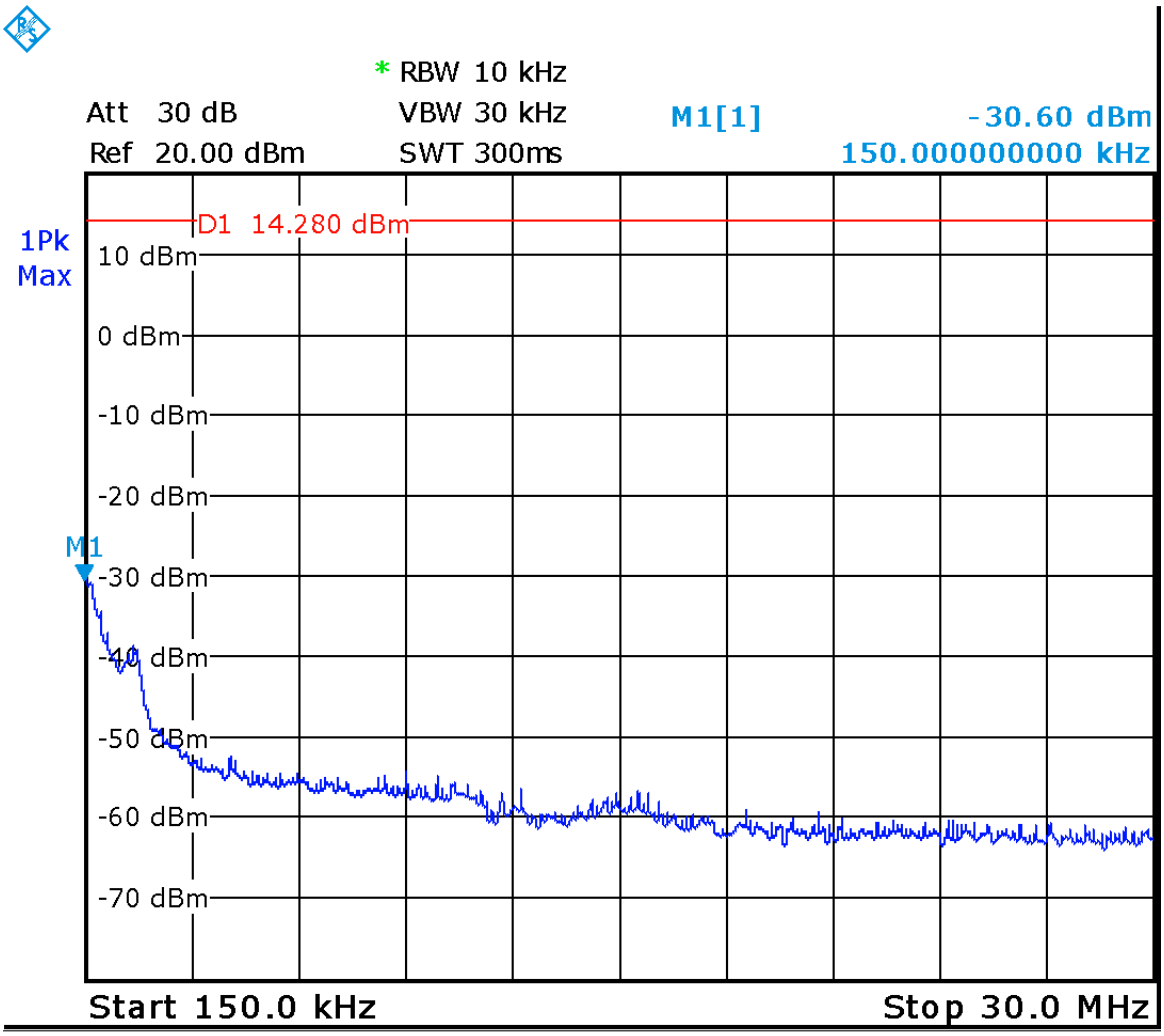

D1=Fundamental Level

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Graph 7 Test Results – Band Edge –150kHz to 30MHz

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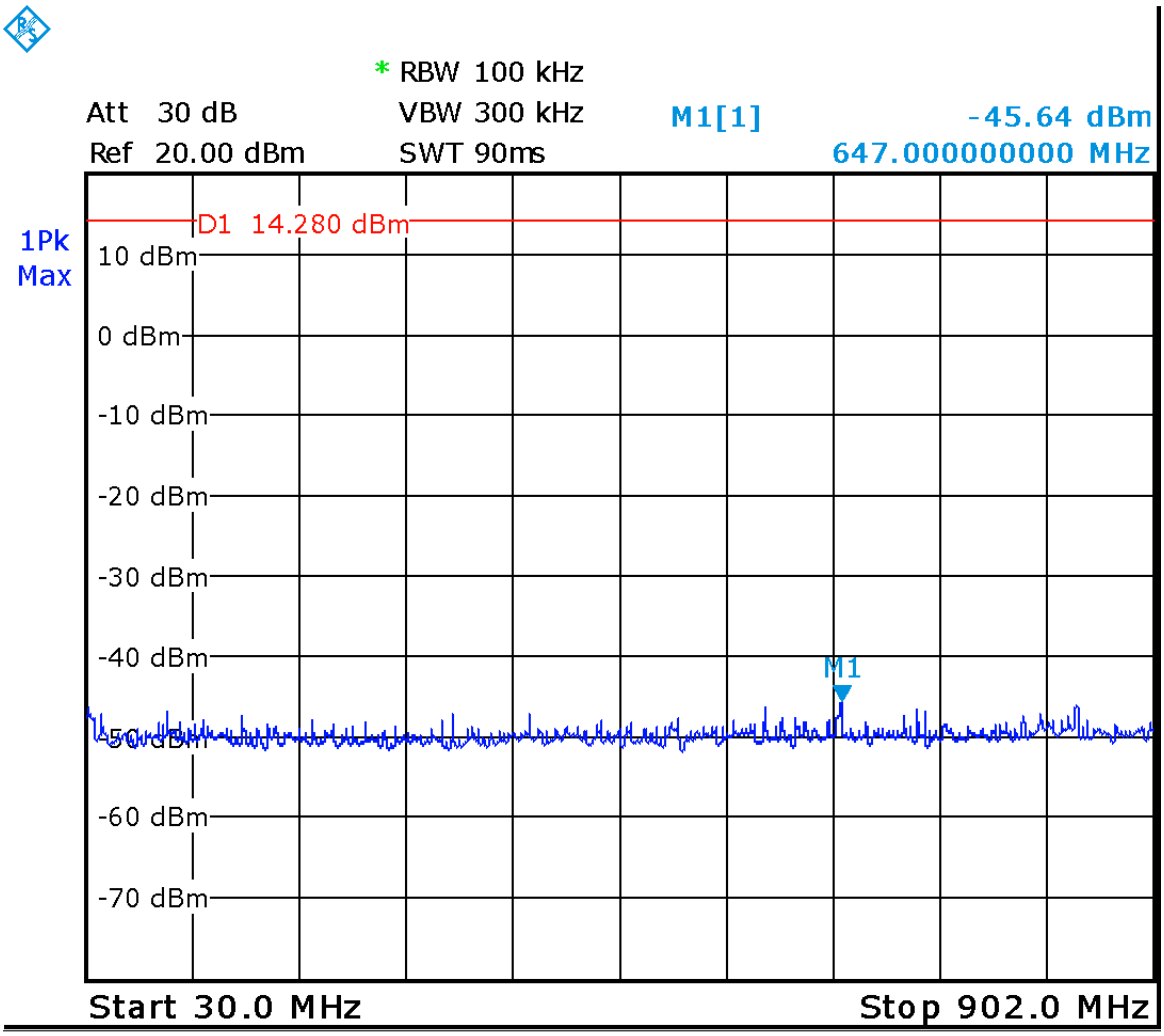

D1=Fundamental Level

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Graph 8 Test Results – Band Edge –30MHz to 902MHz

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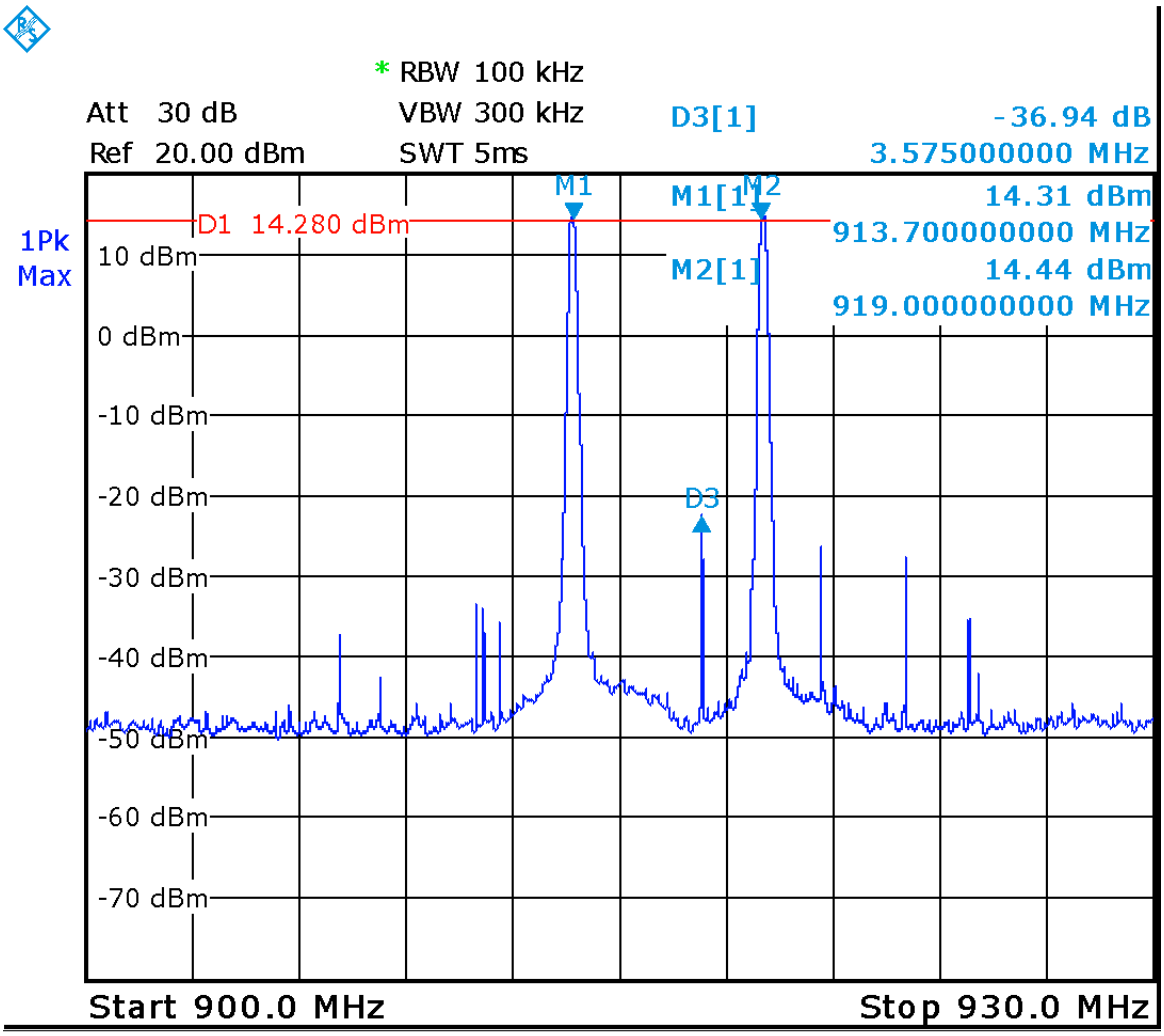

D1=Fundamental Level;D3=margin between fundamental & 2nd Har
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Graph 9 Test Results – Band Edge – 900MHz to 930MHz

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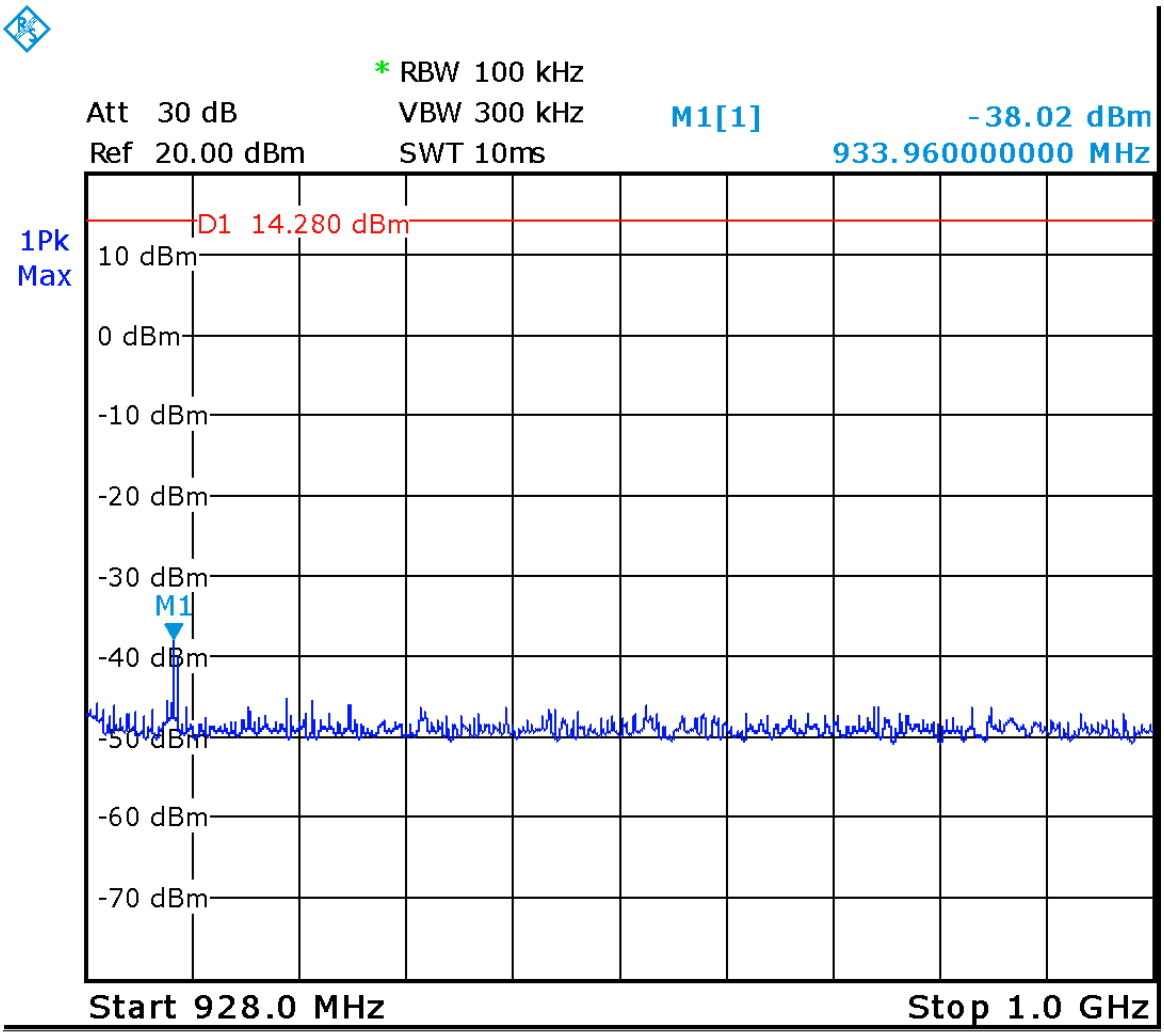

D1=Fundamental Level

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Graph 10 Test Results – Band Edge – 928MHz to 1GHz

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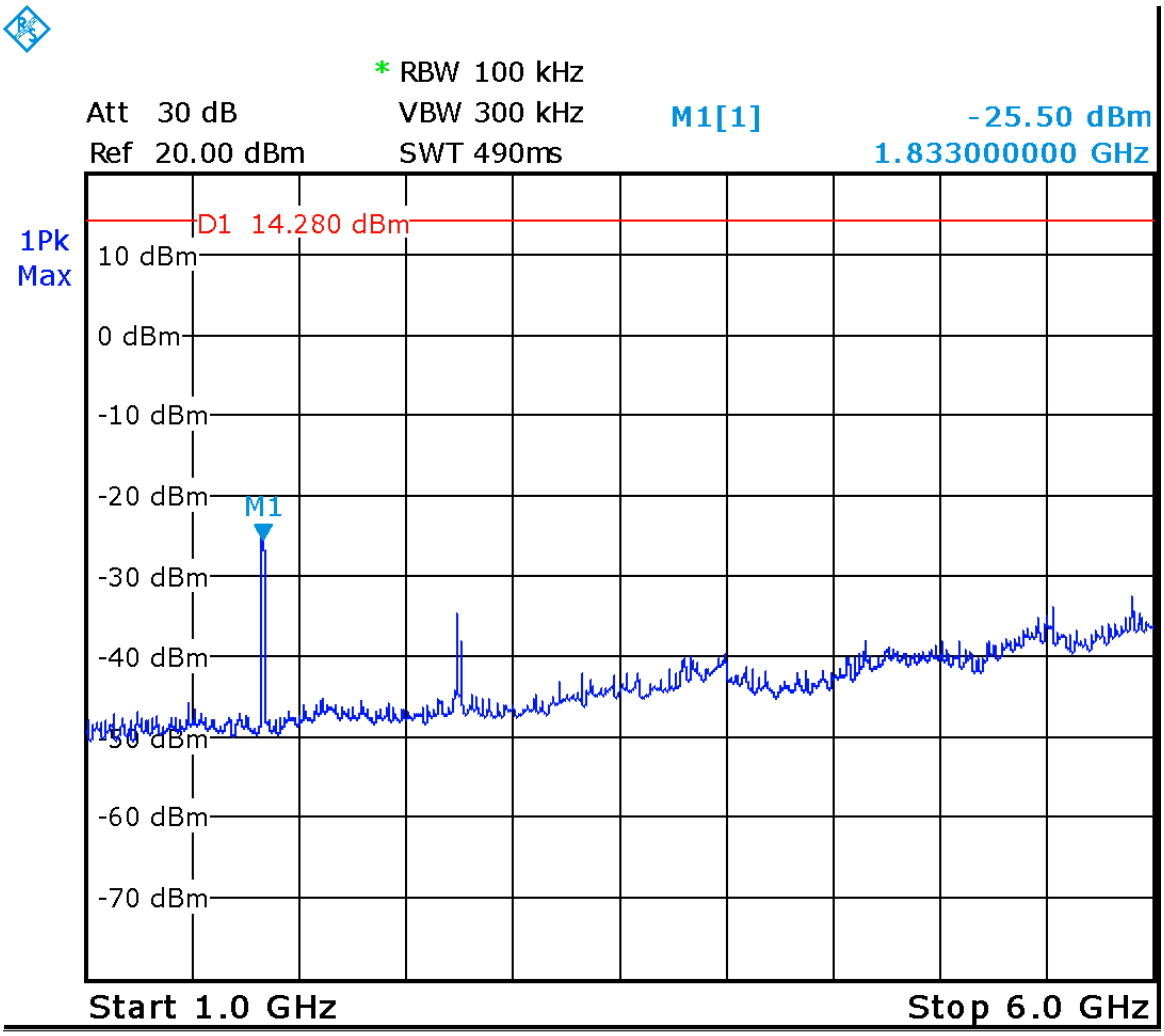

D1=Fundamental Level

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Graph 11 Test Results – Band Edge – 1GHz to 6GHz

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10.7 Test Instruments

This test was carried out in Laval test location

Equipment	Model No.	Manufacturer	Calibration Period (months)	Calibration Due (YYY-MM-DD)	Asset No: LAVE
Spectrum Analyzer	ESU-40	Rohde & Schwarz	24	2021-04-20	4092
Cable 254mm SMA	Minibend-10	Huber+ Suhner	NCR	NCR	4080
Spectrum Analyzer	FSL 6	Rohde & Schwarz	24	2020-09-02	4095

Table 19 – Test Instrumentation – Band Edge

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11 Tx Spurious Radiated Emissions

11.1 Purpose & Methods

The Purpose of this test is to ensure that the RF energy unintentionally emitted from the EUT does not exceed the limits listed below as defined in the applicable test standard, as measured from a receiving antenna. This helps protect broadcast radio services such as television, FM radio, pagers, cellular telephones, emergency services, and so on, from unwanted interference. The method is as defined in Section 12.1 of FCC KDB 558074 and ANSI C63.10.

All unintentional emissions must also meet the 'Spurious Conducted Emissions' requirements of -20 dBc or greater. See also 'Band Edge' for further details.

Frequency	Limit
0.009 MHz – 0.490 MHz	2400/F(kHz) uV/m at 300m([1])
0.490 MHz – 1.705 MHz	24000/F(kHz) uV/m at 30m ([1])
1.705 MHz – 30 MHz	30 uV/m at 30m([1])
30 MHz – 88 MHz	100 uV/m (40.0 dBuV/m) at 3m ([1])
88 MHz – 216 MHz	150 uV/m (43.5 dBuV/m) at 3m ([1])
216 MHz – 960 MHz	200 uV/m (46.0 dBuV/m) at 3m ([1])
Above 960 MHz	500 uV/m (54.0 dBuV/m) at 3m ([1])
Above 1000 MHz	500 uV/m (54 dBuV/m) at 3m ([2])
Above 1000 MHz	500 uV/m (74 dBuV/m) at 3m ([3])
[1]Limit is with Quasi Peak detector with bandwidths as defined in CISPR-16-1-1 [2]Limit is with 1 MHz measurement bandwidth and using an Average detector [3]Limit is with 1 MHz measurement bandwidth and using a Peak detector	

Table 20 Limits – Tx Spurious

Based on ANSI C63.4 Section 4.2, if the Peak detector measurements do not exceed the Quasi-Peak limits, where defined, then the EUT is deemed to have passed the requirements.

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11.2 Test Specifications

REFERENCE STANDARD	FCC Part 15.209(a) RSS-247 5.5 ANSI C63.10 Clause 5.5
SPECIFICATIONS	
Limit (dBuV/m)	See table 20
Frequencies (MHz)	913.7 919
EUT	
Identification	LudwigHook, Remote Radio Control, LudwigHook XL
Voltage Input	3.3Vdc – 6Vdc

ENVIROMENTAL & TEST INFO

Test Date (YYYY-MM-DD)	2020-04-27	2020-04-29
Temperature (°C)	24.1 ± 2	22.7 ± 2
Humidity (%)	15 ± 5	17.6 ± 5
Atmospheric Pressure kPa (For Info Only)	101.51	101.94
Tester	Abdoulaye Ndiaye	
Client Witness	No Witness	

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11.3 Limits

The limits, as defined in 15.247(d) for intentional radiated emissions, apply for those emissions that fall in the restricted bands, as defined in Section 15.205(a). These emissions must comply with the radiated emission limits specified in Section 15.209(a).

11.4 Test Setup

As per ANSI C63.10 Clause 6.3.1, below 1GHz, the height of the EUT was set to 80cm. And above 1GHz, the height was set to 1.5m.

Photo 7: – Test Setup – 9kHz to 30MHz (LudwigHook)

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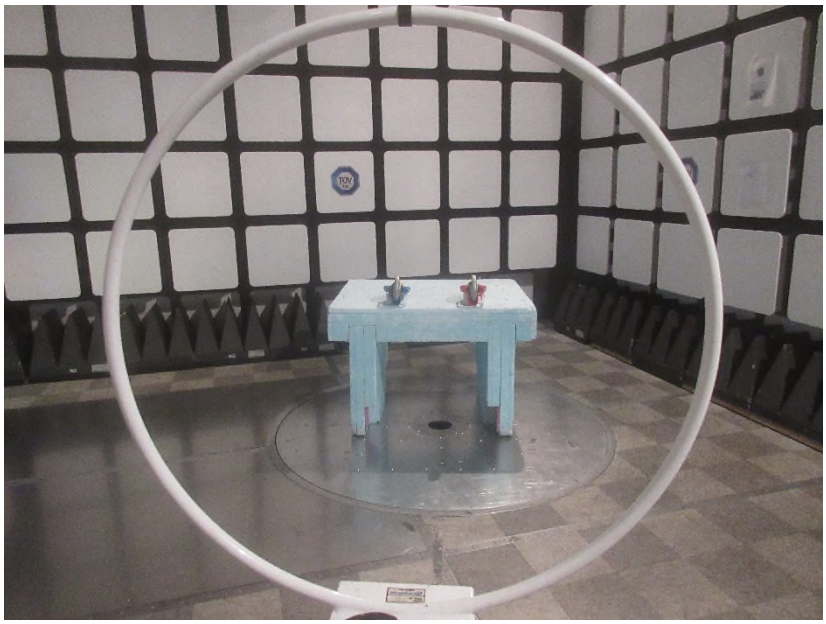

Photo 8: – Test Setup – 9kHz to 30MHz (LudwigHook XL)

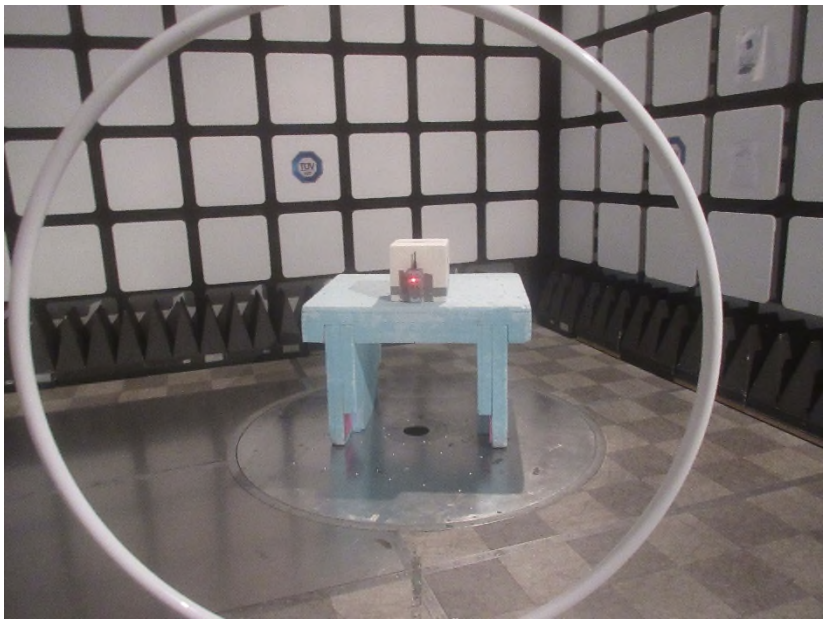

Photo 9: – Test Setup – 9kHz to 30MHz (Radio Remote Control)

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Photo 10: – Test Setup – 30MHz to 1GHz – Vertical Polarization (LudwigHook)

Photo 11: – Test Setup – 30MHz to 1GHz – Vertical Polarization (LudwigHook XL)

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Photo 12: – Test Setup – 30MHz to 1GHz – Vertical Polarization (Radio Remote Control)

Photo 13: – Test Setup >1GHz – Horizontal Polarization (LudwigHook)

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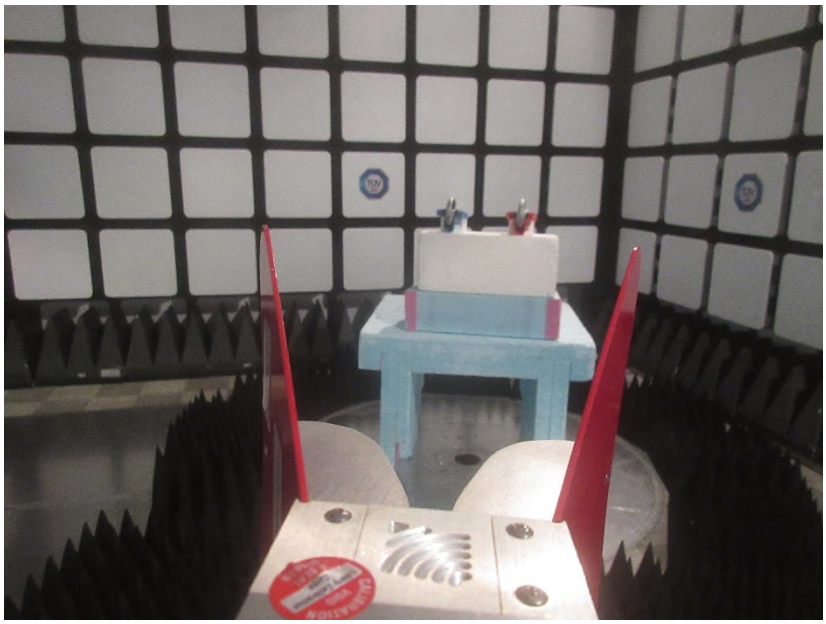

Photo 14: – Test Setup >1GHz – Horizontal Polarization (LudwigHook XL)

Photo 15: – Test Setup >1GHz – Horizontal Polarization (Radio Remote Control)

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11.5 Results

Frequency carrier was tested in several ranges and only the worst-case are presented. Final measurements are given in Appendix A.

Frequency Carrier (MHz)	Frequency Range (MHz)	Frequency (MHz)	Polarization	Detector	Limit	Margin	Results <Note 2>
913.7-919	0.009 – 30	-	-	-		Note 1	Pass
	30 – 1000	911.059	Vertical	Quasi-Peak		16.3	Pass
	>1000	-	-	-		Note 1	Pass
Note 1: No significant emission, i.e., 10dB below the limit was noted Note 2: For Worst cases final measurement please refer to Appendix A: Table A1 to & Table A2							

Table 21 – Test Results for Tx Spurious Emission – Worst Cases (LudwigHook)

Frequency Carrier (MHz)	Frequency Range (MHz)	Frequency (MHz)	Polarization	Detector	Limit	Margin	Results <Note 2>
913.7-919	0.009 – 30	-	-	-		Note 1	Pass
	30 – 1000	930.576	Vertical	Quasi-Peak		16.8	Pass
	>1000	-	-	-		Note 1	Pass
Note 1: No significant emission, i.e., 10dB below the limit was noted Note 2: For Worst cases final measurement please refer to Appendix A: Table A3 to & Table A4							

Table 22 – Test Results for Tx Spurious Emission – Worst Cases (LudwigHook XL)

Frequency Carrier (MHz)	Frequency Range (MHz)	Frequency (MHz)	Polarization	Detector	Limit	Margin	Results <Note 2>
913.7-919	0.009 – 30	-	-	-		Note 1	Pass
	30 – 1000	911.35	Vertical	Quasi-Peak		2.1	Pass
	>1000	-	-	-		Note 1	Pass
Note 1: No significant emission, i.e., 10dB below the limit was noted Note 2: For Worst cases final measurement please refer to Appendix A: Table A5 to & Table A6							

Table 23 – Test Results for Tx Spurious Emission – Worst Cases (Radio Remote Control)

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11.6 Graphs

The graphs shown below are maximized peak measurement graphs measured with a resolution bandwidth greater than or equal to the final required detector over a full 0-360°. This peaking process is done as a worst-case measurement and enables the detection of frequencies of concern for final measurement. For final measurements with the appropriate detector, where applicable, please refer to the tables under Final Measurements.

In accordance with FCC Part 15, Subpart A, Section 15.33, the device was scanned to the 10th harmonic, a minimum of 9.28, however the device was additionally scanned to 10 GHz for information purposes.

Devices scanned may be scanned at alternate test distances and in accordance with FCC Part 15, Subpart A, Section 15.31, an extrapolation factor of 20 dB/decade was used above 30 MHz and 40 dB/decade below 30 MHz for example, for 1-meter measurements, an extrapolation factor 9.5 dB from 20 Log (1m / 3m) is applied.

Only worst-case graphs are presented.

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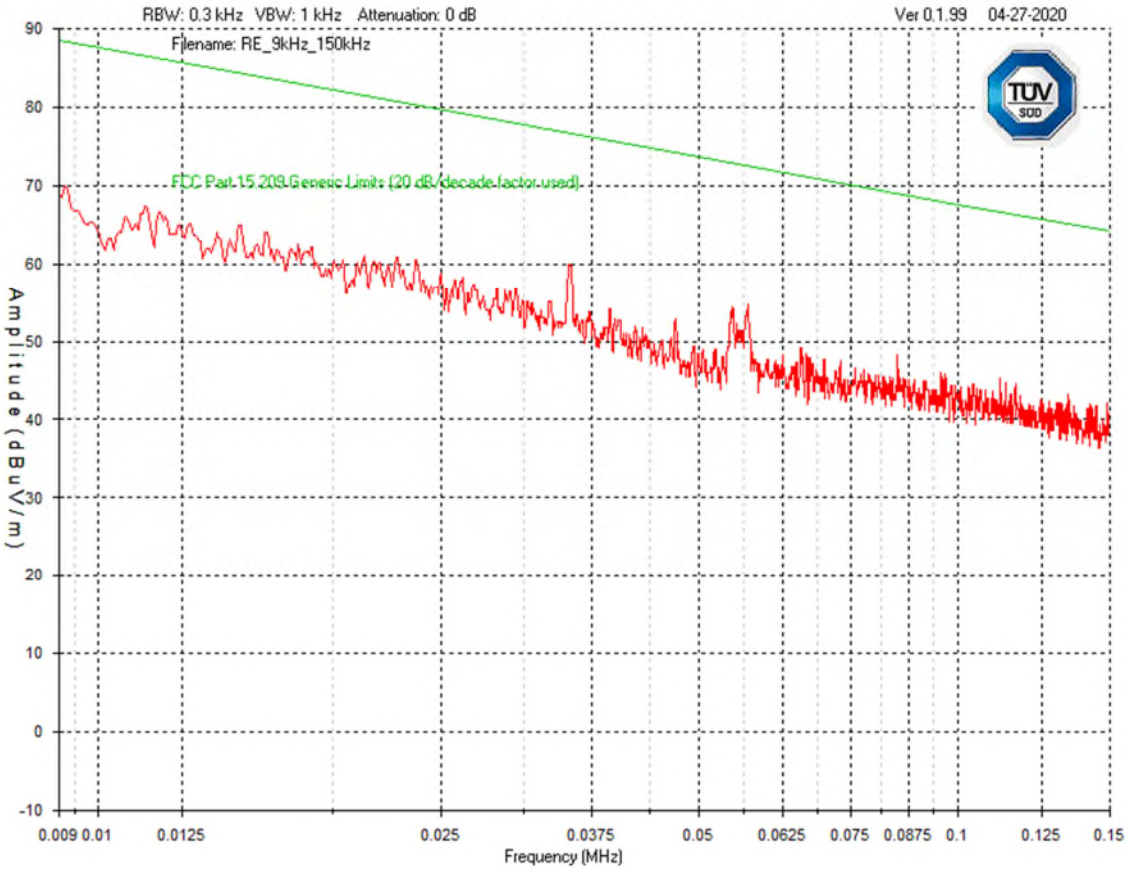
Frequency range from 9kHz to 150kHz



Graph 12 Test Results – Tx Spurious emission 9kHz – 150kHz: LudwigHook

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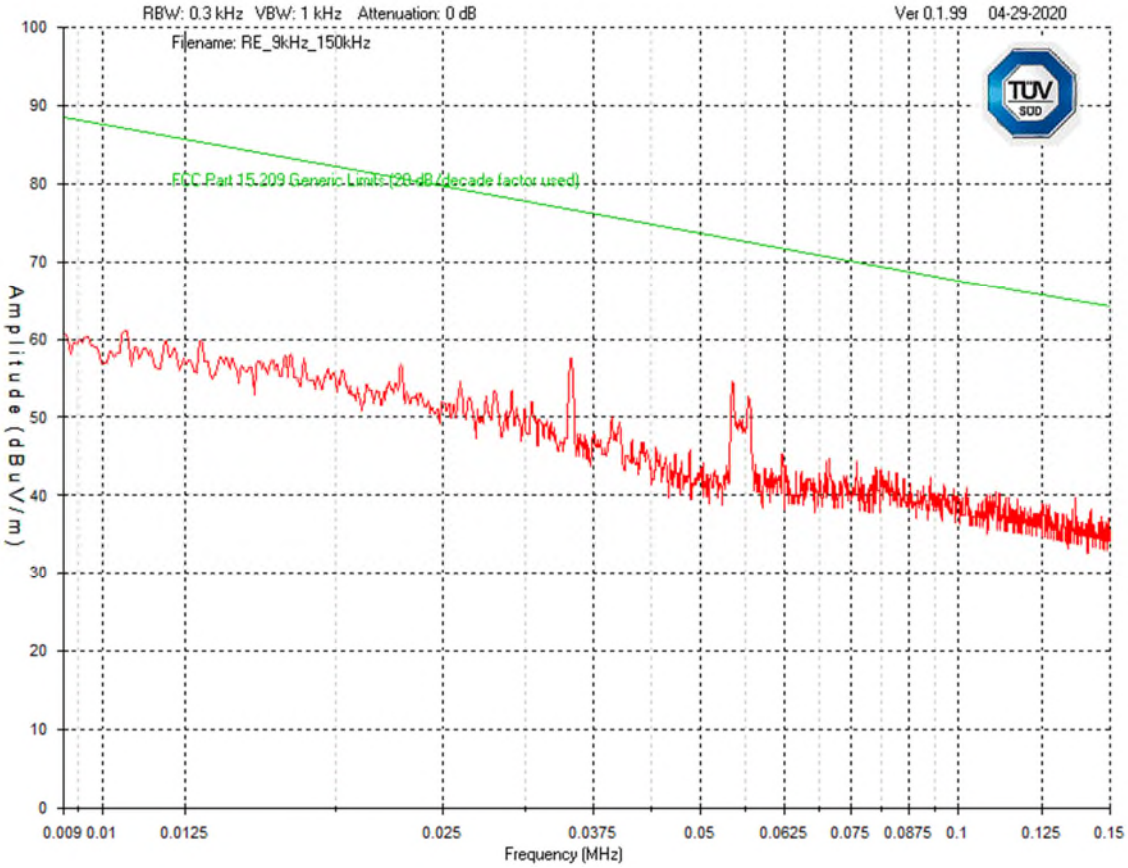

Graph 13 Test Results – Tx Spurious emission 9kHz – 150kHz: LudwigHook XL

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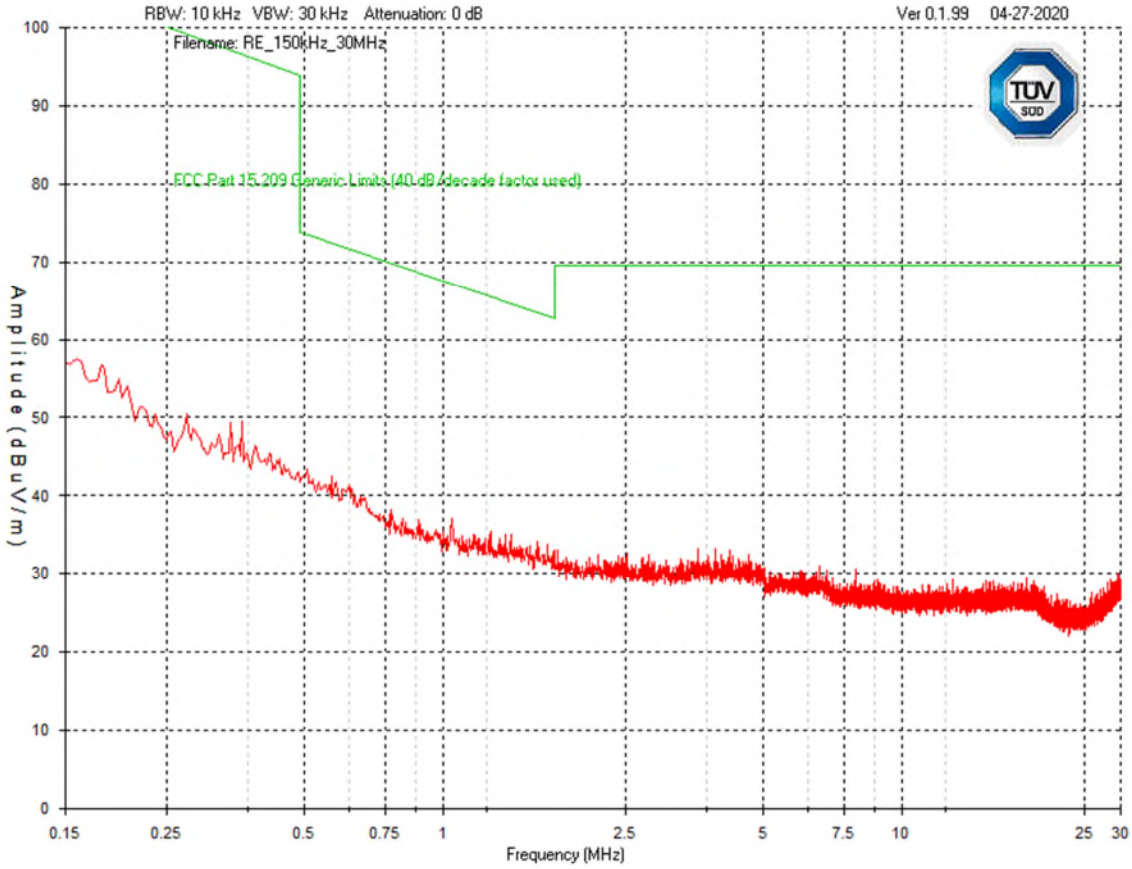
Frequency range from 150kHz to 30MHz



Graph 14 Test Results – Tx Spurious emission 150kHz – 30MHz: LudwigHook

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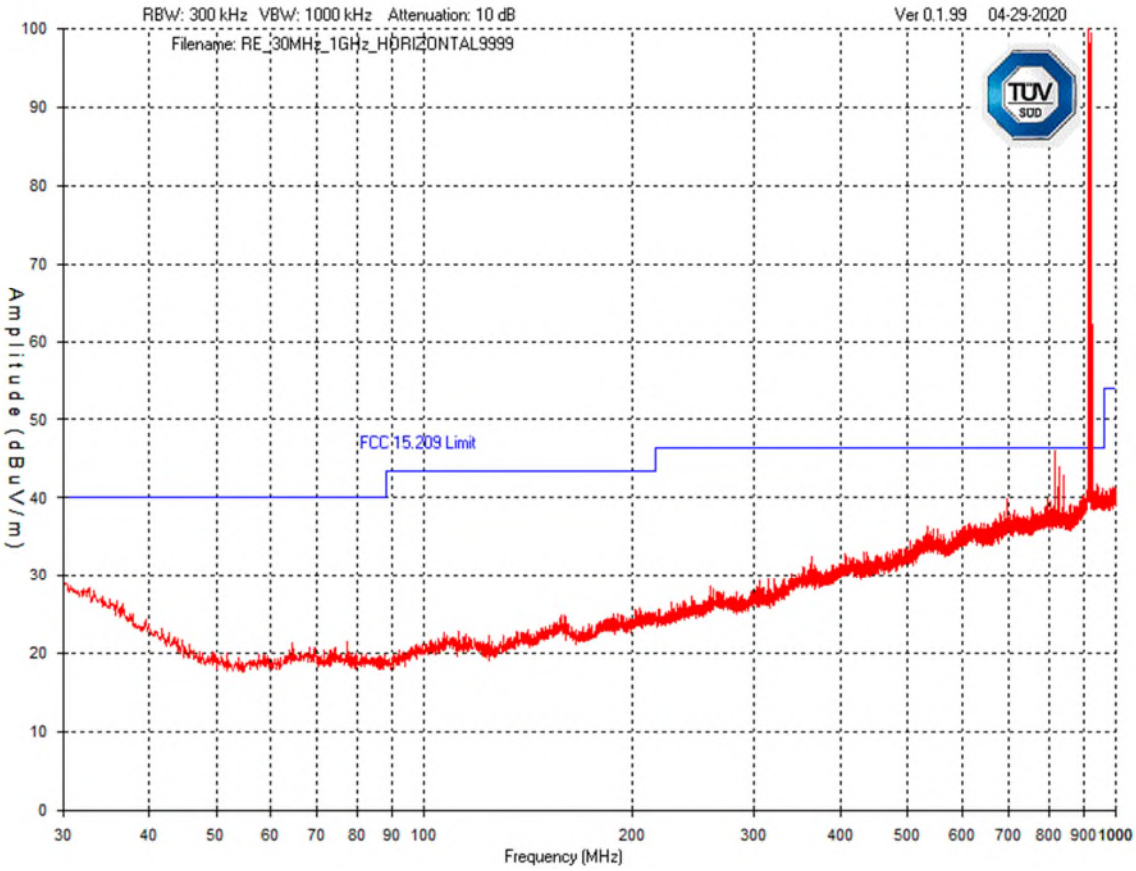
Frequency Range from 30MHz to 1GHz – Worst case



Graph 15 Test Results – Tx Spurious emission 30MHz – 1GHz- (Horizontal polarisation): Radio Remote Control

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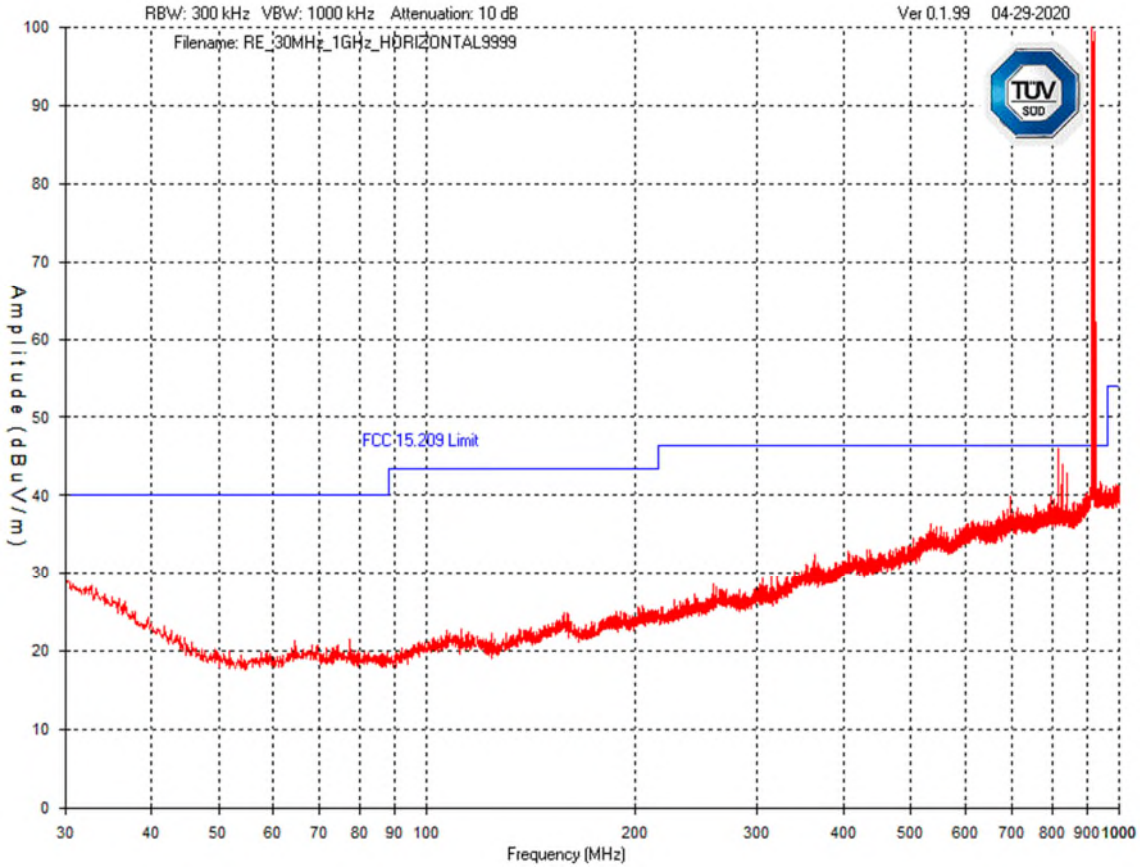

Graph 16 Test Results – Tx Spurious emission 30MHz – 1GHz- (vertical polarisation): Radio Remote Control

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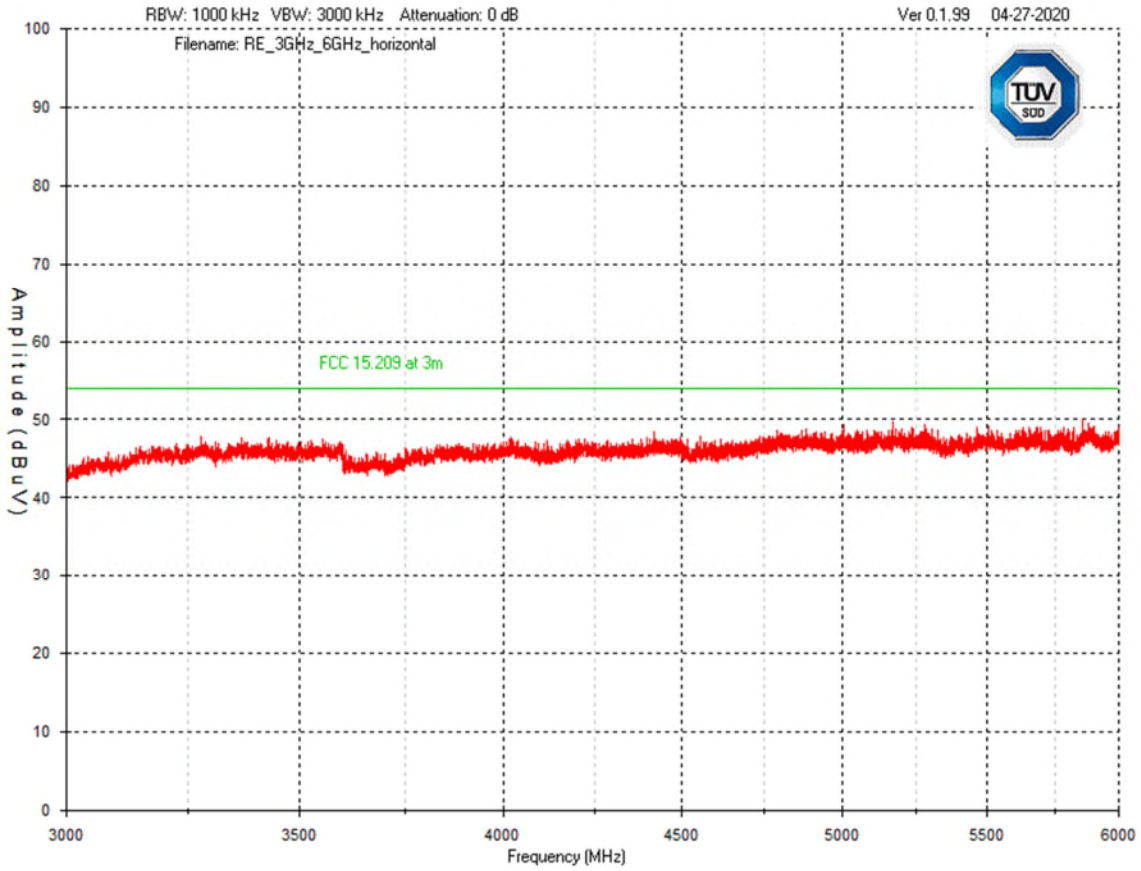
Frequency Range from 3GHz to 6GHz – Worst case



Graph 17 Test Results – Tx Spurious emission 3GHz – 6GHz- (Horizontal polarisation): LudwigHook

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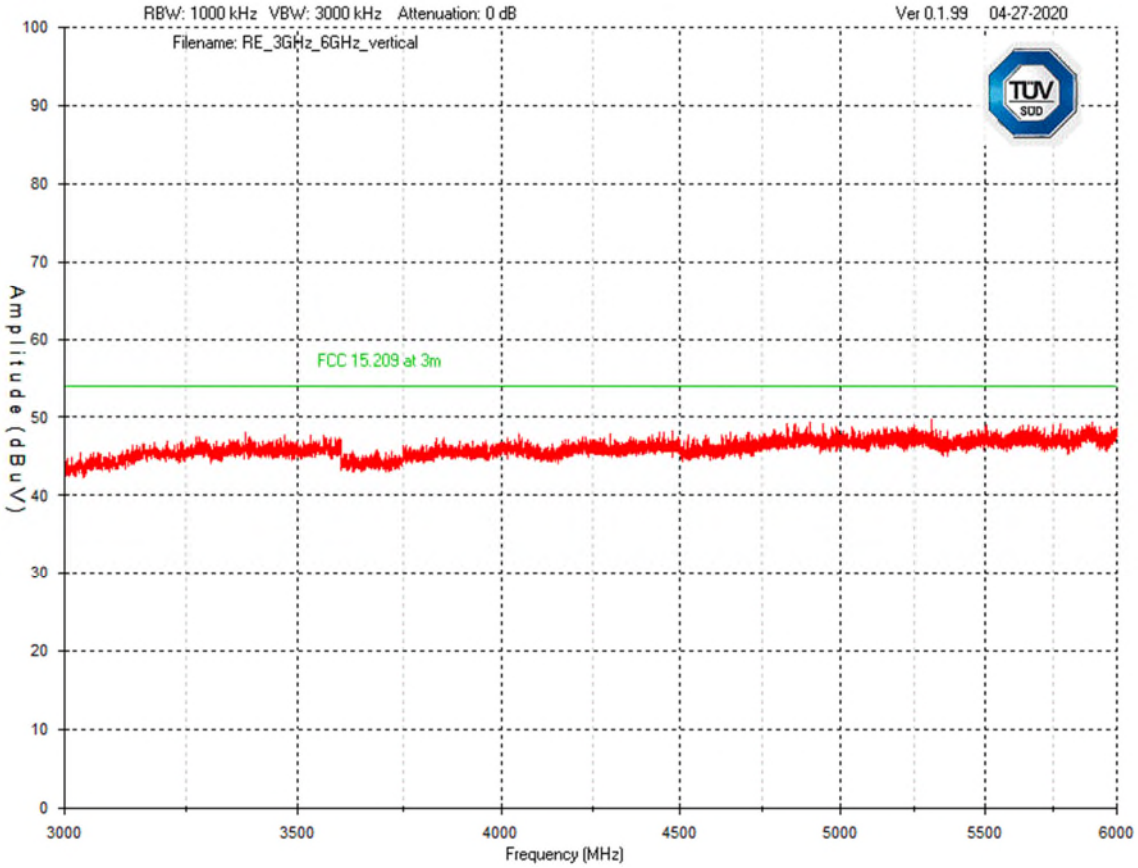

Graph 18 Test Results – Tx Spurious emission 3GHz – 6GHz- (Vertical polarisation): LudwigHook

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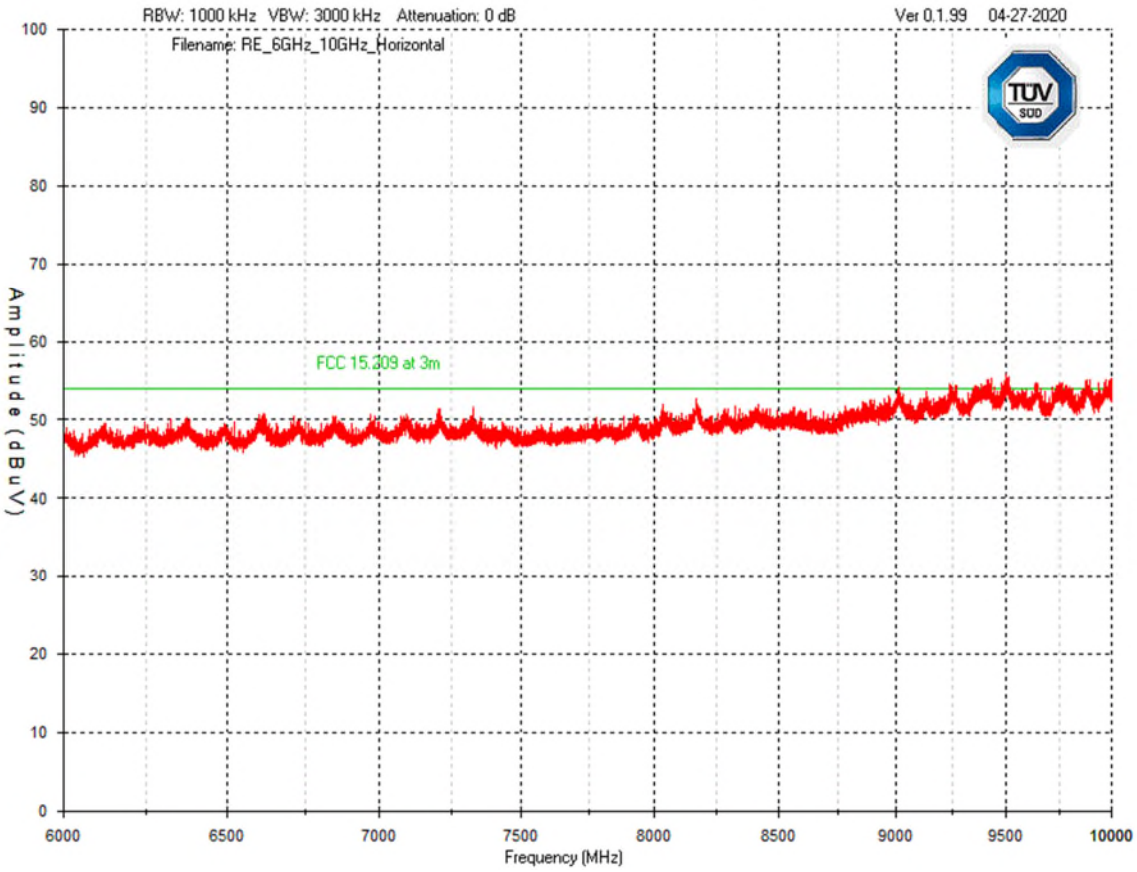
Frequency Range from 6GHz to 10GHz– Worst case (Peak graph shown)



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Graph 19 Test Results – Tx Spurious emission 6GHz – 10GHz-(Horizontal polarisation): LudwigHook

Note: Peak graph shown. When measured with an average detector, no emissions in this range were detected and the noise floor was below the limit over this frequency range.

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11.7 Test Instruments

This test was carried out in Laval test location.

Equipment	Model No.	Manufacturer	Calibration Period (months)	Calibration Due (YYY-MM-DD)	Asset No LAV0
Spectrum Analyzer	ESU-40	Rohde & Schwarz	24	2021-04-20	4092
BiLog Antenna	3142-E	ETS	24	2021-11-29	4002
Attenuator 4 dB	20181128A	KLP	24	2021-11-29	4300
Horn Antenna	ATH1G18G	AR	24	2021-04-25	4005
Attenuator 6 dB	FP-50-3	Trilithic	NCR	NCR	4125
LPA pre-amp	Keysight	LPA-10-20	24	2021-02-28	244
1-26.5GHz preamp	Agilent	8449B	NCR	NCR	4006
RF Cable 10m	LMR-400-10M-50OHM-MN-MN	LexTec	NCR	NCR	4025
RF Cable 7m	LMR-400-7M-50OHM-MN-MN	LexTec	NCR	NCR	4026
Emission software	0.1.94	Global EMC	NCR	NCR	4058

Table 24 – Test Instrumentation – Tx Spurious Emission

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APPENDIX A: Spurious Emissions – Worst Cases

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Frequency	Detector	Raw Reading	Antenna - Bilog3142E_ V Factor	Atten 10dB Factor	Cable 27 - 10m LMR400 Factor	Cable 28 - 7m LMR400 Factor	Cable 30 - 0.5m LMR400 Factor	Preamp - HP 8449B 4006 Factor	Level	FCC 15.209 3m Limit	FCC 15.209 3m Margin
918.924	QP	86	27.5	10	1.4	1	0.2	-32.2	93.9	N/A	N/A
913.681	QP	88.8	27.5	10	1.4	1	0.2	-32.3	96.6	N/A	N/A
911.059	QP	22.4	27.4	10	1.4	1	0.2	-32.3	30.1	N/A	N/A
940.771	QP	21.7	27.4	10	1.4	1	0.2	-32.1	29.6	46.4	16.8
96.997	QP	35.4	13	10	0.5	0.3	0.1	-33.5	25.8	43.5	17.7

Table A.1 Tx Spurious Emission LudwigHook – 30MHz – 1GHz: Vertical Polarization

Note: The intentional emissions shown between 902 – 928 MHz were caused by the remote transmitter required to make the hook receiver operate.

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Frequency	Detector	Raw Reading	Antenna - Bilog3142E_H Factor	Atten 10dB Factor	Cable 27 - 10m LMR400 Factor	Cable 28 - 7m LMR400 Factor	Cable 30 - 0.5m LMR400 Factor	Preamp - HP 8449B 4006 Factor	Level	FCC 15.209 3m Limit	FCC 15.209 3m Margin
913.681	QP	85.8	28.3	10	1.4	1	0.2	-32.3	94.4	N/A	N/A
918.924	QP	80.5	28.3	10	1.4	1	0.2	-32.2	89.2	N/A	N/A
884.26	QP	21.4	27.1	10	1.3	0.9	0.2	-32.4	28.5	46.4	17.9
901.058	QP	21.6	27.9	10	1.3	0.9	0.2	-32.3	29.6	46.4	16.8

Table A.2 Tx Spurious Emission LudwigHook – 30MHz – 1GHz: Horizontal Polarization

Note: The intentional emissions shown between 902 – 928 MHz were caused by the remote transmitter required to make the hook receiver operate.

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Frequency	Detector	Raw Reading	Antenna - Bilog3142E_ V Factor	Atten 10dB Factor	Cable 27 - 10m LMR400 Factor	Cable 28 - 7m LMR400 Factor	Cable 30 - 0.5m LMR400 Factor	Preamp - HP 8449B 4006 Factor	Level	FCC 15.209 3m Limit	FCC 15.209 3m Margin
919.021	QP	89.8	27.5	10	1.4	1	0.2	-32.2	97.7	N/A	N/A
913.681	QP	89.1	27.5	10	1.4	1	0.2	-32.3	96.9	N/A	N/A
45.3413	QP	20.6	12	10	0.3	0.2	0.1	-33.1	10.1	40	29.9
930.576	QP	21.8	27.4	10	1.4	1	0.2	-32.2	29.6	46.4	16.8
907.855	QP	21.7	27.4	10	1.4	0.9	0.2	-32.3	29.3	46.4	17.1
938.246	QP	21.6	27.4	10	1.4	1	0.2	-32.1	29.5	46.4	16.9

Table A.3 Tx Spurious Emission LudwigHook XL – 30MHz – 1GHz: Vertical Polarization

Note: The intentional emissions shown between 902 – 928 MHz were caused by the remote transmitter required to make the hook receiver operate.

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Frequency	Detector	Raw Reading	Antenna - Bilog3142E_ H Factor	Atten 10dB Factor	Cable 27 - 10m LMR40 0 Factor	Cable 28 - 7m LMR40 0 Factor	Cable 30 - 0.5m LMR40 0 Factor	Pream p - HP 8449B 4006 Factor	Level	FCC 15.209 3m Limit	FCC 15.209 3m Margin
913.778	QP	76.4	28.3	10	1.4	1	0.2	-32.3	85	N/A	N/A
918.924	QP	74	28.3	10	1.4	1	0.2	-32.2	82.7	N/A	N/A
919.798	QP	16	28.3	10	1.4	1	0.2	-32.2	24.7	46.4	21.7
925.624	QP	14.8	28.2	10	1.4	1	0.2	-32.2	23.4	46.4	23
923.876	QP	14.9	28.3	10	1.4	1	0.2	-32.2	23.6	46.4	22.8
909.797	QP	15.2	28.2	10	1.4	0.9	0.2	-32.3	23.6	46.4	22.8

Table A.4 Tx Spurious Emission LudwigHook XL – 30MHz – 1GHz: Horizontal Polarization

Note: The intentional emissions shown between 902 – 928 MHz were caused by the remote transmitter required to make the hook receiver operate.

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Frequency	Detector	Raw Reading	Antenna - Bilog3142E_ V Factor	Atten 10dB Factor	Cable 27 - 10m LMR400 Factor	Cable 28 - 7m LMR400 Factor	Cable 30 - 0.5m LMR400 Factor	Preamp - HP 8449B 4006 Factor	Level	FCC 15.209 3m Limit	FCC 15.209 3m Margin
923.585	QP	31.6	27.5	10	1.4	1	0.2	-32.2	39.5	46.4	6.9
911.35	QP	36.6	27.4	10	1.4	1	0.2	-32.3	44.3	46.4	2.1
923.779	QP	30.9	27.5	10	1.4	1	0.2	-32.2	38.8	46.4	7.6
925.138	QP	29.5	27.5	10	1.4	1	0.2	-32.2	37.4	46.4	9

Table A.5 Tx Spurious Emission LudwigHook Radio Remote Control – 30MHz – 1GHz: Vertical Polarization

Note: The intentional emissions shown between 902 – 928 MHz were caused by the remote transmitter required to make the hook receiver operate.

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Frequency	Detector	Raw Reading	Antenna - Bilog3142E_H Factor	Atten 10dB Factor	Cable 27 - 10m LMR400 Factor	Cable 28 - 7m LMR400 Factor	Cable 30 - 0.5m LMR400 Factor	Preamp - HP 8449B 4006 Factor	Level	FCC 15.209 3m Limit	FCC 15.209 3m Margin
916.496	QP	22.7	28.3	10	1.4	1	0.2	-32.3	31.3	46.4	15.1
926.595	QP	21.8	28.2	10	1.4	1	0.2	-32.2	30.4	46.4	16
910.185	QP	22.4	28.2	10	1.4	0.9	0.2	-32.3	30.8	46.4	15.6

Table A.6 Tx Spurious Emission LudwigHook Radio Remote Control – 30MHz – 1GHz: Horizontal Polarization

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