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BoxLock, Inc. MPE REPORT

SCOPE OF WORK
MPE CALCULATION
ON THE BOXLOCK 2

REPORT NUMBER
104350997LEX-015.2

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12/22/2020	2/16/2021

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MPE TEST REPORT

Report Number: 104350997LEX-015.2
Project Number: G104350997

Report Issue Date: 12/22/2020
Report Revised Date: 2/16/2021

Product Name: BoxLock 2

Standards: FCC Part 1.1310 Limits for Maximum
Permissible Exposure (MPE)

RSS-102 Issue 5 RF Field Strength Limits for
Devices Used by the General Public

IEC62311: 2019

Tested by:
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Client:
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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
11	FCC Part 1.1310 Limits for Maximum Permissible Exposure (MPE) (Limits for General Population / Uncontrolled Exposure)	Pass
	RSS-102 Issue 5 RF Field Strength Limits (For Devices Used by the General Public)	Pass
	IEC62311: 2019 MPE Limits (For General Public Exposure)	Pass



3 Client Information

This product was tested at the request of the following:

Client Information	
Client Name:	BoxLock, Inc.
Address:	692 Kirkwood Ave, Suite C1 Atlanta, GA 30316 USA
Contact:	Brad Ruffkess
Telephone:	+1 (404) 786-1889
Email:	bar@getboxlock.com
Manufacturer Information	
Manufacturer Name:	BoxLock, Inc.
Manufacturer Address:	692 Kirkwood Ave, Suite C1 Atlanta, GA 30316 USA



4 Description of Equipment under Test and Variant Models

Equipment Under Test	
Product Name	BoxLock 2
Model Number	BoxLock-003
Serial Number	SN31
Supported Transmit Bands	Wi-Fi: 802.11b/g/n-HT20/n-HT40 Bluetooth, Bluetooth Low-Energy (BLE)
Embedded Modules	Espressif ESP32 Pico Kit
Receive Date	7/30/2020
Test Start Date	12/22/2020
Test End Date	12/22/2020
Device Received Condition	Good
Test Sample Type	Production
Input Rating	3.7V, 0.5A Battery: 3.7V, 2.5AH
Description of Equipment Under Test (provided by client)	
An internet connected padlock. Uses Wi-Fi for secure access to allow authorized unlocking of device.	

4.1 Variant Models:

There were no variant models covered by this evaluation.

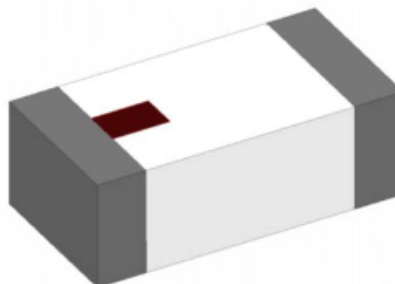
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5 Antenna Gains:

The antenna used for the Wi-Fi/Bluetooth module was manufactured by Johanson, part number 2450AT18A100E. The gain specifications for this antenna provided by the customer are shown below:

General Specifications			
Part Number	2450AT18A100		
Frequency (MHz)	2400 - 2500		
Avg. Rad Efficiency*	76%		
Peak Gain (dBi typ.)	0.5		
Average Gain (dBi typ.)	-0.5		
Return Loss (dB)	9.5 min.	Storage Period	18 months max.
		Storage Temperature	-40 to +125°C
Impedance	50 Ω	Operating Temperature	-40 to +125°C
Input Power	2 Watts max. (CW)	Reel Quantity	3000



6 Output Power:

The maximum output power of the Wi-Fi/Bluetooth module was taken from the report 104350997LEX-006.

**7 FCC Limits**

§ 1.1310: The criteria listed in table 1 shall be used to evaluate the environmental impact of human exposure to radiofrequency (RF) radiation as specified in §1.1307(b), except in the case of portable devices which shall be evaluated according to the provisions of §2.1093 of this chapter.

Part 1.1310 Limits for Maximum Permissible Exposure (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
0.3–3.0	614	1.63	*(100)	6
3.0–30	1842/f	4.89/f	*(900/f ²)	6
30–300	61.4	0.163	1.0	6
300–1500 .....	.....	.....	f/300	6
1500–100,000 .....	.....	.....	5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3–1.34	614	1.63	*(100)	30
1.34–30	824/f	2.19/f	*(180/f ²)	30
30–300	27.5	0.073	0.2	30
300–1500 .....	.....	.....	f/1500	30
1500–100,000 .....	.....	.....	1.0	30

f = frequency in MHz

* = Plane-wave equivalent power density

NOTE 1 TO TABLE 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2 TO TABLE 1: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.



8 RSS-102 Issue 5 Exposure Limits:

Table 4: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)				
Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m ²)	Reference Period (minutes)
0.003-10 ²¹	83	90	-	Instantaneous*
0.1-10	-	0.73/ f	-	6**
1.1-10	87/ $f^{0.5}$	-	-	6**
10-20	27.46	0.0728	-2	6
20-48	58.07/ $f^{0.25}$	0.1540/ $f^{0.25}$	8.944/ $f^{0.5}$	6
48-300	22.06	0.05852	1.291	6
300-6000	3.142 $f^{0.3417}$	0.008335 $f^{0.3417}$	0.02619 $f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	616000/ $f^{1.2}$
150000-300000	0.158 $f^{0.5}$	4.21 x 10 ⁻⁴ $f^{0.5}$	6.67 x 10 ⁻⁵ f	616000/ $f^{1.2}$
Note: f is frequency in MHz. * Based on nerve stimulation (NS). ** Based on specific absorption rate (SAR).				



9 IEC62311 (ICNIRP) Exposure Limits:

Table 7. Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values).^a

Frequency range	E-field strength (V m ⁻¹)	H-field strength (A m ⁻¹)	B-field (μT)	Equivalent plane wave power density S_{eq} (W m ⁻²)
up to 1 Hz	—	3.2×10^4	4×10^4	—
1–8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8–25 Hz	10,000	$4,000/f$	$5,000/f$	—
0.025–0.8 kHz	$250/f$	$4/f$	$5/f$	—
0.8–3 kHz	$250/f$	5	6.25	—
3–150 kHz	87	5	6.25	—
0.15–1 MHz	87	$0.73/f$	$0.92/f$	—
1–10 MHz	$87/f^{1/2}$	$0.73/f$	$0.92/f$	—
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2–300 GHz	61	0.16	0.20	10

^a Note:

1. f as indicated in the frequency range column.
2. Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.
3. For frequencies between 100 kHz and 10 GHz, S_{eq} , E^2 , H^2 , and B^2 are to be averaged over any 6-min period.
4. For peak values at frequencies up to 100 kHz see Table 4, note 3.
5. For peak values at frequencies exceeding 100 kHz see Figs. 1 and 2. Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width does not exceed 1,000 times the S_{eq} restrictions, or that the field strength does not exceed 32 times the field strength exposure levels given in the table.
6. For frequencies exceeding 10 GHz, S_{eq} , E^2 , H^2 , and B^2 are to be averaged over any $68/f^{1.05}$ -min period (f in GHz).
7. No E-field value is provided for frequencies <1 Hz, which are effectively static electric fields, perception of surface electric charges will not occur at field strengths less than 25 kV m⁻¹. Spark discharges causing stress or annoyance should be avoided.



10 Test Procedure

An MPE evaluation for was performed in order to show that the device was compliant with the general population exposure limits from FCC §2.1091 and RSS-102 Issue 5. The maximum power density was calculated for each transmitter band at a separation distance of 20cm using the maximum declared output power including tune up tolerance.

For each transmitter the maximum RF exposure at a 20 cm distance using the formula:

$$ConductedPower_{mW} = 10^{ConductedPower(dBm)/10}$$
$$PowerDensity = \frac{ConductedPower_{mW} \times Ant.Gain}{4\pi \times (20_{cm})^2}$$

For transmitters that could operate simultaneously, the MPE to limit ratio for each was calculated and then summed. If the sum of the MPE to limit ratios was less than 1, that specific combination of transmitters was deemed to comply.



11 Results:

The calculated maximum power density at 20cm distance was equal to or less than the required limits for general population exposure for FCC Part 1.1310, RSS-102 Issue 5, and IEC62311: 2019.

11.1 FCC MPE Data

Duty Cycle	100 (%)							
Separation Dist.	20 (cm)							
Operating Mode	Frequency (MHz)	Declared Max Cond. Power (Inc. Tolerance) (dBm)	Duty Cycle Adjusted Cond. Output Power (dBm)	Antenna Gain (dB)	MPE Value (mW/cm ²)	MPE Limit (mW/cm ²)	Margin to Limit (mW/cm ²)	MPE / Limit Ratio (for Co-Location)
802.11b	2462	15.62	15.62	0.5	0.0081	1.00	0.9919	0.0081
802.11g	2437	15.16	15.16	0.5	0.0073	1.00	0.9927	0.0073
802.11n-HT20	2437	14.62	14.62	0.5	0.0065	1.00	0.9935	0.0065
802.11n-HT40	2442	14.24	14.24	0.5	0.0059	1.00	0.9941	0.0059
BLE	2480	-1.13	-1.13	0.5	0.0002	1.00	0.9998	0.0002
Bluetooth	2440	2.07	2.07	0.5	0.0004	1.00	0.9996	0.0004

The worst case co-location is with 802.11b and Bluetooth transmitting simultaneously. The combined MPE was 0.0085 mW/cm². The combined MPE to limit ratio is:

$$0.0081 + 0.0004 = 0.0085$$

Since the sum is less than 1, the device is deemed to comply with co-location requirements.



11.2 RSS-102 Issue 5 MPE Data

Duty Cycle	100 (%)							
Separation Dist.	20 (cm)							
Operating Mode	Frequency (MHz)	Declared Max Cond. Power (Inc. Tolerance) (dBm)	Duty Cycle Adjusted Cond. Output Power (dBm)	Antenna Gain (dB)	MPE Value (W/m ²)	MPE Limit (W/m ²)	Margin to Limit (W/m ²)	MPE / Limit Ratio (for Co-Location)
802.11b	2462	15.62	15.62	0.5	0.0814	5.44	5.3604	0.0150
802.11g	2437	15.16	15.16	0.5	0.0732	5.40	5.3307	0.0136
802.11n-HT20	2437	14.62	14.62	0.5	0.0647	5.40	5.3393	0.0120
802.11n-HT40	2442	14.24	14.24	0.5	0.0593	5.41	5.3523	0.0109
BLE	2480	-1.13	-1.13	0.5	0.0017	5.47	5.4672	0.0003
Bluetooth	2440	2.07	2.07	0.5	0.0036	5.41	5.4049	0.0007

The worst case co-location is with 802.11b and Bluetooth transmitting simultaneously. The combined MPE was 0.085 W/m². The combined MPE to limit ratio is:

$$0.0150 + 0.0007 = 0.0157$$

Since the sum is less than 1, the device is deemed to comply with co-location requirements.

11.3 IEC 62311 MPE Data

Duty Cycle	100 (%)							
Separation Dist.	20 (cm)							
Operating Mode	Frequency (MHz)	Declared Max Cond. Power (Inc. Tolerance) (dBm)	Duty Cycle Adjusted Cond. Output Power (dBm)	Antenna Gain (dB)	MPE Value (W/m ²)	MPE Limit (W/m ²)	Margin to Limit (W/m ²)	MPE / Limit Ratio (for Co-Location)
802.11b	2462	15.62	15.62	0.5	0.0814	10.00	9.9186	0.0081
802.11g	2437	15.16	15.16	0.5	0.0732	10.00	9.9268	0.0073
802.11n-HT20	2437	14.62	14.62	0.5	0.0647	10.00	9.9353	0.0065
802.11n-HT40	2442	14.24	14.24	0.5	0.0593	10.00	9.9407	0.0059
BLE	2480	-1.13	-1.13	0.5	0.0017	10.00	9.9983	0.0002
Bluetooth	2440	2.07	2.07	0.5	0.0036	10.00	9.9964	0.0004

The worst case co-location is with 802.11b and Bluetooth transmitting simultaneously. The combined MPE was 0.085 W/m². The combined MPE to limit ratio is:

$$0.0081 + 0.0004 = 0.0085$$

Since the sum is less than 1, the device is deemed to comply with co-location requirements.

**12 Revision History**

Revision Level	Date	Report Number	Prepared By	Reviewed By	Notes
0	12/22/2020	104350997LEX-015	BZ	BCT	Original Issue
1	2/2/2021	104350997LEX-015.1	BZ	BCT	Updated with TCB feedback
2	2/16/2021	104350997LEX-015.2	BZ	BCT	Fixed wording