RF Exposure Exhibit

EUT Name: Wi-Fi Router

Model No.: B010001 (USA), B010002 (IC)

CFR Part 1.1310 and RSS 102

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1 Test Methodology

In this document, we evaluate the RF Exposure to human body due the intentional transmission from the transmitter (EUT). The limit for Maximum Permissible Exposure (MPE) specified in FCC 1.1310 is followed. Through the Friis transmission formula and the maximum gain of the antenna, we can calculate the distance, away from the product, where the limit of MPE is reached.

Although the Friis transmission formula is a far field assumption, the calculated result of that is an over-prediction for near field power density. We will take that as the worst case to specify the safety range.

1.1 RF Exposure Limit

According to FCC 1.1310 table 1: The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b)

LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Average Time (minutes)
(A)Limits For Occupational / Control Exposures				
0.3-1.34	614	1.63	*(100)	6
1.34-30	1842/f	4.89/f	*(900/f²)	6
30-300	61.4	0.163	1.0	6
30-1500	…	…	F/300	6
1500-100000	…	…	1.0	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/f²)	30
30-300	27.5	0.073	0.2	30
30-1500	…	…	F(MHz)/1500MHz	30
1500-100000	…	…	1.0	30

F = Frequency in MHz

*=Plane wave equivalent density

According to RSS-102 Issue 5: The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation

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	$3.142\,f^{0.3417}$	$0.008335\,f^{0.3417}$	$0.02619f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	$616000/f^{1.2}$
150000-300000	$0.158\,f^{0.5}$	$4.21 \times 10^{-4}\,f^{0.5}$	$6.67 \times 10^{-5}\,f$	$616000/f^{1.2}$

Note: f is frequency in MHz.
*Based on nerve stimulation (NS).
** Based on specific absorption rate (SAR).

1.2   EUT Operating Condition

The Model B010001 (USA), B010002 (IC), is a Wi-Fi router for the home capable of operating in the 2.4 GHz and 5 GHz frequency bands over 20 MHz, 40 MHz and 80 MHz channels.

1.3   MPE calculation

1.3.1   Antenna Gain

The antennas used are:

1. Bluetooth LE and Thread (Zigbee) 2.4 GHz Flex PCB Antenna peak gain: +3.09 dBi or 2.04 (numeric).

2. Wifi 2.4 GHz Flex PCB Antenna peak gain: +5.43 dBi or 3.49 (numeric). Total directional gain: 7.68 dBi

3. Wifi 5.15-5.25 GHz Flex PCB Antenna peak gain: +4.58 dBi or 2.87 (numeric). Total directional gain: 6.84 dBi

4. Wifi 5.725-5.850 GHz Flex PCB Antenna peak gain: +3.84 dBi or 2.42 (numeric). Total directional gain: 6.58 dBi

1.3.2   Conducted Output Power

1. Bluetooth LE 2.480 GHz, TUV Test Report 31761398.001, maximum power: 11.82 dBm (15.21 mW)

2. Thread 2.405 GHz, TUV Test Report 31761398.001, maximum power: 18.40 dBm (69.18 mW)

3. Wifi 2.452 GHz, TUV Test Report 31761398.001, total power (summed 2 chains) for non-beamforming: 29.73 dBm (939.72 mW) and for beamforming: 2.462 GHz at 28.19 dBm (659.17 mW)

4. Wifi 5.23 GHz, TUV Test Report 31761399.001, total power for FCC (summed 2 chains): 29.05 dBm (803.53 mW) and for beamforming: 29.05 dBm (803.53 mW)

5. Wifi 5.21 GHz, TUV Test Report 31761399.001, total power for RSS (summed 2 chains): 18.18 dBm (65.77 mW) and for beamforming: 5.19 GHz at 15.98 dBm (39.63 mW)

6. Wifi 5.785 GHz, TUV Test Report 31761402.001, total power (summed 2 chains): 29.24 dBm (839.46 mW) and for beamforming: 29.24 dBm (839.46 mW)

1.3.3   Output Power into Antenna & RF Exposure value (Non-Beamforming Mode)

Calculations for this report are based on highest power measurement (summed 2 chains) and its antenna gain, therefore 2.452 GHz. Result below is Non-Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.73	dBm
The Gain of the antenna:	5.43	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.939723311	Watts
or:	939.72331	mW
or:	939723.31	μW
or:	29.73	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.452	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.16
Power (mW):	3280.953
Power (W):	3.280953

R = distance in	25	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.4177439	mW/cm^2
Controlled Margin to Limit =	4.5823	mW/cm^2
Uncontrolled Margin to Limit =	0.5823	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	29.73	dBm
The Gain of the antenna:	5.43	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.939723311	Watts
or:	939.72331	mW
or:	939723.31	µW
or:	29.73	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.452	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.16
Power (mW):	3280.953
Power (W):	3.280953

R = distance in	26	cm

IC:

Controlled Exposures to Limit =	31.96365832	W/m²
Uncontrolled Exposures Limit =	5.426674651	W/m²
Pd =	3.862277	W/m²
Controlled Margin to Limit =	28.1014	W/m²
Uncontrolled Margin to Limit =	1.5644	W/m²

Calculations for this report are based on highest power measurement (summed 2 chains) and its antenna gain, therefore 5.23 GHz. Result below is Non-Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.05	dBm
The Gain of the antenna:	4.58	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.803526122	Watts
or:	803.52612	mW
or:	803526.12	µW
or:	29.05	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.23	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	33.63
Power (mW):	2306.747
Power (W):	2.306747

R = distance in	25	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.2937042	mW/cm^2
Controlled Margin to Limit =	4.7063	mW/cm^2
Uncontrolled Margin to Limit =	0.7063	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	18.18	dBm
The Gain of the antenna:	4.58	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.065765784	Watts
or:	65.76578	mW
or:	65765.78	µW
or:	18.18	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.21	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	22.76
Power (mW):	188.799
Power (W):	0.188799

R = distance in	26	cm

IC:

Controlled Exposures to Limit =	46.59240284	W/m^2
Uncontrolled Exposures Limit =	9.082855364	W/m^2
Pd =	0.222251	W/m^2
Controlled Margin to Limit =	46.3702	W/m^2
Uncontrolled Margin to Limit =	8.8606	W/m^2

Calculations for this report are based on highest power measurement (summed 2 chains) and its antenna gain, therefore 5.785 GHz. Result below is Non-Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.24	dBm
The Gain of the antenna:	3.84	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.839459987	Watts
or:	839.45999	mW
or:	839459.99	µW
or:	29.24	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	33.08
Power (mW):	2032.357
Power (W):	2.032357

R = distance in	25	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.2587677	mW/cm^2
Controlled Margin to Limit =	4.7412	mW/cm^2
Uncontrolled Margin to Limit =	0.7412	mW/cm^2

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IC:

Corrected (including cal factors) Measurement:	29.24	dBm
The Gain of the antenna:	3.84	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.839459987	Watts
or:	839.45999	mW
or:	839459.99	µW
or:	29.24	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	33.08
Power (mW):	2032.357
Power (W):	2.032357

R = distance in	26	cm

IC:

Controlled Exposures to Limit =	49.09620552	W/m^2
Uncontrolled Exposures Limit =	9.756490295	W/m^2
Pd =	2.392453	W/m^2
Controlled Margin to Limit =	46.7038	W/m^2
Uncontrolled Margin to Limit =	7.3640	W/m^2

1.3.4 RF Exposure value when 3 radios operating simultaneously (Non-Beamforming Mode)

Non-Beamforming Exposure result (FCC)

Operating Frequency (MHz)	Power Density (mW/cm²)	
2452	0.41774	
5230	0.29370	
5785	0.25877	
	0.97022	**Total Power Density (mW/cm²)**
	1.00000	**Uncontrolled Exposure Limit (mW/cm²)**
	-0.02978	**Margin (mW/cm²)**
Note: Minimum distance from the user must be at 25 cm		

Non-Beamforming Exposure result (IC)

Operating Frequency (MHz)	Power Density (W/cm²)	Limit (W/cm²)	Ratio	
2452	3.862277	5.426675	0.711721	
5210	0.222251	9.082855	0.024469	
5785	2.392453	9.756490	0.245217	
			0.981407	**∑ ratio**
Note: 1. The MPE calculation for simultaneous transmission is less than 1.				
2. Minimum distance from the user must be at 26 cm				

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1.3.5 Output Power into Antenna & RF Exposure value (Beamforming Mode)

Calculations for this report are based on highest power measurement (summed 2 chains) and its antenna gain, therefore 2.462 GHz. Result below is Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	28.19	dBm
The Gain of the antenna:	7.68	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.659173895	Watts
or:	659.17390	mW
or:	659173.90	µW
or:	28.19	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.462	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.87
Power (mW):	3863.670
Power (W):	3.863670

R = distance in	32	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.3002550	mW/cm^2
Controlled Margin to Limit =	4.6997	mW/cm^2
Uncontrolled Margin to Limit =	0.6997	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	28.19	dBm
The Gain of the antenna:	7.68	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.659173895	Watts
or:	659.17390	mW
or:	659173.90	µW
or:	28.19	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.462	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.87
Power (mW):	3863.670
Power (W):	3.863670

R = distance in	30	cm

IC:

Controlled Exposures to Limit =	32.02877075	W/m²
Uncontrolled Exposures Limit =	5.441789657	W/m²
Pd =	3.416234	W/m²
Controlled Margin to Limit =	28.6125	W/m²
Uncontrolled Margin to Limit =	2.0256	W/m²

Calculations for this report are based on highest power measurement (summed 2 chains) and its antenna gain, therefore 5.23 GHz. Result below is Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.05	dBm
The Gain of the antenna:	6.84	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.803526122	Watts
or:	803.52612	mW
or:	803526.12	µW
or:	29.05	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.23	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.89
Power (mW):	3881.504
Power (W):	3.881504

R = distance in	32	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.3016409	mW/cm^2
Controlled Margin to Limit =	4.6984	mW/cm^2
Uncontrolled Margin to Limit =	0.6984	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	15.98	dBm
The Gain of the antenna:	6.84	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be: 0.039627803 Watts
or: 39.62780 mW
or: 39627.80 µW
or: 15.98 dBm

Frequency range from 10 MHz to 40 GHz:
Frequency: 5.19 GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	22.82
Power (mW):	191.426
Power (W):	0.191426

R = distance in 30 cm

IC:

Controlled Exposures to Limit =	46.50288806	W/m²
Uncontrolled Exposures Limit =	9.059012747	W/m²
Pd =	0.169257	W/m²
Controlled Margin to Limit =	46.3336	W/m²
Uncontrolled Margin to Limit =	8.8898	W/m²

Report Number: MPE Calculation
Model: B010001 (USA), B010002 (IC)
EMC / Rev 1.0
FCC ID: 2AEM4-B010001, IC: 20631-1117160

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Calculations for this report are based on highest power measurement (summed 2 chains) and its antenna gain, therefore 5.785 GHz. Result below is Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.94	dBm
The Gain of the antenna:	6.58	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.986279486	Watts
or:	986.27949	mW
or:	986279.49	µW
or:	29.94	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	36.52
Power (mW):	4487.454
Power (W):	4.487454

R = distance in	32	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.3487307	mW/cm^2
Controlled Margin to Limit =	4.6513	mW/cm^2
Uncontrolled Margin to Limit =	0.6513	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	29.24	dBm
The Gain of the antenna:	6.58	dBi
Type of Measurement:	Conducted	Direct measurement at Antenna Port
Impedance:	50.00	Ω
Measuring Distance:	0.00	m
Time weighted Duty Cycle:	100.00	%

The Power Out would be:	0.839459987	Watts
or:	839.45999	mW
or:	839459.99	µW
or:	29.24	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.82
Power (mW):	3819.443
Power (W):	3.819443

R = distance in	30	cm

IC:

Controlled Exposures to Limit =	49.09620552	W/m^2
Uncontrolled Exposures Limit =	9.756490295	W/m^2
Pd =	3.377129	W/m^2
Controlled Margin to Limit =	45.7191	W/m^2
Uncontrolled Margin to Limit =	6.3794	W/m^2

1.3.6 RF Exposure value when 3 radios operating simultaneously (Beamforming Mode)

Beamforming Mode Exposure result (FCC)

Frequency (MHz)	Power Density (mW/cm²)	
2462	0.30025	
5230	0.30164	
5785	0.34873	
	0.95063	Total Power Density (mW/cm²)
	1.00000	Uncontrolled Exposure Limit (mW/cm²)
	-0.04937	Margin (mW/cm²)
Note: Minimum distance from the user must be at 32 cm		

Beamforming Mode Exposure result (IC)

Operating Frequency (MHz)	Power Density (W/cm²)	Limit (W/cm²)	Ratio	
2462	3.416234	5.441790	0.627778	
5190	0.169257	9.059013	0.018684	
5785	3.377129	9.756490	0.346142	
			0.992603	∑ ratio
Note: 1. The MPE calculation for simultaneous transmission is less than 1.				
2. Minimum distance from the user must be at 30 cm				

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

FCC: Minimum distance from the user must be at 32 cm.

IC: Minimum distance from the user must be at 30 cm.

1.3.7 Sample Calculation

The Friss transmission formula: $Pd = (Pout*G) / (4*\pi*R^2)$

Where;

Pd = power density in mW/cm^2

$Pout$ = output power to antenna in mW

G = gain of antenna in linear scale

$\pi \approx 3.1416$

R = distance between observation point and center of the radiator in cm

Ref. : David K. Cheng, *Field and Wave Electromagnetics*, Second Edition, Page 640, Eq. (11-133).