RF Exposure Exhibit

EUT Name: Wi-Fi Router

Model No.: D010001 (USA), D010002 (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	$3.142\,f^{0.3417}$	$0.008335\,f^{0.3417}$	$0.02619\,f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	$616000/f^{1.2}$
150000-300000	$0.158\,f^{0.5}$	$4.21 \times 10^{-4}\,f^{0.5}$	$6.67 \times 10^{-5}\,f$	$616000/f^{1.2}$

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

1.2   EUT Operating Condition

The Model D010001 (USA), D010002 (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: +4.14 dBi or 2.59 (numeric).

2. Wifi 2.4 GHz Flex PCB Antenna peak gain: +4.08 dBi or 2.56 (numeric). Total directional gain: 6.87 dBi

3. Wifi 5.15-5.25 GHz Flex PCB Antenna peak gain: +6.29 dBi or 4.26 (numeric). Total directional gain: 8.67 dBi

4. Wifi 5.725-5.850 GHz Flex PCB Antenna peak gain: +5.22 dBi or 3.33 (numeric). Total directional gain: 8.09 dBi

1.3.2   Conducted Output Power

1. Bluetooth LE 2.402 GHz, TUV Test Report 31760707.001, maximum power: 12.78 dBm (18.97 mW)

2. Thread 2.405 GHz, TUV Test Report 31760707.001, maximum power: 18.65 dBm (73.28 mW)

3. Wifi 2.437 GHz, TUV Test Report 31760707.001, total power (summed 2 chains) for non-beamforming: 29.89 dBm (974.99 mW) and for beamforming: 28.86 dBm (769.13 mW)

4. Wifi 5.23 GHz, TUV Test Report 31760709.001, total power for FCC (summed 2 chains): 27.87 dBm (612.35 mW) and for beamforming: 27.32 dBm (539.51 mW)

5. Wifi 5.23 GHz, TUV Test Report 31760709.001, total power for RSS (summed 2 chains): 16.38 dBm (43.45 mW) and for beamforming: 13.96 dBm (24.89 mW)

6. Wifi 5.785 GHz, TUV Test Report 31760712.001, total power (summed 2 chains): 29.10 dBm (812.83 mW) and for beamforming: 27.71 dBm (590.20 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 2.437 GHz. Result below is Non-Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.89	dBm
The Gain of the antenna:	4.08	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:	0.974989638	Watts
or:	974.98964	mW
or:	974989.64	µW
or:	29.89	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.437	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	33.97
Power (mW):	2494.595
Power (W):	2.494595

R = distance in	21	cm

FCC:		
Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.4501441	mW/cm^2
Controlled Margin to Limit =	4.5499	mW/cm^2
Uncontrolled Margin to Limit =	0.5499	mW/cm^2

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IC:

Corrected (including cal factors) Measurement:	29.89	dBm
The Gain of the antenna:	4.08	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:	0.974989638	Watts
or:	974.98964	mW
or:	974989.64	µW
or:	29.89	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.437	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	33.97
Power (mW):	2494.595
Power (W):	2.494595

R = distance in	25	cm

IC:

Controlled Exposures to Limit =	31.86574021	W/m^2
Uncontrolled Exposures Limit =	5.403965492	W/m^2
Pd =	3.176217	W/m^2
Controlled Margin to Limit =	28.6895	W/m^2
Uncontrolled Margin to Limit =	2.2277	W/m^2

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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 Non-Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	29.10	dBm
The Gain of the antenna:	5.22	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:	0.812830516	Watts
or:	812.83052	mW
or:	812830.52	μW
or:	29.10	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	34.32
Power (mW):	2703.958
Power (W):	2.703958

R = distance in	21	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.4879233	mW/cm^2
Controlled Margin to Limit =	4.5121	mW/cm^2
Uncontrolled Margin to Limit =	0.5121	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	29.10	dBm
The Gain of the antenna:	5.22	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:	0.812830516	Watts
or:	812.83052	mW
or:	812830.52	µW
or:	29.10	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	34.32
Power (mW):	2703.958
Power (W):	2.703958

R = distance in	25	cm

IC:

Controlled Exposures to Limit =	49.09620552	W/m²
Uncontrolled Exposures Limit =	9.756490295	W/m²
Pd =	3.442787	W/m²
Controlled Margin to Limit =	45.6534	W/m²
Uncontrolled Margin to Limit =	6.3137	W/m²

1.3.4 RF Exposure value when 2 radios operating simultaneously (Non-Beamforming Mode)

Non-Beamforming Exposure result (FCC)

Operating Frequency (MHz)	Power Density (mW/cm²)	
2437	0.45014	
5785	0.48792	
	0.93807	Total Power Density (mW/cm²)
	1.00000	Uncontrolled Exposure Limit (mW/cm²)
	-0.06193	Margin (mW/cm²)
Note: Minimum distance from the user must be at 21 cm		

Non-Beamforming Exposure result (IC)

Operating Frequency (MHz)	Power Density (W/cm²)	Limit (W/cm²)	Ratio	
2437	3.176217	5.403966	0.587757	
5785	3.442787	9.756490	0.352871	
			0.940628	∑ ratio
Note: 1. The MPE calculation for simultaneous transmission is less than 1.				
2. Minimum distance from the user must be at 25 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 2.437 GHz. Result below is Beamforming Mode.

FCC:

Corrected (including cal factors) Measurement:	28.86	dBm
The Gain of the antenna:	6.87	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:	0.769130440	Watts
or:	769.13044	mW
or:	769130.44	µW
or:	28.86	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.437	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.73
Power (mW):	3741.106
Power (W):	3.741106

R = distance in	25	cm

FCC:		
Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.4763324	mW/cm^2
Controlled Margin to Limit =	4.5237	mW/cm^2
Uncontrolled Margin to Limit =	0.5237	mW/cm^2

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IC:

Corrected (including cal factors) Measurement:	28.86	dBm
The Gain of the antenna:	6.87	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:	0.769130440	Watts
or:	769.13044	mW
or:	769130.44	µW
or:	28.86	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	2.437	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.73
Power (mW):	3741.106
Power (W):	3.741106

R = distance in	30	cm

IC:

Controlled Exposures to Limit =	31.86574021	W/m²
Uncontrolled Exposures Limit =	5.403965492	W/m²
Pd =	3.307864	W/m²
Controlled Margin to Limit =	28.5579	W/m²
Uncontrolled Margin to Limit =	2.0961	W/m²

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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:	27.71	dBm
The Gain of the antenna:	8.09	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:	0.590201080	Watts
or:	590.20108	mW
or:	590201.08	µW
or:	27.71	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.80
Power (mW):	3801.894
Power (W):	3.801894

R = distance in	25	cm

FCC:

Controlled Exposures - Limit =	5	mW/cm^2
Uncontrolled Exposures - Limit =	1	mW/cm^2
Pd =	0.4840722	mW/cm^2
Controlled Margin to Limit =	4.5159	mW/cm^2
Uncontrolled Margin to Limit =	0.5159	mW/cm^2

IC:

Corrected (including cal factors) Measurement:	27.71	dBm
The Gain of the antenna:	8.09	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:	0.590201080	Watts
or:	590.20108	mW
or:	590201.08	µW
or:	27.71	dBm

Frequency range from 10 MHz to 40 GHz:

Frequency:	5.785	GHz

Power output with DC and antenna Gain (EiRP):

Power (dBm):	35.80
Power (mW):	3801.894
Power (W):	3.801894

R = distance in	30	cm

IC:

Controlled Exposures to Limit =	49.09620552	W/m^2
Uncontrolled Exposures Limit =	9.756490295	W/m^2
Pd =	3.361612	W/m^2
Controlled Margin to Limit =	45.7346	W/m^2
Uncontrolled Margin to Limit =	6.3949	W/m^2

1.3.6 RF Exposure value when 2 radios operating simultaneously (Beamforming Mode)

Beamforming Mode Exposure result (FCC)

Frequency (MHz)	Power Density (mW/cm²)	
2437	0.47633	
5785	0.48407	
	0.96040	Total Power Density (mW/cm²)
	1.00000	Uncontrolled Exposure Limit (mW/cm²)
	-0.03960	Margin (mW/cm²)
Note: Minimum distance from the user must be at 25 cm		

Beamforming Mode Exposure result (IC)

Operating Frequency (MHz)	Power Density (W/cm²)	Limit (W/cm²)	Ratio	
2437	3.307864	5.403966	0.612118	
5785	3.361612	9.756490	0.344551	
			0.956669	∑ 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 25 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).