MPE Calculation

§ 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.

The RSS-102 Issue 5 power density and field strength limits are shown below:

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

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

1.1 Test Procedure

An MPE evaluation for was performed in order to show that the device was compliant with §2.1091 and RSS-102 Issue 5. The maximum power density was calculated for each transmitter at a separation distance of 20cm.

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

$$ConductedPower_{mW} = 10^{ConductedPower(dBm)/10}$$

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

1.2 Results:

The device contains 2.4GHz WiFi, 5GHz WiFi, and Bluetooth transmitters. The Bluetooth can transmit simultaneously with the WiFi radios. The 5GHz WiFi and 2.4Ghz WiFi cannot transmit at the same time.

The following calculations show that the total power density from each transmitter at 20cm is less than the limit for general population / un-controlled exposure. With the worst case WiFi and Bluetooth radios transmitting simultaneously, the MPE calculations are less than the applicable limit.

The device meets the RF exposure limit at a 20cm separation distance as required by part 2.1091 of the FCC rules with Bluetooth and WiFi radios transmitting simultaneously

The total sum of the ratio of the power densities to the corresponding limit for all radios capable of transmitting simultaneously was computed as follows:

Total = (Worst Case WiFi Power Density / Limit WiFi) + (Worst Case Bluetooth Power Density / Limit Bluetooth)

Total = 0.0476 + 0.0036 = 0.512

Compliance is shown by the sum of the radio of the power densities for all radios that can transmit simultaneously being less than 1.

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Individual Radio Test Results:

2.4GHz WiFi	Value	Unit	Comments
Frequency	2390	MHz	
Distance	20	cm	
Maximum Scaled Power	18.32	dBm	Maximum Conducted Power
TX Antenna Gain	5.47	dBi	Antenna Gain (Array)
Source Based Duty Cycle	100	%	Percent of time transmitter is active
EIRP	**23.79**	**dBm**	Maximum Conducted Power + Antenna Gain
Source Based Output Power	**23.79**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0476**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^0
Ratio of Power Density to Limit	**0.0476**		Power Density / FCC Limit Ratio (for simultaneous transmission)
Power Density @ Distance	**0.0048**	**W/m^2**	Power Densiy in W/m^2
ISED Limit (RSS-102)	**5.3325**	**W/m^2**	0.02619 x f^0.6834

U-NII-1 WiFi	Value	Unit	Comments
Frequency	5150	MHz	
Distance	20	cm	
Maximum Scaled Power	15.39	dBm	Maximum Conducted Power
TX Antenna Gain	6	dBi	Antenna Gain (Array)
Source Based Duty Cycle	100	%	Percent of time transmitter is active
EIRP	**21.39**	**dBm**	Maximum Conducted Power + Antenna Gain
Source Based Output Power	**21.39**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0274**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^0
Ratio of Power Density to Limit	**0.0274**		Power Density / FCC Limit Ratio (for simultaneous transmission)
Power Density @ Distance	**0.0027**	**W/m^2**	Power Densiy in W/m^2
ISED Limit (RSS-102)	**9.0112**	**W/m^2**	0.02619 x f^0.6834

U-NII-2A WiFi	Value	Unit	Comments
Frequency	5250	MHz	
Distance	20	cm	
Maximum Scaled Power	17.7	dBm	Maximum Conducted Power
TX Antenna Gain	6	dBi	Antenna Gain (Array)
Source Based Duty Cycle	100	%	Percent of time transmitter is active
EIRP	**23.7**	**dBm**	Maximum Conducted Power + Antenna Gain
Source Based Output Power	**23.7**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0466**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^0
Ratio of Power Density to Limit	**0.0466**		Power Density / FCC Limit Ratio (for simultaneous transmission)
Power Density @ Distance	**0.0047**	**W/m^2**	Power Densiy in W/m^2
ISED Limit (RSS-102)	**9.1305**	**W/m^2**	0.02619 x f^0.6834

U-NII-2C WiFi	Value	Unit	Comments
Frequency	5470	MHz	
Distance	20	cm	
Maximum Scaled Power	14.7	dBm	Maximum Conducted Power
TX Antenna Gain	6	dBi	Antenna Gain (Array)
Source Based Duty Cycle	100	%	Percent of time transmitter is active
EIRP	**20.7**	**dBm**	Maximum Conducted Power + Antenna Gain
Source Based Output Power	**20.7**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0234**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^0
Ratio of Power Density to Limit	**0.0234**		Power Density / FCC Limit Ratio (for simultaneous transmission)
Power Density @ Distance	**0.0023**	**W/m^2**	Power Densiy in W/m^2
ISED Limit (RSS-102)	**9.3902**	**W/m^2**	0.02619 x f^0.6834

U-NII-3 WiFi	Value	Unit	Comments
Frequency	5725	MHz	
Distance	20	cm	
Maximum Scaled Power	13.4	dBm	Maximum Conducted Power
TX Antenna Gain	6	dBi	Antenna Gain (Array)
Source Based Duty Cycle	100	%	Percent of time transmitter is active
EIRP	**19.4**	**dBm**	Maximum Conducted Power + Antenna Gain
Source Based Output Power	**19.4**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0173**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^0
Ratio of Power Density to Limit	**0.0173**		Power Density / FCC Limit Ratio (for simultaneous transmission)
Power Density @ Distance	**0.0017**	**W/m^2**	Power Densiy in W/m^2
ISED Limit (RSS-102)	**9.6872**	**W/m^2**	0.02619 x f^0.6834

Bluetooth	Value	Unit	Comments
Frequency	2402	MHz	
Distance	20	cm	
Maximum Scaled Power	6.63	dBm	Maximum Conducted Power
TX Antenna Gain	6	dBi	Antenna Gain (Array)
Source Based Duty Cycle	100	%	Percent of time transmitter is active
EIRP	**12.63**	**dBm**	Maximum Conducted Power + Antenna Gain
Source Based Output Power	**12.63**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0036**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^0
Ratio of Power Density to Limit	**0.0036**		Power Density / FCC Limit Ratio (for simultaneous transmission)
Power Density @ Distance	**0.0004**	**W/m^2**	Power Densiy in W/m^2
ISED Limit (RSS-102)	**5.3508**	**W/m^2**	0.02619 x f^0.6834