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/cm²)	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/f²)	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/f²)	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.

1.1   Test Procedure

An MPE evaluation for was performed in order to show that the device was compliant with §2.1091. 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   Duty Cycle Correction

1.2.1   Short Range Transmitter (SRT)

Once every 30 minutes the device transmits the following sequence using the short range transmitter (SRT):

- Get event count – 19 bytes – 8ms
- Get events – 21 bytes – 8.75ms
- Get reading count – 21 bytes – 8.75ms
- Get reading – 21 bytes 8.75ms
- Get date/time – 19 bytes – 8ms
- Set date/time – 25 bytes – 10.4ms
- End RF session – 19 bytes – 8ms

Total 145 bytes – 60.42ms
Duty cycle = (0.06042s) / (30 x 60s) x 100% = **0.0035%**

1.2.2   Wi-Fi Radio

The Wi-Fi duty cycle was obtained by measuring the total transmit time which over a period of 5 seconds.
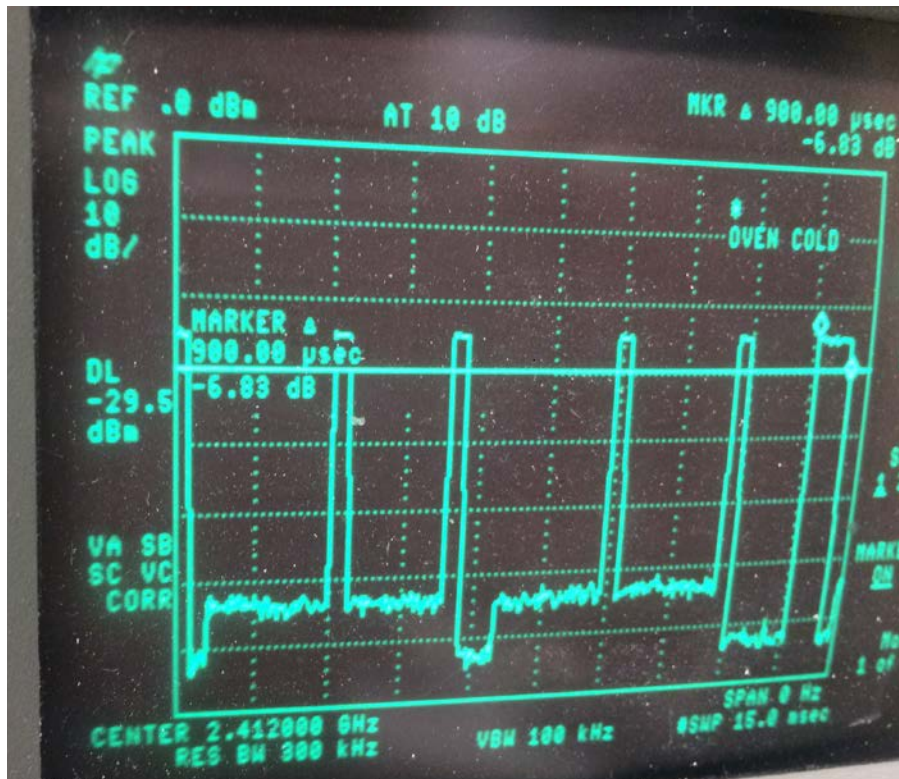
Duty cycle= (6 pulses x 900µs/pulse) / (5s) x 100% = 0.1%.

1.2.3   Cellular Radio

The cellular radio duty cycle was obtained by measuring the total transmission time in a 615 second period. During this period, the total transmit time was measured to be 45 seconds.

Duty cycle = (45s) / (615s) x 100% = 7.3%

1.3   Results:

The device contains a short range transmitter (SRT), Wi-Fi radio, and cellular radio which can all transmit simultaneously. The following calculations show that the total power density from each transmitter at 20cm is less than the limit for general population / uncontrolled exposure. With all radios transmitting simultaneously in their worst mode, 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 all modules transmitting simultaneously.

The worst modes were identified as Band 1 (SRT), Band 3 (Wi-Fi), and Band 11 (Cellular), as shown later in this document.

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 = (Cellular Power Density / Cellular Limit) + (Wi-fi Power Density / Wi-Fi Limit) + (SRT Power Density / SRT Limit)

Total = (0.0283 mW/cm^2 / 1.0000 mW/cm^2) + (0.0001 mW/cm^2 / 1.0000 mW/cm^2) + (0.0000 mW/cm^2 / 0.6110 mW/cm^2)

Total = 0.0283 + 0.0001 + 0.0000 = **0.0284**

Compliance is shown by the sum of the ratio of the power densities for all radios that can transmit simultaneously being less than 1. Since the sum of 0.0284 is less than 1, the device was found to be compliant.

Individual Radio Test Results:

Band 1 (SRT)	Value	Unit	Comments
Frequency	916.5	MHz	
Distance	20	cm	
Maximum Scaled Power	-4.24	dBm	Measured conducted power
TX Antenna Gain	0	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	0.004	%	Percent of time transmitter is active
EIRP	**-4.24**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**-48.2**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0000**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**0.6110**	**mW/cm^2**	.0007 x f^1.
Ratio of Power Density to Limit	**0.0000**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**83.09**	**dBi**	((Limit, mW/cm^2) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 2 (Wi-Fi 802.11b)	Value	Unit	Comments
Frequency	2400	MHz	
Distance	20	cm	
Maximum Scaled Power	19.15	dBm	Measured conducted power
TX Antenna Gain	3.6	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	0.1	%	Percent of time transmitter is active
EIRP	**22.75**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**-7.3**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0000**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^.
Ratio of Power Density to Limit	**0.0000**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**47.86**	**dBi**	((Limit, mW/cm^2) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 3 (Wi-Fi 802.11g)	Value	Unit	Comments
Frequency	2400	MHz	
Distance	20	cm	
Maximum Scaled Power	22.01	dBm	Measured conducted power
TX Antenna Gain	3.6	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	0.1	%	Percent of time transmitter is active
EIRP	**25.61**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**-4.4**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0001**	**mW/cm^2**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm^2**	1. x f^.
Ratio of Power Density to Limit	**0.0001**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**45.00**	**dBi**	((Limit, mW/cm^2) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 4 (Wi-Fi 802.11n)	Value	Unit	Comments
Frequency	2400	MHz	
Distance	20	cm	
Maximum Scaled Power	18.21	dBm	Measured conducted power
TX Antenna Gain	3.6	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	0.1	%	Percent of time transmitter is active
EIRP	**21.81**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**-8.2**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0000**	**mW/cm²**	(Source Based Output Power, mW) / (4π x (distance, cm)²)
FCC Limit	**1.0000**	**mW/cm²**	1. x f^.
Ratio of Power Density to Limit	**0.0000**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**48.80**	**dBi**	((Limit, mW/cm²) x 4π x (distance, cm)²) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 5 (Cell)	Value	Unit	Comments
Frequency	1712.4	MHz	
Distance	20	cm	
Maximum Scaled Power	23.54	dBm	Measured conducted power
TX Antenna Gain	3	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	7.3	%	Percent of time transmitter is active
EIRP	**26.54**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**15.2**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0065**	**mW/cm²**	(Source Based Output Power, mW) / (4π x (distance, cm)²)
FCC Limit	**1.0000**	**mW/cm²**	1. x f^.
Ratio of Power Density to Limit	**0.0065**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**24.84**	**dBi**	((Limit, mW/cm²) x 4π x (distance, cm)²) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 6 (Cell)	Value	Unit	Comments
Frequency	1852.4	MHz	
Distance	20	cm	
Maximum Scaled Power	26.39	dBm	Measured conducted power
TX Antenna Gain	3	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	7.3	%	Percent of time transmitter is active
EIRP	**29.39**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**18.0**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0126**	**mW/cm²**	(Source Based Output Power, mW) / (4π x (distance, cm)²)
FCC Limit	**1.0000**	**mW/cm²**	1. x f^.
Ratio of Power Density to Limit	**0.0126**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**21.99**	**dBi**	((Limit, mW/cm²) x 4π x (distance, cm)²) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 7 (Cell)	Value	Unit	Comments
Frequency	826.4	MHz	
Distance	20	cm	
Maximum Scaled Power	26.63	dBm	Measured conducted power
TX Antenna Gain	-1	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	7.3	%	Percent of time transmitter is active
EIRP	**25.63**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**14.3**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0053**	**mW/cm²**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**0.5509**	**mW/cm²**	.0007 x f^1.
Ratio of Power Density to Limit	**0.0096**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**19.16**	**dBi**	((Limit, mW/cm²) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 8 (Cell)	Value	Unit	Comments
Frequency	1850.2	MHz	
Distance	20	cm	
Maximum Scaled Power	28.6	dBm	Measured conducted power
TX Antenna Gain	3	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	7.3	%	Percent of time transmitter is active
EIRP	**31.6**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**20.2**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0210**	**mW/cm²**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**1.0000**	**mW/cm²**	1. x f^.
Ratio of Power Density to Limit	**0.0210**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**19.78**	**dBi**	((Limit, mW/cm²) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 9 (Cell)	Value	Unit	Comments
Frequency	824.2	MHz	
Distance	20	cm	
Maximum Scaled Power	29.9	dBm	Measured conducted power
TX Antenna Gain	-1	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	7.3	%	Percent of time transmitter is active
EIRP	**28.9**	**dBm**	Maximum Scaled Power x Antenna Gain
Source Based Output Power	**17.5**	**dBm**	EIRP x Duty Cycle
Power Density @ Distance	**0.0113**	**mW/cm²**	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	**0.5495**	**mW/cm²**	.0007 x f^1.
Ratio of Power Density to Limit	**0.0205**		Power Density / FCC Limit
Maximum Permissible Antenna Gain	**15.88**	**dBi**	((Limit, mW/cm²) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)

Band 10 (Cell)	Value	Unit	Comments
Frequency	1850.2	MHz	
Distance	20	cm	
Maximum Scaled Power	29.9	dBm	Measured conducted power
TX Antenna Gain	3	dBi	From datasheet, or calculated from peak radiated field strength and measured conducted power
Source Based Duty Cycle	7.3	%	Percent of time transmitter is active
EIRP	32.9	dBm	Maximum Scaled Power x Antenna Gain
Source Based Output Power	21.5	dBm	EIRP x Duty Cycle
Power Density @ Distance	0.0283	mW/cm^2	(Source Based Output Power, mW) / (4π x (distance, cm)^2)
FCC Limit	1.0000	mW/cm^2	1. x f^.
Ratio of Power Density to Limit	0.0283		Power Density / FCC Limit
Maximum Permissible Antenna Gain	18.48	dBi	((Limit, mW/cm^2) x 4π x (distance, cm)^2) / ((Maximum Scaled Power, mW) x Source Based Duty Cycle)