5. FCC §15.247(i), §1.1310, § 2.1091 - Maximum Permissible Exposure (MPE)

5.1. Applicable Standard

According to subpart 15.247(i)and subpart §1.1310, systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy level in excess of the Commission's guidelines.

Limits for Maximum Permissible Exposure (MPE) (§1.1310, §2.1091)

(B) Limits for General Population/Uncontrolled Exposure				
Frequency Range (MHz)	**Electric Field Strength (V/m)**	**Magnetic Field Strength (A/m)**	**Power Density (mW/cm^2)**	**Averaging Time (minutes)**
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;

According to §1.1310 and §2.1091 RF exposure is calculated.

Calculated Formulary:

Predication of MPE limit at a given distance

$S = PG/4\pi R^2$ = power density (in appropriate units, e.g. mW/cm^2);

P = power input to the antenna (in appropriate units, e.g., mW);

G = power gain of the antenna in the direction of interest relative to an isotropic radiator, the power gain factor, is normally numeric gain;

R = distance to the center of radiation of the antenna (appropriate units, e.g., cm);

For simultaneously transmit system, the calculated power density should comply with:

$$\sum_i \frac{S_i}{S_{Limit,i}} \leq 1$$

5.2. RF Exposure Evaluation Result

Calculated Data (worst case):

Model 1

Mode	Frequency Range (MHz)	Antenna Gain		Target Power		Evaluation Distance (cm)	Power Density (mW/cm^2)	MPE Limit (mW/cm^2)
		(dBi)	(numeric)	(dBm)	(mW)			
LoRa (125kHz)	902.3-927.7	0.87	1.222	24	251.189	20	0.0611	0.602
LoRa (250kHz)	902.3-927.5	0.87	1.222	24	251.189	20	0.0611	0.602
LoRa (500kHz)	903-927.5	0.87	1.222	23.5	223.87	20	0.0544	0.602
WIFI (Internal Antenna)	2412-2462	-0.5	0.891	18	63.096	20	0.0112	1
BLE (Internal Antenna)	2402-2480	-0.5	0.891	3.5	2.239	20	0.0004	1
BT2.1+EDR (Internal Antenna)	2402-2480	-0.5	0.891	5.5	3.548	20	0.0006	1
WIFI (External Antenna)	2412-2462	2	1.585	18	63.096	20	0.0199	1
BLE (External Antenna)	2402-2480	2	1.585	3.5	2.239	20	0.0007	1
BT2.1+EDR (External Antenna)	2402-2480	2	1.585	5.5	3.548	20	0.0011	1

Note: WIFI 2.4G/BLE/BT (FCC ID: 2AJMTWIPY3R) and LoRa can transmit simultaneously; the worst condition as below:

$\sum_i \frac{S_i}{S_{Limit,i}}$ = 0.0611/0.602+0.0199/1.00= 0.1213 < 1.0

Model 2

Mode	Frequency Range (MHz)	Antenna Gain		Target Power		Evaluation Distance (cm)	Power Density (mW/cm^2)	MPE Limit (mW/cm^2)
		(dBi)	(numeric)	(dBm)	(mW)			
LoRa (125kHz)	902.3-927.7	0.87	1.222	24	251.189	20	0.0611	0.602
LoRa (250kHz)	902.3-927.5	0.87	1.222	24	251.189	20	0.0611	0.602
LoRa (500kHz)	903-927.5	0.87	1.222	23.5	223.87	20	0.0544	0.602
WIFI	2412-2462	1.3	1.349	23	199.526	20	0.0535	1
BLE	2402-2480	1.3	1.349	3	1.995	20	0.0005	1
BT3.0	2402-2480	1.3	1.349	6	3.981	20	0.0011	1
Sigfox	902-928	0.87	1.222	20	100.000	20	0.0243	0.601

Note: WIFI 2.4G/BLE/BT (FCC ID: 2AJMTLOPY4R) and LoRa can transmit simultaneously; the worst condition as below:

$\sum_i \frac{S_i}{S_{Limit,i}}$ = 0.0611/0.602+0.0535/1.00= 0.1549 < 1.0

Model 3

Mode	Frequency Range (MHz)	Antenna Gain		Target Power		Evaluation Distance (cm)	Power Density (mW/cm^2)	MPE Limit (mW/cm^2)
		(dBi)	(numeric)	(dBm)	(mW)			
LoRa (125kHz)	902.3-927.7	0.87	1.222	24	251.189	20	0.0611	0.602
LoRa (250kHz)	902.3-927.5	0.87	1.222	24	251.189	20	0.0611	0.602
LoRa (500kHz)	903-927.5	0.87	1.222	23.5	223.87	20	0.0544	0.602
WIFI	2412-2462	1.3	1.35	23	199.526	20	0.0535	1
BLE	2402-2480	1.3	1.35	5	3.16	20	0.0008	1
BT3.0	2402-2480	1.3	1.35	6.5	4.47	20	0.0012	1
FDD Band4	1710-1755	7	5.012	23	199.53	20	0.1989	1
FDD Band12	699-716	9.4	8.710	23.5	223.87	20	0.3879	0.466
FDD Band13	777-787	10.4	10.965	23	199.53	20	0.4352	0.518

Note: WIFI 2.4G/BLE/BT, LTE (FCC ID: 2AJMTGPY01R) and LoRa can transmit simultaneously; the worst condition as below:

$\sum_i \frac{S_i}{S_{Limit,i}}$ =0.0611/0.602+0.0535/1.00+0.4352/0.518= 0.995 < 1.0

Result: MPE evaluation of single and simultaneous transmission meet **20cm** the requirement of standard.