Maximum Permissible Exposure Report

Product Information

EUT	:	NucBox5
Model Number	:	KB5
Model Declaration	:	N/A
Test Model	:	KB5
Power Supply	:	DC 19V by adapter
Hardware version	:	IP3_APB20_MB_V11_20210814A
Software version	:	Windows 11 Pro
Sample ID	:	TZ220102886–2#&TZ220102886–4#
Bluetooth		
Bluetooth Version	:	V4.2
Channel Number	:	79 Channels for Bluetooth BR/EDR(DSS) 40 Channels for BLE (DTS)
Modulation Technology	:	GFSK, π/4-DQPSK, 8-DPSK for Bluetooth BR/EDR (DSS) GFSK for BLE (DTS)
Data Rates	:	Bluetooth BR/EDR (DSS): 1/2/3Mbps BLE (DTS): 1Mbps
Antenna Type And Gain	:	Internal Antenna 1: 1.26dBi
WiFi		
WLAN	:	Supported IEEE 802.11a/b/g/n/ac
WLAN FCC Operation Frequency	:	IEEE 802.11b:2412-2462MHz IEEE 802.11g:2412-2462MHz IEEE 802.11n HT20:2412-2462MHz / 5180-5240MHz IEEE 802.11n HT40: 2422-2452MHz / 5190-5230MHz IEEE 802.11a: 5180-5240MHz IEEE 802.11ac VHT20: 5180-5240MHz IEEE 802.11ac VHT40: 5190-5230MHz IEEE 802.11ac VHT80: 5210MHz
WLAN Modulation Technology	:	IEEE 802.11b: DSSS(CCK,DQPSK,DBPSK) IEEE 802.11g: OFDM (64QAM, 16QAM, QPSK, BPSK) IEEE 802.11n: OFDM (64QAM, 16QAM, QPSK, BPSK) IEEE 802.11a: OFDM (64QAM, 16QAM, QPSK, BPSK) IEEE 802.11ac: OFDM (256QAM, 64QAM, 16QAM, QPSK, BPSK)
Antenna Type And Gain	:	Antenna 1: 1.26dBi(Max.), for TX/RX (WLAN 2.4G Band) 1.93dBi(Max.), for TX/RX (WLAN 5.2G Band) Antenna 2: 0.5dBi(Max.), for TX/RX (WLAN 2.4G Band) 0.49dBi(Max.), for TX/RX (WLAN 5.2G Band) 802.11n/ac support 2T2R.[Antenna 1 and Antenna 2]

Note: Antenna position refer to EUT Photos.

2. Evaluation Method

Systems operating under the provisions of FCC 47 CFR 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. In accordance with 47 CFR FCC Part 2 Subpart J, section 2.1091 this device has been defined as mobile device whereby a distance of 0.2m normally can be maintained between the user and the device, and below RF Permissible Exposure limit shall comply with.

In accordance with KDB447498D01 for Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneous transmitting antennas incorporated in a host device, based on the calculated/estimated, numerically modelled or measured field strengths or power density, is ≤ 1.0. The MPE ratio of each antenna is determined at the minimum test separation distance required by the operating configurations and exposure conditions of the host device, according to the ratio of field strengths or power density to MPE limit, at the test frequency. Either the maximum peak or spatially averaged results from measurements or numerical simulations may be used to determine the MPE ratios. Spatial averaging does not apply when MPE is estimated using simple calculations based on far-field plane-wave equivalent conditions. The antenna installation and operating requirements for the host device must meet the minimum test separation distances required by all antennas, in both standalone and simultaneous transmission operations, to satisfy compliance.

3. Limit

3. 1 Refer evaluation method

ANSI C95.1–1999: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.
FCC KDB publication 447498 D01 General 1 RF Exposure Guidance v06: Mobile and Portable Devices RF Exposure Procedures and Equipment Authorization Policies.
FCC CFR 47 part1 1.1310: Radiofrequency radiation exposure limits.
FCC CFR 47 part2 2.1091: Radiofrequency radiation exposure evaluation: mobile devices

3. 2 Limit

Limits for Maximum Permissible Exposure (MPE)/Controlled Exposure

Frequency Range(MHz)	Electric Field Strength(V/m)	Magnetic Field Strength(A/m)	Power Density (mW/cm^2)	Averaging Time (minute)
Limits for Occupational/Controlled Exposure				
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

Limits for Maximum Permissible Exposure (MPE)/Uncontrolled Exposure

Frequency Range(MHz)	Electric Field Strength(V/m)	Magnetic Field Strength(A/m)	Power Density (mW/cm^2)	Averaging Time (minute)
Limits for Occupational/Controlled Exposure				
0.3 – 3.0	614	1.63	(100) *	30
3.0 – 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

4. MPE Calculation Method

Predication of MPE limit at a given distance
Equation from page 18 of OET Bulletin 65, Edition 97-01

$S=PG/4\pi R^2$

Where: S=power density
P=power input to antenna
G=power gain of the antenna in the direction of interest relative to an isotropic radiator
R=distance to the center of radiation of the antenna

5. Antenna Information

This Product can only use antennas certificated as follows provided by manufacturer;

Antenna Gain and type refer to Product information

6. Conducted Power

2.4G Band:
Bluetooth(BDR+EDR)

TestMode	Antenna	Channel	Result[dBm]
DH5	Ant1	2402	-0.67
		2441	-1.17
		2480	-2.67
2DH5	Ant1	2402	0.37
		2441	-0.01
		2480	-1.61
3DH5	Ant1	2402	0.72
		2441	0.22
		2480	-1.06

Bluetooth(BLE)

TestMode	Antenna	Channel	Result[dBm]
BLE_1M	Ant1	2402	-0.68
		2440	-1.17
		2480	-2.7

WiFi 2.4GHz Band

TestMode	Antenna	Channel	Result[dBm]	Limit[dBm]	Verdict
11B	Ant1	2412	15.09	≤30	PASS
	Ant2	2412	14.71	≤30	PASS
	Ant1	2437	15.17	≤30	PASS
	Ant2	2437	14.48	≤30	PASS
	Ant1	2462	15.11	≤30	PASS
	Ant2	2462	14.23	≤30	PASS
11G	Ant1	2412	14.06	≤30	PASS
	Ant2	2412	13.60	≤30	PASS
	Ant1	2437	14.22	≤30	PASS
	Ant2	2437	14.15	≤30	PASS
	Ant1	2462	14.59	≤30	PASS
	Ant2	2462	13.84	≤30	PASS
11N20MIMO	Ant1	2412	13.56	≤30	PASS
	Ant2	2412	13.32	≤30	PASS
	total	2412	16.45	≤30	PASS
	Ant1	2437	13.95	≤30	PASS
	Ant2	2437	13.65	≤30	PASS
	total	2437	16.81	≤30	PASS
	Ant1	2462	13.80	≤30	PASS
	Ant2	2462	12.97	≤30	PASS
	total	2462	16.42	≤30	PASS
11N40MIMO	Ant1	2422	12.16	≤30	PASS
	Ant2	2422	11.28	≤30	PASS
	total	2422	14.75	≤30	PASS
	Ant1	2437	12.04	≤30	PASS
	Ant2	2437	11.80	≤30	PASS
	total	2437	14.93	≤30	PASS
	Ant1	2452	12.15	≤30	PASS
	Ant2	2452	11.34	≤30	PASS
	total	2452	14.77	≤30	PASS

5G Band
UNII-1 Band

TestMode	Antenna	Channel	Result[dBm]	Limit[dBm]	Verdict
11A	Ant1	5180	11.34	≤23.98	PASS
	Ant2	5180	11.43	≤23.98	PASS
	Ant1	5200	11.70	≤23.98	PASS
	Ant2	5200	11.71	≤23.98	PASS
	Ant1	5240	12.36	≤23.98	PASS
	Ant2	5240	11.73	≤23.98	PASS
11N20MIMO	Ant1	5180	9.17	≤23.98	PASS
	Ant2	5180	8.83	≤23.98	PASS
	total	5180	12.01	≤23.98	PASS
	Ant1	5200	8.92	≤23.98	PASS
	Ant2	5200	8.88	≤23.98	PASS
	total	5200	11.91	≤23.98	PASS
	Ant1	5240	9.00	≤23.98	PASS
	Ant2	5240	8.46	≤23.98	PASS
	total	5240	11.75	≤23.98	PASS
11N40MIMO	Ant1	5190	9.59	≤23.98	PASS
	Ant2	5190	10.11	≤23.98	PASS
	total	5190	12.87	≤23.98	PASS
	Ant1	5230	9.12	≤23.98	PASS
	Ant2	5230	8.97	≤23.98	PASS
	total	5230	12.06	≤23.98	PASS
11AC20MIMO	Ant1	5180	8.03	≤23.98	PASS
	Ant2	5180	8.49	≤23.98	PASS
	total	5180	11.71	≤23.98	PASS
	Ant1	5200	7.94	≤23.98	PASS
	Ant2	5200	7.61	≤23.98	PASS
	total	5200	10.79	≤23.98	PASS
	Ant1	5240	8.41	≤23.98	PASS
	Ant2	5240	7.55	≤23.98	PASS
	total	5240	11.01	≤23.98	PASS
11AC40MIMO	Ant1	5190	5.53	≤23.98	PASS
	Ant2	5190	6.01	≤23.98	PASS
	total	5190	8.79	≤23.98	PASS
	Ant1	5230	6.88	≤23.98	PASS
	Ant2	5230	6.60	≤23.98	PASS
	total	5230	9.75	≤23.98	PASS
11AC80MIMO	Ant1	5210	6.93	≤23.98	PASS
	Ant2	5210	7.29	≤23.98	PASS
	total	5210	10.12	≤23.98	PASS

7. Manufacturing Tolerance

Bluetooth(BDR+EDR)

GFSK (Peak)			
Channel	Channel 0	Channel 39	Channel 78
Target (dBm)	-1.0	-1.5	-3.0
Tolerance ±(dB)	1.0	1.0	1.0
π/4-DQPSK (Peak)			
Channel	Channel 0	Channel 39	Channel 78
Target (dBm)	0.0	-0.5	-2.0
Tolerance ±(dB)	1.0	1.0	1.0
8-DPSK (Peak)			
Channel	Channel 0	Channel 39	Channel 78
Target (dBm)	0.0	-0.5	-1.5
Tolerance ±(dB)	1.0	1.0	1.0

Bluetooth(BLE)

GFSK(1Mbps) (Peak)			
Channel	Channel 0	Channel 39	Channel 78
Target (dBm)	-1.0	-1.5	-3.0
Tolerance ±(dB)	1.0	1.0	1.0

WiFi 2.4GHz Band – Antenna 1

IEEE 802.11b(Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	14.5	14.5	14.5
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11g (Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	13.5	13.5	14.0
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT20 (Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	13.0	13.5	13.5
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT40 (Average)			
Channel	Channel 3	Channel 6	Channel 9
Target (dBm)	11.5	11.5	11.5
Tolerance ±(dB)	1.0	1.0	1.0

WiFi 2.4GHz Band – Antenna 2

IEEE 802.11b (Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	14.0	14.0	13.5
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11g (Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	13.0	13.5	13.5
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT20 (Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	13.0	13.0	12.5
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT40 (Average)			
Channel	Channel 1	Channel 6	Channel 11
Target (dBm)	11.0	11.5	11.0
Tolerance ±(dB)	1.0	1.0	1.0

UNII-1 Band – Antenna 1

IEEE 802.11a (Average)			
Channel	Channel 36	Channel 40	Channel 48
Target (dBm)	11.0	11.0	12.0
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT20 (Average)			
Channel	Channel 36	Channel 40	Channel 48
Target (dBm)	8.5	8.5	8.5
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11ac VHT20 (Average)			
Channel	Channel 36	Channel 40	Channel 48
Target (dBm)	7.5	7.5	8.0
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT40 (Average)			
Channel	Channel 38	Channel 46	--
Target (dBm)	9.0	8.5	--
Tolerance ±(dB)	1.0	1.0	--
IEEE 802.11ac VHT40 (Average)			
Channel	Channel 38	Channel 46	--
Target (dBm)	5.0	6.5	--
Tolerance ±(dB)	1.0	1.0	--
IEEE 802.11ac VHT80 (Average)			
Channel	Channel 42	--	--
Target (dBm)	6.5	--	--
Tolerance ±(dB)	1.0	--	--

UNII-1 Band – Antenna 2

IEEE 802.11a (Average)			
Channel	Channel 36	Channel 40	Channel 48
Target (dBm)	11.0	11.0	11.0
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT20 (Average)			
Channel	Channel 36	Channel 40	Channel 48
Target (dBm)	8.5	8.5	8.0
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11ac VHT20 (Average)			
Channel	Channel 36	Channel 40	Channel 48
Target (dBm)	8.0	7.0	7.0
Tolerance ±(dB)	1.0	1.0	1.0
IEEE 802.11n HT40 (Average)			
Channel	Channel 38	Channel 46	--
Target (dBm)	9.5	8.5	--
Tolerance ±(dB)	1.0	1.0	--
IEEE 802.11ac VHT40 (Average)			
Channel	Channel 38	Channel 46	--
Target (dBm)	5.5	6.0	--
Tolerance ±(dB)	1.0	1.0	--
IEEE 802.11ac VHT80 (Average)			
Channel	Channel 42	--	--
Target (dBm)	7.0	--	--
Tolerance ±(dB)	1.0	--	--

8. Measurement Results

8.1 Standalone MPE

As declared by the Applicant, the EUT is a wireless device used in a fix application, at least 20 cm from any body part of the user or nearby persons; from the maximum EUT RF output power, the minimum separation distance, r =20cm, as well as the gain of the used antenna refer to antenna information, the RF power density can be obtained.

Bluetooth(BDR+EDR)

Modulation Type	Output power		Antenna Gain (dBi)	Antenna Gain (linear)	Duty Cycle	MPE (mW/cm^2)	MPE Limits (mW/cm^2)
	dBm	mW					
GFSK	0.00	1.0000	1.26	1.3366	100%	0.0003	1.0000
π/4-DQPSK	1.00	1.2589	1.26	1.3366	100%	0.0003	1.0000
8-DPSK	1.00	1.2589	1.26	1.3366	100%	0.0003	1.0000

Bluetooth(BLE)

Modulation Type	Output power		Antenna Gain (dBi)	Antenna Gain (linear)	Duty Cycle	MPE (mW/cm^2)	MPE Limits (mW/cm^2)
	dBm	mW					
GFSK	0.00	1.0000	1.26	1.3366	100%	0.0003	1.0000

WiFi 2.4GHz Band – Ant 1

Modulation Type	Output power		Antenna Gain (dBi)	Antenna Gain (linear)	Duty Cycle	MPE (mW/cm^2)	MPE Limits (mW/cm^2)
	dBm	mW					
IEEE 802.11b	15.50	35.4813	1.26	1.3366	100%	0.0094	1.0000
IEEE 802.11g	15.00	31.6228	1.26	1.3366	100%	0.0084	1.0000
IEEE 802.11n HT20	14.50	28.1838	1.26	1.3366	100%	0.0075	1.0000
IEEE 802.11n HT40	12.50	17.7828	1.26	1.3366	100%	0.0047	1.0000

WiFi 2.4GHz Band – Ant 2

Modulation Type	Output power		Antenna Gain (dBi)	Antenna Gain (linear)	Duty Cycle	MPE (mW/cm^2)	MPE Limits (mW/cm^2)
	dBm	mW					
IEEE 802.11b	15.00	31.6228	0.50	1.1220	100%	0.0071	1.0000
IEEE 802.11g	14.50	28.1838	0.50	1.1220	100%	0.0063	1.0000
IEEE 802.11n HT20	14.00	25.1189	0.50	1.1220	100%	0.0056	1.0000
IEEE 802.11n HT40	12.50	17.7828	0.50	1.1220	100%	0.0040	1.0000

UNII-1 Band – Ant 1

Modulation Type	Output power		Antenna Gain (dBi)	Antenna Gain (linear)	Duty Cycle	MPE (mW/cm^2)	MPE Limits (mW/cm^2)
	dBm	mW					
IEEE 802.11a	13.00	19.9526	1.93	1.5596	100%	0.0062	1.0000
IEEE 802.11n HT20	9.50	8.9125	1.93	1.5596	100%	0.0028	1.0000
IEEE 802.11ac VHT20	9.00	7.9433	1.93	1.5596	100%	0.0025	1.0000
IEEE 802.11n HT40	10.00	10.0000	1.93	1.5596	100%	0.0031	1.0000
IEEE 802.11ac VHT40	7.50	5.6234	1.93	1.5596	100%	0.0017	1.0000
IEEE 802.11ac VHT80	7.50	5.6234	1.93	1.5596	100%	0.0017	1.0000

UNII-1 Band – Ant 2

Modulation Type	Output power		Antenna Gain (dBi)	Antenna Gain (linear)	Duty Cycle	MPE (mW/cm^2)	MPE Limits (mW/cm^2)
	dBm	mW					
IEEE 802.11a	12.00	15.8489	0.49	1.1194	100%	0.0035	1.0000
IEEE 802.11n HT20	9.50	8.9125	0.49	1.1194	100%	0.0020	1.0000
IEEE 802.11ac VHT20	9.00	7.9433	0.49	1.1194	100%	0.0018	1.0000
IEEE 802.11n HT40	10.50	11.2202	0.49	1.1194	100%	0.0025	1.0000
IEEE 802.11ac VHT40	7.00	5.0119	0.49	1.1194	100%	0.0011	1.0000
IEEE 802.11ac VHT80	8.00	6.3096	0.49	1.1194	100%	0.0014	1.0000

Remark:

1. Output power including tune-up tolerance;

2. MPE evaluate distance is 20cm from user manual provide by manufacturer;

8.2 Simultaneous Transmission MPE

Bluetooth + Wi-Fi

Maximum MPE(mW/cm^2) BT Ant./WIFI Ant.1	Maximum MPE(mW/cm^2) WIFI Ant.2	∑MPE (mW/cm^2)	Limit (mW/cm^2)	Results
0.0094	0.0062	0.0156	1.0000	PASS

Remark:
1. Output power including tune-up tolerance;
2. MPE evaluate distance is 20cm from user manual provide by manufacturer;

9. Conclusion

The measurement results comply with the FCC Limit per 47 CFR 2.1091 for the uncontrolled RF Exposure of mobile device.

----------THE END OF REPORT----------