FCC ID:	BCGA2589
Date:	December 07, 2021
Test Method:	Per FCC KDB Inquiry
iPad EUT S/N:	W357HHVWRP
Pencil S/N	GQX05120JWGL6V7AZ

RF Exposure Measurements of Wireless Charging Transmitter Per FCC KDB Inquiry

Purpose: The purpose of this test report is to determine the worst-case H-Field and E-Field levels emitted by the wireless charging transmitter of the EUT Host to the pencil per FCC KDB Inquiry to determine qualification for SAR test exclusion.

Wireless Charging Maximum Output Power from Host: 6.5 W

Wireless Charging Operating Frequency: 127.7 kHz

Test results reported herein relate only to the item(s) tested.

Test Equipment

Manufacturer	Model	Description	Cal. Date	Cal. Due Date	Serial Number
Narda	ELT-400	Exposure Level Probe	12/02/2021	12/02/2022	C-0232
Narda	ELT-400	Exposure Level Tester	12/02/2021	12/02/2022	N-0701
Narda	EHP-200A	E and H Field Probe Analyzer	12/02/2021	12/02/2022	170WX50927

Definitions

- Optimal Placement (Max Coupling) = Optimal pencil location as positioned by the magnets that hold the pencil in place.
- Min Coupling = Misalignment as described in the KDB inquiry.
- 10C, 3C, 2.5C, 1C = Charging profiles, with 10C as highest output power and 1C lowest output power.
- Charging Profiles:

Charge Rate	Battery State of Charge	Charge Duration in Min
10.0 C	0-5%	0 m 12s
3.0 C	5-12%	1m 30s
2.5 C	12-82%	14m 0s
1 C (Trickle)	82-100%	19m 18s

Objection Detection Mode

Without the Pencil, the WPT transmitter will be in the ODM (object detection mode) mode, where the total ON time is about 2.5 ms out of every 100 ms without the smart cover or 1 s with the smart cover and will excite the TX coil with a very small amount of energy to sense whether there is any magnetic or metallic object in its vicinity. When the Pencil is mated to the iPad, the WPT will detect that there is an object matching the signature of a compatible RX coil and then attempt to establish in-band communication link with a digital ping. This digital pinging is a process where the TX coil is energized much more but still below the limit so that the WPT receiver on the Pencil can be powered up.

X, Y, Z Axis Description

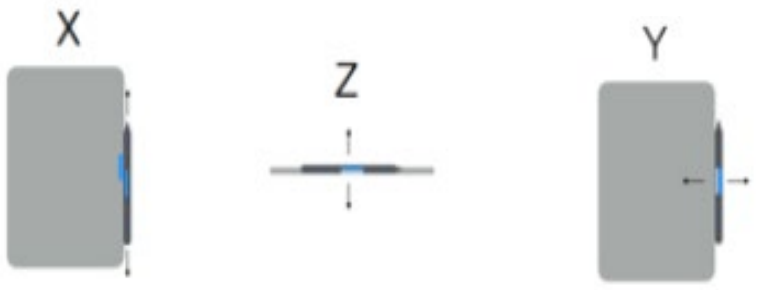
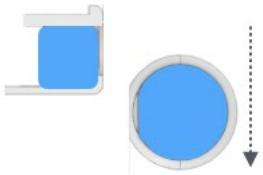
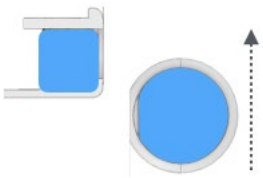
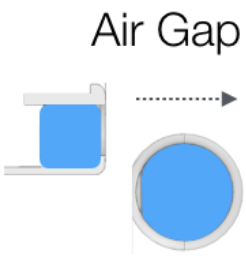


Figure 1 Pencil Alignment X, Y, Z Axis

- For the X axis, the positive direction is towards the writing tip of the pencil and the negative direction is towards the tail of the pencil.
- For the Y axis, the negative direction is increasing air gap
- For the Z axis, the positive direction is towards the front screen of device, and the negative direction is towards the back shell of the device.

Verification of H-Field Control (HFC) Algorithm

- Tx coil current (I_{TX}) and Rx current (I_{RECT}) and efficiency are used to define the hard thresholds used in H-Field control algorithm. H-field control algorithm will always limit the Max H-fields below worst-case value.
- Measurement procedure was performed per FCC KDB Inquiry.
- Data in the following table were recorded from real time streaming command prompt output that monitors the current and efficiency of the EUT Host's wireless charging function with pencil.

Measurement Cases		Pencil alignment	Charging condition	I_{Tx} (A)	I_{RECT} (A)
Optimal Alignment (Max Coupling)		0	10C	0.84	0.21
		0	3C	0.51	0.11
		0	2.5C	0.50	0.09
		0	1C	0.44	0.06
	**Min Coupling, shifting pencil towards back (-Z) until charging throttles, then move back by 0.2 mm**	Δz= -3.9 mm	10C	1.43	0.21
		Δz= -4.2 mm	3C	0.89	0.11
		Δz= -4.2 mm	2.5C	0.88	0.09
		Δz= -4.6 mm	1C	0.84	0.06
	**Min Coupling, shifting pencil towards Display (+Z) until charging throttles, then move back by 0.2 mm**	Δz = 3.8 mm	10C	1.42	0.21
		Δz = 4.1 mm	3C	0.89	0.11
		Δz = 4.1 mm	2.5C	0.88	0.09
		Δz = 4.9 mm	1C	0.85	0.06
	**Min Coupling, shifting pencil away from iPad(-Y) until charging throttles, then move back by 0.2 mm**	Δy = -1.8 mm	10C	1.43	0.21
		Δy = -1.9 mm	3C	0.89	0.11
		Δy = -1.9 mm	2.5C	0.87	0.09
		Δy = -2.4 mm	1C	0.85	0.06

	**Min Coupling, shifting pencil upward in lateral plane(+X) until charging throttles, then move back by 0.2 mm**	Δx = 3.2 mm	10C	1.33	0.21
		Δx = 3.7 mm	3C	0.88	0.11
		Δx = 3.7 mm	2.5C	0.86	0.09
		Δx = 4.2 mm	1C	0.84	0.06
	Min Coupling, shifting pencil downward in lateral plane(-X) until charging throttles, then move back by 0.2 mm	Δx = -3.5 mm	10C	1.36	0.21
		Δx = -3.9 mm	3C	0.89	0.11
		Δx = -3.9 mm	2.5C	0.86	0.09
		Δx = -4.4 mm	1C	0.84	0.06

H-Field and E-Field Measurements

- Measurement procedure was performed per FCC KDB Inquiry.
- H-Field testing was performed with calibrated field probes (ELT-400).
- E-Field testing was performed with calibrated field probe (EHP-200A).
- Measurements were performed on the front screen (Top), back shell (Bottom), and side of the EUT where the pencil is charging (Side).
- Testing was performed per FCC KDB Inquiry.

Measurement Cases	Pencil alignment	Probe plane	Charge Profile	Measured H-Field (A/m)	Measured E-Field (V/m)
Optimal Placement (Max Coupling)	0	Top	10C	28.8	15.0
	0	Bottom		29.6	12.0
	0	Side		16.4	10.6
Min coupling, shifting pencil towards back (-Z) until charging throttles, then move back in by 0.2 mm	Δz = -3.9 mm	Top	10C	39.2	20.4
	Δz = -3.9 mm	Bottom		36.2	18.3
	Δz = -3.9 mm	Side		20.5	16.0
Min coupling, shifting pencil towards Display (+Z) until charging throttles, then move back in by 0.2 mm	Δz = 3.8 mm	Top	10C	32.3	18.3
	Δz = 3.8 mm	Bottom		39.5	16.1
	Δz = 3.8 mm	Side		21.7	14.7

Min coupling, shifting pencil towards Display (+Z) until charging throttles, then move back in by 0.2 mm	Δz = 4.1 mm	Bottom	3C	24.3	9.5
Min coupling, shifting pencil towards Display (+Z) until charging throttles, then move back in by 0.2 mm	Δz = 4.1 mm	Bottom	2.5C	22.7	8.1
Min coupling, shifting pencil towards Display (+Z) until charging throttles, then move back in by 0.2 mm	Δz = 4.9 mm	Bottom	1C	23.5	8.7
Digital Ping (No RX)	No Pencil (No RX)	Side (right in front of the TX window)	N.A.	25.7	0.4

Conclusion

The worst-case H-Field and E-Field measurements have been determined to be 39.5 A/m and 20.4 V/m respectively.

Correlation between Measured and Simulated H-Field

Numerical analysis for WPT was carried out to establish correlation between measured and simulated H-field. Following Table shows that correlation information. The Measured H-field shows good agreement with Numerical analysis.

BCGA2589			H-field Measurements (A/m)		H-field Simulations (A/m)	
Charge Profile	Probe Position	Probe distance from the DUT (mm)	Optimal alignment (Max coupling)	Worst Case (Min Coupling)	Optimal alignment (Max coupling)	Worst Case (Min Coupling)
10C	Bottom	0 mm	29.6	39.5	29.8	41.8
		5 mm	15.5	19.9	13.7	19.8
		10 mm	9.1	11.5	7.3	10.8

Standalone SAR Test Exclusion

Numerical analysis for WPT operation in different orientations for Max and Min coupling configurations yields SAR values which are < 0.000852 W/kg @ Max charge profile of 10C. These values are well below ambient noise levels measurable in commercially available SAR systems.

There is no intentional transmission taking place in object detection mode. Additionally, the overall duty cycle of ping mechanism is less than 0.1% hence this mode is not included in analysis.

Based on above, per FCC guidance, the Apple pencil charging function qualifies for standalone SAR test exclusion.

Simultaneous SAR Test Exclusion

A comprehensive numerical SAR analysis is carried out for WPT operation in conjunction with SAR hotspot analysis for WLAN antennas to address compliance in simultaneous transmit conditions. The Tx coil is very small (~8.3 mm) and its at least ~ mm away from the closest radiating element on its either side.

The SAR gradient for nearest radiating elements to the WPT Tx Coil is very localized and falls off substantially at the location of the WPT Tx coils (see Figure 2). SAR hotspot gradient shown in Figure 2 is without the Apple pencil attached to the iPad. With Apple pencil attached to the iPad, SAR will be lower.

Based on above, per FCC guidance, the Apple pencil charging function qualifies for simultaneous SAR test exclusion.

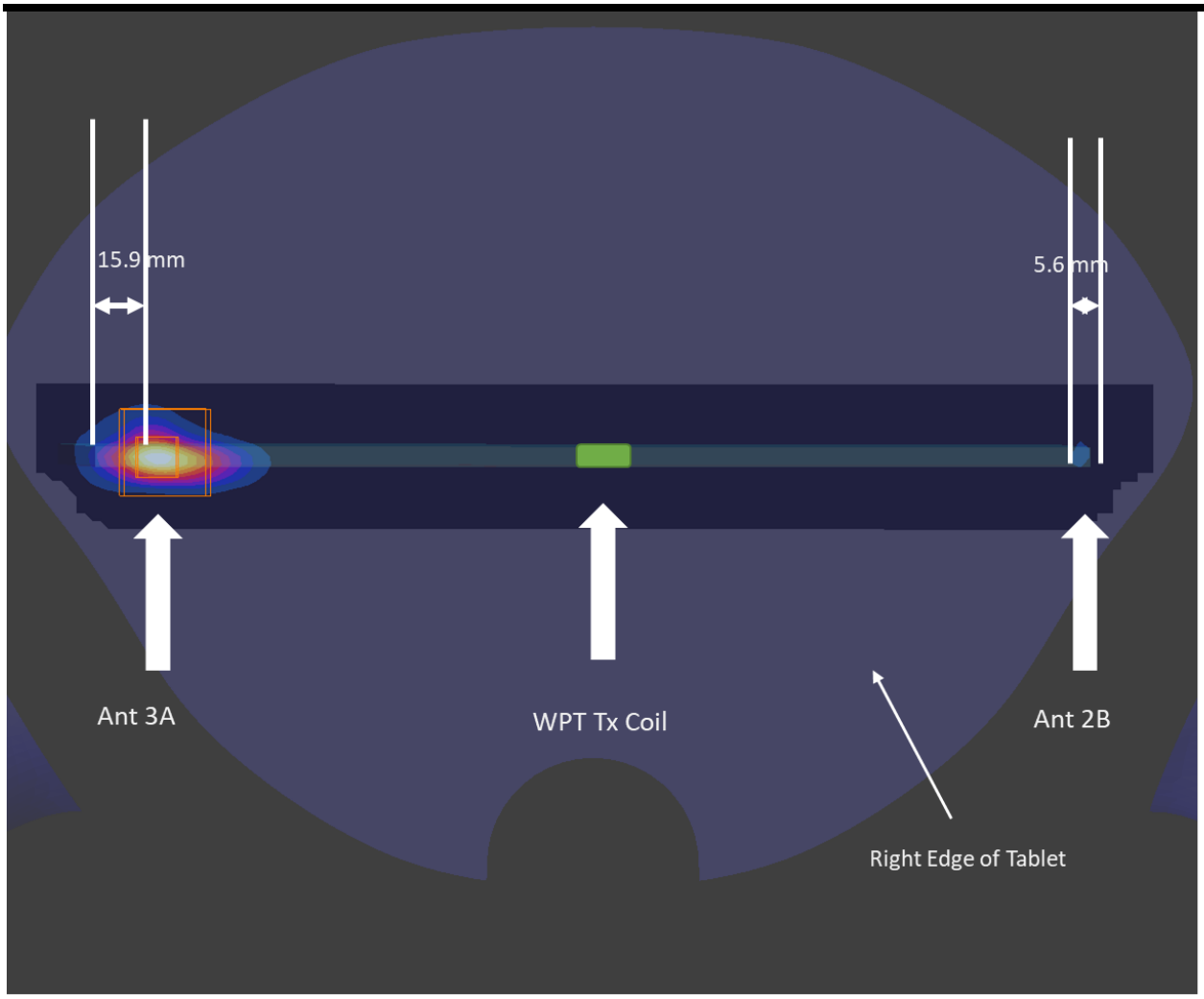


Figure 2 Right Edge Overlay Showing Localization of Simultaneous Peaks