

|               |                                     |
|---------------|-------------------------------------|
| FCC ID:       | BCGA2379                            |
| Date:         | January 22, 2021 – February 1, 2021 |
| Test Method:  | Per FCC KDB Inquiry                 |
| iPad EUT S/N: | CQHJQKHY03                          |
| Pencil S/N    | GQX83550HVPKWD62B                   |

## 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: 7.0 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         | 11/16/2020 | 11/16/2021    | C-0232        |
| Narda        | ELT-400  | Exposure Level Tester        | 11/16/2020 | 11/16/2021    | N-0701        |
| Narda        | EHP-200A | E and H Field Probe Analyzer | 11/12/2020 | 11/12/2021    | 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 14s                |
| 3.0 C         | 5-12%                   | 1m 30s                 |
| 2.5 C         | 12-82%                  | 15m 30s                |
| 1 C (Trickle) | 82-100%                 | 16m 0s                 |

## X, Y, Z Axis Description

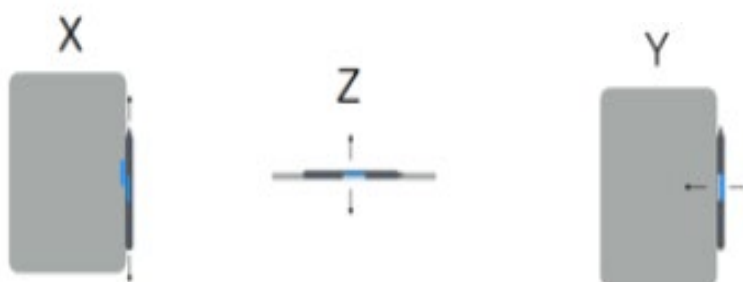
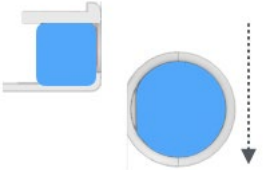
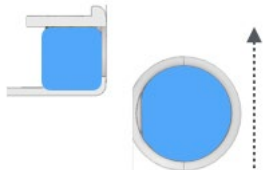
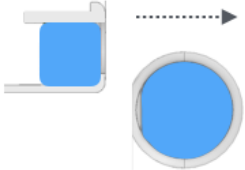


Figure 1 Pencil Alignment X, Y, Z Axis

- 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) |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|----------------------|--------------------|--------------|----------------|
| <b>Optimal Alignment (Max Coupling)</b>                                             |                                                                                                              | 0                    | 10C                | 0.92         | 0.21           |
|                                                                                     |                                                                                                              | 0                    | 3C                 | 0.52         | 0.11           |
|                                                                                     |                                                                                                              | 0                    | 2.5C               | 0.51         | 0.09           |
|                                                                                     |                                                                                                              | 0                    | 1C                 | 0.44         | 0.06           |
|  | <b>Min Coupling, shifting pencil towards back (-Z) until charging throttles, then move back by 0.2 mm</b>    | $\Delta z = -4.0$ mm | 10C                | 1.52         | 0.21           |
|                                                                                     |                                                                                                              | $\Delta z = -4.2$ mm | 3C                 | 0.87         | 0.11           |
|                                                                                     |                                                                                                              | $\Delta z = -4.3$ mm | 2.5C               | 0.85         | 0.09           |
|                                                                                     |                                                                                                              | $\Delta z = -4.5$ mm | 1C                 | 0.72         | 0.06           |
|  | <b>Min Coupling, shifting pencil towards Display (+Z) until charging throttles, then move back by 0.2 mm</b> | $\Delta z = 3.8$ mm  | 10C                | 1.51         | 0.21           |
|                                                                                     |                                                                                                              | $\Delta z = 4.0$ mm  | 3C                 | 0.88         | 0.11           |
|                                                                                     |                                                                                                              | $\Delta z = 4.0$ mm  | 2.5C               | 0.84         | 0.09           |
|                                                                                     |                                                                                                              | $\Delta z = 4.2$ mm  | 1C                 | 0.72         | 0.06           |
|  | <b>Min Coupling, shifting pencil away from iPad (-Y) until charging throttles, then move back by 0.2 mm</b>  | $\Delta y = -1.4$ mm | 10C                | 1.54         | 0.22           |
|                                                                                     |                                                                                                              | $\Delta y = -1.4$ mm | 3C                 | 0.88         | 0.11           |
|                                                                                     |                                                                                                              | $\Delta y = -1.4$ mm | 2.5C               | 0.85         | 0.09           |
|                                                                                     |                                                                                                              | $\Delta y = -1.5$ mm | 1C                 | 0.74         | 0.06           |

## FCC Test Results

|                                                                                   |                                                                                                                       |                              |      |      |      |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|------------------------------|------|------|------|
|  | <b>Min Coupling, shifting pencil upward in lateral plane(+X) until charging throttles, then move back by 0.2 mm</b>   | $\Delta x = 3.3 \text{ mm}$  | 10C  | 1.48 | 0.22 |
|                                                                                   |                                                                                                                       | $\Delta x = 3.4 \text{ mm}$  | 3C   | 0.87 | 0.11 |
|                                                                                   |                                                                                                                       | $\Delta x = 3.4 \text{ mm}$  | 2.5C | 0.84 | 0.09 |
|                                                                                   |                                                                                                                       | $\Delta x = 3.6 \text{ mm}$  | 1C   | 0.71 | 0.06 |
|                                                                                   | <b>Min Coupling, shifting pencil downward in lateral plane(-X) until charging throttles, then move back by 0.2 mm</b> | $\Delta x = -3.7 \text{ mm}$ | 10C  | 1.48 | 0.22 |
|                                                                                   |                                                                                                                       | $\Delta x = -3.8 \text{ mm}$ | 3C   | 0.87 | 0.11 |
|                                                                                   |                                                                                                                       | $\Delta x = -3.9 \text{ mm}$ | 2.5C | 0.85 | 0.09 |
|                                                                                   |                                                                                                                       | $\Delta x = -4.0 \text{ mm}$ | 1C   | 0.71 | 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<br>(Max Coupling)                                                                                                         | 0                           | Top         | 10C            | 38.4                   | 22.6                   |
|                                                                                                                                             | 0                           | Bottom      |                | 27.0                   | 15.2                   |
|                                                                                                                                             | 0                           | Side        |                | 16.5                   | 12.3                   |
| <b>Min Coupling,<br/>shifting pencil<br/>upward in lateral<br/>plane(+X) until<br/>charging throttles,<br/>then move back by<br/>0.2 mm</b> | $\Delta x = 3.3 \text{ mm}$ | Top         | 10C            | 49.4                   | 31.6                   |
|                                                                                                                                             | $\Delta x = 3.3 \text{ mm}$ | Bottom      |                | 32.8                   | 22.0                   |
|                                                                                                                                             | $\Delta x = 3.3 \text{ mm}$ | Side        |                | 19.8                   | 17.5                   |

|                                                                                                                                               |                              |        |      |      |      |
|-----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|--------|------|------|------|
| <b>Min Coupling,<br/>shifting pencil<br/>downward in lateral<br/>plane(-X) until<br/>charging throttles,<br/>then move back by<br/>0.2 mm</b> | $\Delta x = -3.7 \text{ mm}$ | Top    | 10C  | 49.1 | 25.1 |
|                                                                                                                                               | $\Delta x = -3.7 \text{ mm}$ | Bottom |      | 31.6 | 20.4 |
|                                                                                                                                               | $\Delta x = -3.7 \text{ mm}$ | Side   |      | 23.0 | 17.9 |
| <b>Min Coupling,<br/>shifting pencil<br/>upward in lateral<br/>plane(+X) until<br/>charging throttles,<br/>then move back by<br/>0.2 mm</b>   | $\Delta x = 3.4 \text{ mm}$  | Top    | 3C   | 27.7 | 16.4 |
| <b>Min Coupling,<br/>shifting pencil<br/>upward in lateral<br/>plane(+X) until<br/>charging throttles,<br/>then move back by<br/>0.2 mm</b>   | $\Delta x = 3.4 \text{ mm}$  | Top    | 2.5C | 25.9 | 15.0 |
| <b>Min Coupling,<br/>shifting pencil<br/>upward in lateral<br/>plane(+X) until<br/>charging throttles,<br/>then move back by<br/>0.2 mm</b>   | $\Delta x = 3.6 \text{ mm}$  | Top    | 1C   | 21.3 | 12.3 |

|                                 |                      |                                              |      |      |     |
|---------------------------------|----------------------|----------------------------------------------|------|------|-----|
| <b>Digital Ping<br/>(No RX)</b> | No Pencil<br>(No RX) | Side (right in<br>front of the TX<br>window) | N.A. | 21.1 | 0.6 |
|---------------------------------|----------------------|----------------------------------------------|------|------|-----|

## Conclusion

The worst-case H-Field and E-Field measurements have been determined to be 49.4 A/m and 31.6 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.

| A2379          |                |                                  | 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            | Top            | 0 mm                             | 38.4                             | 49.4                      | 36.2                             | 56.0                      |
|                |                | 5 mm                             | 20.9                             | 27.4                      | 16.6                             | 27.1                      |
|                |                | 10 mm                            | 12.5                             | 16.6                      | 9.0                              | 15.0                      |

### Standalone SAR Test Exclusion

Numerical analysis for WPT operation in different orientations for Max and Min coupling configurations yields SAR values which are < 0.00229 mW/g @ 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 ~26 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.

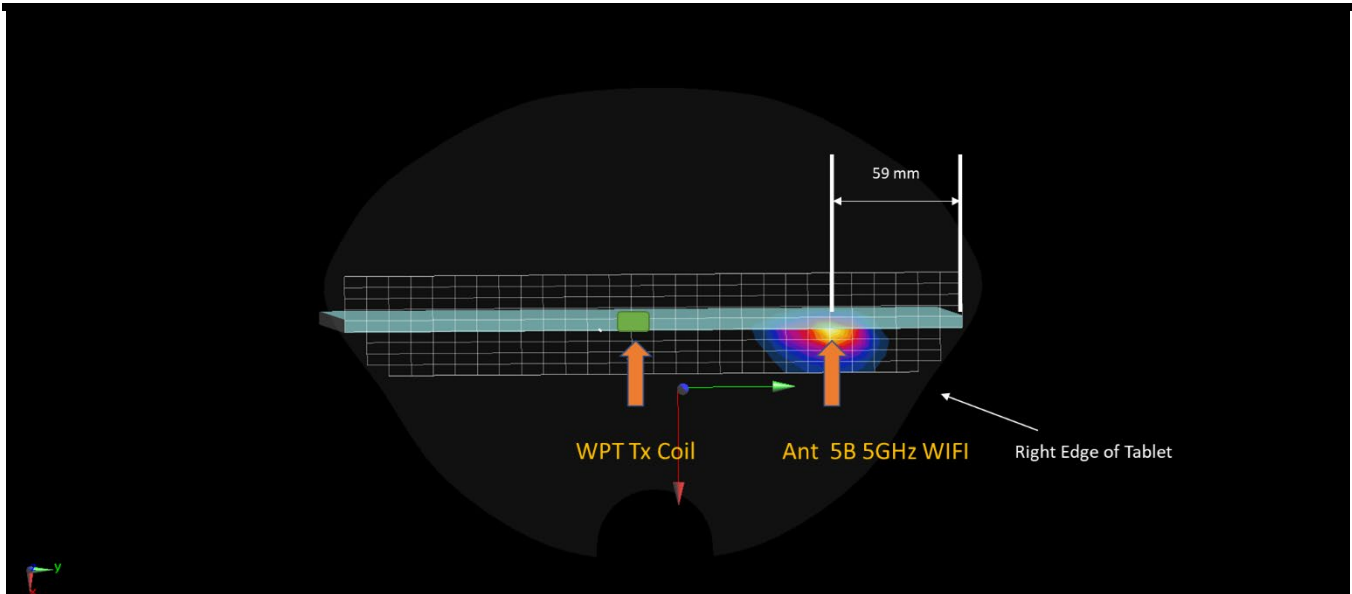


Figure 2 Right Edge Overlay Showing Localization of Simultaneous Peaks

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

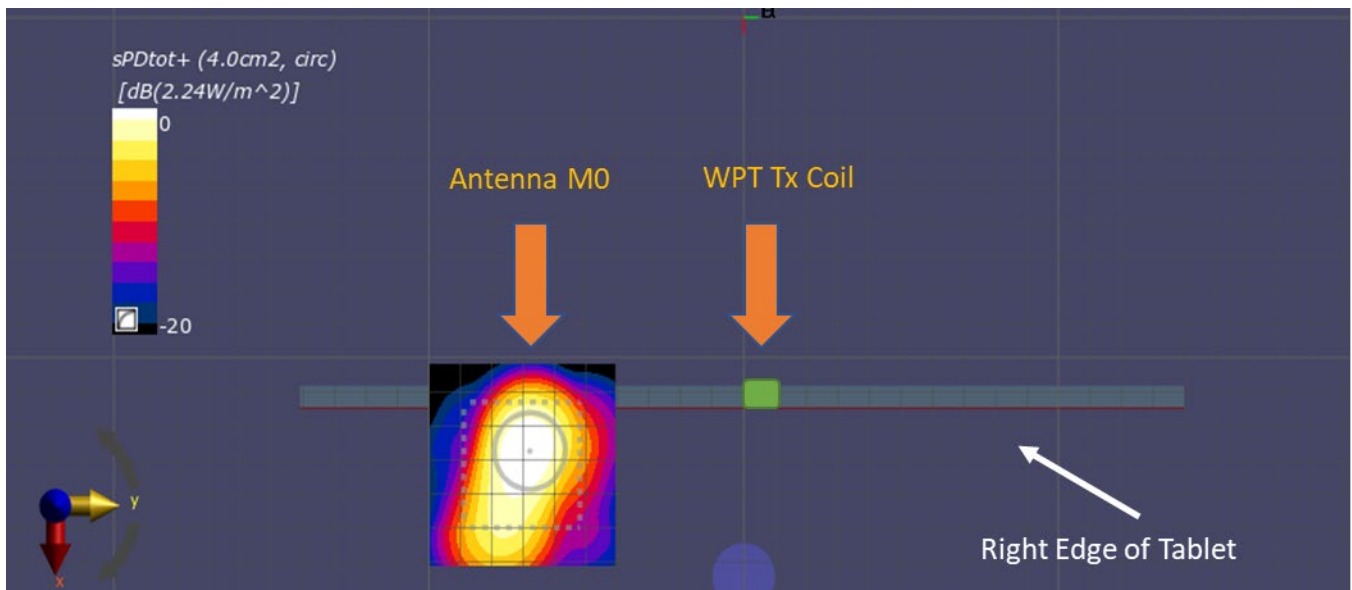


Figure 3 Right Edge Overlay Showing Power Density distribution

Additionally, this device supports 5G mmW NR. As shown above, the power density distribution for the nearest radiating elements to the WPT Tx Coil falls off substantially at the location of the WPT Tx coils (see Figure 3).