



# RF EXPOSURE EVALUATION REPORT




For: Apple Inc.

**Product: A1991**

**FCC ID: BCGA1991**

**RF Exposure Evaluation Report Serial No.:**

UL/REGA1/MPE12718494B

<b>This RF Exposure Evaluation Report Is Issued Under The Authority Of Alan Binks, Head of Inspection:</b>	
PP: 	
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**UL**

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## **RF Exposure Evaluation for the A1991**

The A1991 is a desktop computer which contains 2.4GHz and 5GHz WIFI and 2.4GHz Bluetooth BR/EDR and LE transmitters.

WLAN supports 3x3 MIMO operation with beam forming, and there can be simultaneous transmission between all of the transmitters.

### **The following FCC Rule Parts and procedures are applicable:**

Part 1.1310 – Radiofrequency radiation exposure limits

Part 2.1091 – Radiofrequency radiation exposure evaluation: mobile devices

KDB447498 D01 v06 - Mobile and Portable Devices RF Exposure Procedures and Equipment Authorisation Policies

KDB 662911 D01 v02 r01 – Multiple Transmitter Output

## **MAXIMUM TRANSMITTER POWER CONSIDERATIONS**

From Tune Up tables (conducted power):

### **WLAN 2.4GHz:**

**Power (SISO) = 23.0dBm max**

For non-beam forming MIMO, conducted power for each antenna:

Power (2x2MIMO) = 23.0dBm max (200mW)

Power (3x3 MIMO) = 23.0dBm max (200mW)

For BF MIMO:

Power (2x2MIMO) = 23.0dBm max (200mW)

Power (3x3MIMO) = 21.0dBm max (125.9mW)

### **ANTENNA GAINS:**

Antenna Gain Ant0: +4.56dBi (x2.9)

Antenna Gain Ant1: +4.32dBi (x2.7)

Antenna Gain Ant2: +4.47dBi (x2.8)

From KDB 662911 D01 v02 r01., Max. beamforming max antenna gain is calculated as (see Appendix):

For 2Tx BF = +7.53dBi (x5.66) (Ant0 & Ant2)

For 3Tx BF = +9.22dBi (x8.36)

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RADIATED POWER:

**EIRP<sub>SISO0</sub> = 27.56dBm = 570.2 mW**

EIRP<sub>SISO1</sub> = 27.32dBm = 539.5 mW

EIRP<sub>SISO2</sub> = 27.47dBm = 558.5 mW

Power<sub>max</sub> for non BF 2x2 MIMO operation:

EIRP<sub>MIMO2</sub> = 27.56dBm + 27.47dBm = 570.2mW + 558.5mW = 1.13W

Power for 2Tx BF operation (23dBm + Ant0 & Ant2 antenna gain):

EIRP<sub>BF2</sub> = 23dBm + 7.53dBi = 30.53dBm = 1.13W

Power for non BF 3x3 MIMO operation:

**EIRP<sub>MIMO3</sub> = 27.56dBm + 27.32dBm + 27.47dBm = 570.2mW + 539.5mW + 558.5mW = 1.67W\***

Power for 3Tx BF operation (21dBm + ant gain):

EIRP<sub>BF3</sub> = 21dBm + 9.22dBi = 30.22dBm = 1.05W

**\*max power to be considered in calculations**

WLAN 5GHz:

**Power = 22.0dBm max** (For SISO + 2x2 MIMO + 3x3MIMO + 2 X TxBF)

Power = 20.0dBm max (For 3 X TxBF)

ANTENNA GAINS:

Antenna Gain Ant0: +6.06dBi

Antenna Gain Ant1: +5.71dBi

Antenna Gain Ant2: +4.93dBi

From KDB 662911 D01 v02 r01., Max. beamforming antenna gain is calculated as (see Appendix):

For 2TX BF = +8.9dBi (x7.76) (Ant0 & Ant1)

For 3Tx BF = +10.35dBi (x10.84)

RADIATED POWER:

**EIRP<sub>SISO1</sub> = 28.06dBm = 639.7 mW**

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$$\text{EIRP}_{\text{SISO2}} = 27.71\text{dBm} = 590.2 \text{ mW}$$

$$\text{EIRP}_{\text{SISO3}} = 26.93\text{dBm} = 493.2 \text{ mW}$$

Power for non BF 2x2 MIMO operation:

$$\text{EIRP}_{\text{MIMO2}} = 28.06\text{dBm} + 27.71\text{dBm} = 639.7\text{mW} + 590.2\text{mW} = 1.23\text{W}$$

Power for 2TX BF operation (22dBm + WF2 & WF3 antenna gain):

$$\text{EIRP}_{\text{BF2}} = 22\text{dBm} + 8.9\text{dBi} = 30.9\text{dBm} = 1.23\text{W}$$

Power for non BF 3x3 MIMO operation:

$$\text{EIRP}_{\text{MIMO3}} = 28.06\text{dBm} + 27.71\text{dBm} + 26.93\text{dBm} = 639.7\text{mW} + 590.2\text{mW} + 493.2\text{mW} = 1.72\text{W}^*$$

Power for 3TX BF operation (20dBm + ant gain):

$$\text{EIRP}_{\text{BF3}} = 20\text{dBm} + 10.35\text{dBi} = 30.35\text{dBm} = 1.08\text{W}$$

**\*max power to be considered in calculations**

#### **Bluetooth (Basic Rate, EDR & Low Energy) 2.4GHz**

Power conducted = 13.0dBm

Antenna Gain Ant 3: 4.5dBi

$$\text{EIRP} = 17.5\text{dBm} = 56.2\text{mW}$$

#### **MPE CALCULATIONS**

The MPE calculation used to calculate the safe operating distance for the user is.

$$S = \text{EIRP} / 4 \pi R^2$$

**Where**

S = Power density

EIRP = Effective Isotropic Radiated Power (EIRP = P x G)

P = Conducted Transmitter Power

G = Antenna Gain (relative to an isotropic radiator)

R = distance to the centre of radiation of the antenna (20cm requirement).

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### **For WLAN 2.4GHz**

#### Values:

Transmitter frequency range = 2412 MHz to 2472MHz

Max. EIRP<sub>SISO</sub> = 570.2 mW

EIRP<sub>MIMO</sub> = 1.67W

R = 20cm

#### Power Density Requirement

From table 1 (b) - Limits for General Population/ Uncontrolled Exposure of  
FCC Rule Part 1.1310 for 2.4GHz

$$S_{\text{req1}} = 1.0 \text{ mW/cm}^2$$

#### Calculation:

$$S = \text{EIRP}_{\text{SISO}} / 4 \pi R^2$$

$$S = 570.2 / (12.56 \times 20^2)$$

$$S = 570.2 / (5024)$$

$$S_{1 \text{ SISO}} = 0.11 \text{ mW/ cm}^2 (<1.0 \text{ mW/cm}^2)$$

Similarly for MIMO:  $S_{1 \text{ MIMO}} = 0.33 \text{ mW/ cm}^2 (<1.0 \text{ mW/cm}^2)$

**This equates to minimum safe operating distance ( 3x3 MIMO operation) of 11.5 cm at the RF exposure limit of 1.0 mW/cm<sup>2</sup>**

### **For WLAN 5GHz**

#### Values:

Transmitter frequency range = 5150 MHz to 5850MHz

Max. EIRP<sub>SISO</sub> = 639.7mW

EIRP<sub>MIMO</sub> = 1.72W

R = 20cm

#### Power Density Requirement

From table 1 (b) - Limits for General Population/ Uncontrolled Exposure of  
FCC Rule Part 1.1310 for 5GHz

$$S_{\text{req2}} = 1.0 \text{ mW/cm}^2$$

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Calculation:

$$S = \text{EIRP}_{\text{SISO}} / 4 \pi R^2$$

$$S = 639.7 / (12.56 \times 20^2)$$

$$S = 639.7 / (5024)$$

$$S_{2 \text{ SISO}} = 0.13 \text{ mW/cm}^2 (< 1.0 \text{ mW/cm}^2)$$

Similarly for BF:  $S_{2 \text{ MIMO}} = 0.34 \text{ mW/cm}^2 (< 1.0 \text{ mW/cm}^2)$

**This equates to minimum safe operating distance (3TX BF operation) of 11.7 cm at the RF exposure limit of 1.0 mW/cm<sup>2</sup>**

**For Bluetooth 2.4 GHz**

Values:

Transmitter frequency range = 2402 MHz to 2480MHz

EIRP = 56.23 mW

R = 20cm

Power Density Requirement

From table 1 (b) - Limits for General Population/ Uncontrolled Exposure of  
FCC Rule Part 1.1310 for 5GHz

$$S_{\text{req3}} = 1.0 \text{ mW/cm}^2$$

Calculation:

$$S = \text{EIRP} / 4 \pi R^2$$

$$S = 56.23 / (12.56 \times 20^2)$$

$$S = 56.23 / (5024)$$

$$S_3 = 0.011 \text{ mW/cm}^2 (< 1.0 \text{ mW/cm}^2)$$

**This equates to a minimum safe operating distance of 2.1cm at the RF exposure limit of 1.0 mW/cm<sup>2</sup>**

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### **KDB447498 D01 v05 Section 7.2 SIMULTANEOUS TRANSMISSION CONSIDERATIONS**

Worst case summation of calculated MPE ratios for 2.4GHz/ 5GHz WLAN and 2.4GHz BT simultaneously transmitting transmitters from each respective antenna is:

$$\begin{aligned}\text{ie: } \sum \text{MPE}_{\text{ratios}} &= (\text{S}_1 \text{ SISO} / \text{S}_{\text{req1}}) + (\text{S}_2 \text{ SISO} / \text{S}_{\text{req2}}) + (\text{S}_3 \text{ SISO} / \text{S}_{\text{req3}}) \\ &= (0.33/1.0) + (0.34/1.0) + (0.011/1.0) \\ &= \mathbf{0.68}\end{aligned}$$

$\sum$  of MPE ratios < 1.0, so in accordance with KDB447498 Section 7.2, simultaneous transmission test exclusion applies for the WLAN and Bluetooth transmitters.

### **Conclusion**

The required 20cm RF exposure limits for General Population/ Uncontrolled Exposure will not be exceeded for the A1991 using antennas as specified.

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### Appendix

Antenna gain calculation for BF operation:

**From KDB 662911 D01 v02 r01:**

For 2TX BF - Directional Gain =

$$10 \log \left[ \frac{\sum_{j=1}^{N_{SS}} \left( \sum_{k=1}^{N_{ANT}} g_{j,k} \right)^2}{N_{ANT}} \right] = 10 \log \left[ \frac{\sum_{j=1}^1 \left( \sum_{k=1}^3 g_{j,k} \right)^2}{2} \right]$$

For 3TX BF - Directional Gain =

$$10 \log \left[ \frac{\sum_{j=1}^{N_{SS}} \left( \sum_{k=1}^{N_{ANT}} g_{j,k} \right)^2}{N_{ANT}} \right] = 10 \log \left[ \frac{\sum_{j=1}^1 \left( \sum_{k=1}^3 g_{j,k} \right)^2}{3} \right]$$

### **Example - 2.4GHz 3TX BF:**

Antenna Gain Ant0: +4.56dBi (x2.9)

Antenna Gain Ant1: +4.32dBi (x2.7)

Antenna Gain Ant2: +4.47dBi (x2.8)

Directional Gain =

$$\begin{aligned} 10 \log \left[ \frac{(g_{1,1} + g_{1,2} + g_{1,3})^2}{3} \right] &= 10 \log \left[ \frac{\left( 10^{\frac{G_1}{20}} + 10^{\frac{G_2}{20}} + 10^{\frac{G_3}{20}} \right)^2}{3} \right] \\ &= 10 \log \left[ \frac{\left( 10^{\frac{4.56}{20}} + 10^{\frac{4.32}{20}} + 10^{\frac{4.47}{20}} \right)^2}{3} \right] = \mathbf{9.22 \text{ dBi}} \end{aligned}$$


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