



RF EXPOSURE EVALUATION REPORT

For: Apple Inc.

Product: A1991

FCC ID: BCGA1991

RF Exposure Evaluation Report Serial No.:
UL/REGA1/MPE12718494B

**This RF Exposure Evaluation Report Is Issued Under The Authority
Of Alan Binks, Head of Inspection:**

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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_{SISO0} = 27.56dBm = 570.2 mW

EIRP_{SISO1} = 27.32dBm = 539.5 mW

EIRP_{SISO2} = 27.47dBm = 558.5 mW

Power_{max} for non BF 2x2 MIMO operation:

EIRP_{MIMO2} = 27.56dBm + 27.47dBm = 570.2mW + 558.5mW = 1.13W

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

EIRP_{BF2} = 23dBm + 7.53dBi = 30.53dBm = 1.13W

Power for non BF 3x3 MIMO operation:

EIRP_{MIMO3} = 27.56dBm + 27.32dBm + 27.47dBm = 570.2mW + 539.5mW + 558.5mW = 1.67W*

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

EIRP_{BF3} = 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_{SISO1} = 28.06dBm = 639.7 mW

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$EIRP_{SISO2} = 27.71\text{dBm} = 590.2\text{ mW}$

$EIRP_{SISO3} = 26.93\text{dBm} = 493.2\text{ mW}$

Power for non BF 2x2 MIMO operation:

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

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

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

Power for non BF 3x3 MIMO operation:

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

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

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

***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

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

MPE CALCULATIONS

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

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

Where $S = \text{Power density}$

$EIRP = \text{Effective Isotropic Radiated Power (EIRP} = P \times G)$

$P = \text{Conducted Transmitter Power}$

$G = \text{Antenna Gain (relative to an isotropic radiator)}$

$R = \text{distance to the centre of radiation of the antenna (20cm requirement).}$

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For WLAN 2.4GHz

Values:

Transmitter frequency range = 2412 MHz to 2472MHz

Max. EIRP_{SISO} = 570.2 mW

EIRP_{MIMO} = 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

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

Calculation:

$$S = EIRP_{SISO} / 4 \pi R^2$$

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

$$S = 570.2 / (5024)$$

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

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/cm²

For WLAN 5GHz

Values:

Transmitter frequency range = 5150 MHz to 5850MHz

Max. EIRP_{SISO} = 639.7mW

EIRP_{MIMO} = 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

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

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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/cm²

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/cm²

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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:

$$\begin{aligned} \text{ie: } \sum \text{MPE}_{\text{ratios}} &= (S_1 \text{ SISO} / S_{\text{req1}}) + (S_2 \text{ SISO} / S_{\text{req2}}) + (S_3 \text{ SISO} / S_{\text{req3}}) \\ &= (0.33/1.0) + (0.34/1.0) + (0.011/1.0) \\ &= \mathbf{0.68} \end{aligned}$$

Σ 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 =

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