



Maximum Permissible Exposure Study - Engineering Analysis

**ISR-AP1101AC-I-B (WLAN)
P-LTE-VZ (Cellular)
P-LTE-EA (Cellular)**

Inside of C1109-4PLTE2PWB host router

FCC ID: LDKC11011757

**700MHz-2700MHz (Cellular), 2400-2483.5 MHz, 5150-5250 MHz,
5250-5350 MHz, 5470-5725 MHz, 5725-5850 MHz**

**Against the following Specifications:
47 Code of Federal Regulations 2.1091**

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This report replaces any previously entered test report under EDCS – 13349131. This test report has been electronically authorized and archived using the CISCO Doc Central. Test Report Template EDCS# 11556830.

Attestation Statement of Compliance

The Cisco ISR-AP1101AC-I-B Wi-Fi module has been evaluated for Maximum Permissible Exposure in compliance with 47 Code of Federal Regulations [Part 1.1307(b) (for fixed devices), Part 2.1091 (for mobile devices), and Part 2.1093 (for portable devices)]. Part 1.1307(b) refers to limits in Part 1.1310 and 2.1093. The evaluation was in accordance with methodology as referenced in KDB 447498 D01 General RF Exposure Guidance v06. This report serves as the additional technical analysis of the Cisco radio modules.

This study addresses the following transmitters using the data derived in these test reports:

2.4GHz DTS report EDCS# 12316909
5GHz UNII-1 report EDCS# 12777514
5GHz UNII-2 report EDCS# 12857632
5GHz UNII-2ext reports EDCS# 12857638
5GHz UNII-3 report EDCS# 12857642
Cellular (info derived from the documents: AirPrime EM7455 Product Technical Specification & Customer Design Guidelines and Cisco LTE-ANTM-D antenna)
Cellular (info derived from the documents: AirPrime_WP76xx_Product_Technical_Specification_Rev6_2.pdf and Cisco LTE-ANTM-D antenna)

The limits used for this evaluation are in line with the recommendations of the World Health Organizations (WHO) International Committee on Non Ionizing Radiation Protection (ICNIRP) as well as the American National Standards Institute (ANSI) C95.1.

The limits chosen are of **General Population/Uncontrolled Exposure**.

The following case scenarios were used:

- **Cellular pluggable 1**
- **Cellular pluggable 2**
- **2.4GHz WLAN**
- **5GHz WLAN**

This device must be installed to provide a separation distance of at least 20 cm from all persons. Installers must be provided with antenna installation and transmitter operating conditions for satisfying RF exposure compliance.

Based on the study this case scenario, the General Population/Uncontrolled Exposure and the minimum recommended distance is around 20cm (8 inches) from the antenna.

1.0 EUT Description

The C1109 is an enterprise/MSP/M2M next generation router with the unified platform idea GE WAN, next generation Wave 2 802.11a/g/n/ac WLAN and LTE WWAN on Polaris IOS XE.

The ISR-AP1101AC-I-B supports the following radio modes:

802.11b - Legacy CCK, One Antenna, 1 to 11 Mbps

802.11b - Legacy CCK, Two Antennas, 1 to 11 Mbps

802.11g - Non HT20, One Antenna, 6 to 54 Mbps, 1ss

802.11g - Non HT20, Two Antennas, 6 to 54 Mbps, 1ss

802.11g - Non HT20 Beam Forming, Two Antennas, 6 to 54 Mbps, 1ss

802.11a - Non HT20, One Antenna, 6 to 54 Mbps, 1ss

802.11a - Non HT20, Two Antennas, 6 to 54 Mbps, 1ss

802.11a - Non HT20 Beam Forming, Two Antennas, 6 to 54 Mbps, 1ss

802.11n/ac - HT/VHT20, One Antenna, M0 to M7, 1ss

802.11n/ac - HT/VHT20, Two Antennas, M0 to M7, 1ss

802.11n/ac - HT/VHT20, Two Antennas, M8 to M15, 2ss

802.11n/ac - HT/VHT20 Beam Forming, Two Antennas, M0 to M7, 1ss

802.11n/ac - HT/VHT20 Beam Forming, Two Antennas, M8 to M15, 2ss

802.11n/ac - HT/VHT20 STBC, Two Antennas, M0 to M7, 2ss

802.11a - Non HT40, One Antenna, 6 to 54 Mbps, 1ss

802.11a - Non HT40, Two Antennas, 6 to 54 Mbps, 1ss

802.11n/ac - HT/VHT40, One Antenna, M0 to M7, 1ss

802.11n/ac - HT/VHT40, Two Antennas, M0 to M7, 1ss

802.11n/ac - HT/VHT40, Two Antennas, M8 to M15, 2ss

802.11n/ac - HT/VHT40 Beam Forming, Two Antennas, M0 to M7, 1ss

802.11n/ac - HT/VHT40 Beam Forming, Two Antennas, M8 to M15, 2ss

802.11n/ac - HT/VHT40 STBC, Two Antennas, M0 to M7, 2ss

802.11a - Non HT80, One Antenna, 6 to 54 Mbps, 1ss

802.11a - Non HT80, Two Antennas, 6 to 54 Mbps, 1ss

802.11n/ac - HT/VHT80, One Antenna, M0 to M7, 1ss

802.11n/ac - HT/VHT80, Two Antennas, M0 to M7, 1ss

802.11n/ac - HT/VHT80, Two Antennas, M8 to M15, 2ss

802.11n/ac - HT/VHT80 Beam Forming, Two Antennas, M0 to M7, 1ss

802.11n/ac - HT/VHT80 Beam Forming, Two Antennas, M8 to M15, 2ss

802.11n/ac - HT/VHT80 STBC, Two Antennas, M8 to M15, 2ss

EDCS – 13349131

The following antennas are supported by this product series.

The data included in this report represent the worst case data for all antennas.

Frequency	Part Number	Antenna Type	Antenna Gain (dBi)
2.4GHz / 5GHz	07-1147-01	Dipole	2.14 / 4
2.4GHz / 5GHz	07-100497-01	Ceiling Mount Omni Directional	2.14 / 4
2.4GHz / 5GHz	07-100496-01	Roof Mount	2.14 / 4
700MHz- 2700MHz	LTE-ANTM-D	Cisco 3G/4G LTE and LTEA Omnidirectional Dipole Antenna	3.7 (worst case for all supported bands)

2.0 Methodology

All calculations were made in accordance with ANSI C95.1.

Measurement Uncertainty Values

Parameter	Max MU from standard	Declared MU
Occupied Channel Bandwidth	+/- 5%	+/-2%
RF Output Power, conducted	+/- 1,5dB	+/-1.4dB
Power Spectral Density, conducted	+/- 3dB	+/- 2dB
Unwanted emissions, conducted	+/- 3dB	+/- 2dB
All emissions, radiated	+/- 6dB	+/- 3.2dB
Temperature	+/- 3C	+/- 0.7C
Supply Voltages	+/- 3%	+/- 2.5%
Time	+/- 5%	+/-2%

3.0 Technical Requirements

3.1 Single Band Operation – Limits

FCC Limits for Maximum Permissible Exposure (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm ²)	Averaging Time E ² , H ² or S (minutes)
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

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm ²)	Averaging Time E ² , H ² or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	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

NOTE 1: See Section 1 for discussion of exposure categories.

NOTE 2: The averaging time for General Population/Uncontrolled exposure to fixed transmitters is not applicable for mobile and portable transmitters. See 47 CFR §§2.1091 and 2.1093 on source-based time-averaging requirements for mobile and portable transmitters.

4.0 Calculations

Given

$$E = \sqrt{(30 \cdot P \cdot G)/d} \text{ and } S = E^2/3770$$

where

E=Field Strength in Volts/meter

P=Power in Watts

G=Numeric Antenna Gain

d=Distance in meters

S=Power Density in mW/cm²

Combine equations and rearrange the terms to express the distance as a function of the remaining variables:

$$d = \sqrt{((30 \cdot P \cdot G)/(3770 \cdot S))}$$

Changing to units of power in mW and distance in cm, using:

$$P(\text{mW}) = P(\text{W})/1000 \quad d(\text{cm}) = 100 \cdot d(\text{m})$$

yields

$$d = 100 \cdot \sqrt{((30 \cdot (P/1000) \cdot G)/(3770 \cdot S))}$$
$$d = 0.282 \cdot \sqrt{(P \cdot G/S)}$$

where

d=Distance in cm

P=Power in mW

G=Numeric Antenna Gain

S=Power Density in mW/cm²

Substituting the logarithmic form of power and gain using:

$$P(\text{mW}) = 10^{(P(\text{dBm})/10)} \quad G(\text{numeric}) = 10^{(G(\text{dBi})/10)}$$

yields

$$d = 0.282 \cdot 10^{((P+G)/20)} / \sqrt{S} \quad \text{Equation (1)}$$

and

$$s = ((0.282 \cdot 10^{((P+G)/20)})/d)^2 \quad \text{Equation (2)}$$

where

d=MPE distance in cm

P=Power in dBm

G=Antenna Gain in dBi

S=Power Density in mW/cm²

5.0 Results

Equation (1) and the measured peak power are used to calculate the MPE distance. Note that for mobile or fixed location transmitters such as an access point, the minimum separation distance is 20 cm even if the calculations indicate that the MPE distance may be less.

$S=1\text{mW/cm}^2$ maximum. Using the peak power levels recorded in the test report along with Equation 1 above, the MPE distances are calculated as follows.

MPE Calculations:

Frequency (MHz)	Power Density (mW/cm ²)	Radiated Transmit Power (dBm)	Antenna Gain (dBi)	MPE Distance (cm)	Limit (cm)	Margin (cm)
Cellular (698)	0.114	24	3.58	9.89	20	10.11
Cellular (777)	0.113	24	3.53	9.32	20	10.68
2.4GHz DTS	0.073	20.53	5.14*	5.42	20	14.58
UNII-1	0.075	18.77	7*	5.48	20	14.52
UNII-2A	0.077	18.87	7*	5.54	20	14.46
UNII-2C	0.081	19.12	7*	5.70	20	14.30
UNII-3	0.077	18.87	7*	5.54	20	14.46

*Correlated Gain

To maintain compliance, installations will assure a separation distance of at least 20 cm.

Using Equation 2, the MPE levels (s) at 20 cm are calculated as follows:

Frequency (MHz)	MPE Distance (cm)	Radiated Transmit Power (dBm)	Antenna Gain (dBi)	Power Density (mW/cm ²)	Limit (mW/cm ²)	Margin (mW/cm ²)
Cellular (698)	20	24	3.58	0.114	0.465	0.350
Cellular (777)	20	24	3.53	0.113	0.518	0.410
2.4GHz DTS	20	20.53	5.14*	0.073	1.0	0.927
UNII-1	20	18.77	7*	0.075	1.0	0.925
UNII-2A	20	18.87	7*	0.077	1.0	0.923
UNII-2C	20	19.12	7*	0.081	1.0	0.919
UNII-3	20	18.87	7*	0.077	1.0	0.923

* Correlated Gain

Calculations with additional transmitters

LTE (Highest Power)

LTE (Highest Power)

2.4GHz WLAN (Highest power)

5GHz WLAN (Highest power)

Total Power Densities (Percentages) = 2.4GHz Power Density % + 5GHz Power Density %
+ LTE1 Power Density % + LTE2 Power Density %

Total Relative Power Densities (Percentages) = $(0.073/1.0)*100 + (0.081/1.0)*100 + (0.114/0.465)*100 +$
 $(0.113/0.518)*100 = 7.3 \% + 8.1 \% + 24.5\% + 21.8\%$
= 61.7%

Distance (estimate) = $20 * \sqrt{0.617} = 20 * (0.617)^{0.5} = 15.71 \text{ cm}$

The calculated separation distance of 15.71 cm is less than the 20 cm recommended distance.

The configuration above co-location calculation is for **General Population/Uncontrolled exposure**. The minimum distance recommended is **20 cm (8 inches)** when all antennas are within 20 cm of each other.

References

American National Standards Institute (ANSI), "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992 (previously issued as IEEE C95.1-1991). Copyright 1992 by the Institute of Electrical and Electronics Engineers, Inc. (IEEE), New York, N.Y. 10017. For copies contact the IEEE: 1-800-678-4333 or 1-908-981-1393.

American National Standards Institute (ANSI), "Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave". ANSI/IEEE C95.3-1992. Copyright 1992, The Institute of Electrical and Electronics Engineers, Inc. (IEEE), New York, NY 10017. For copies contact the IEEE: 1-800-678-4333 or 1-908-981-1393.