Powering Connectivity

TN201SC - Human Exposure to RF EMF - FCC and ISED

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Version History

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1	DF	2022-03-14	Approved version

Related Documents

Ref.	Title	Number	Version & Date
[1]	TN201SC user guide (FCC/ISED compliant)	BW-009016-SD	March 2022
[2]	FCC - OET Bulletin 65	Edition 97-01	Aug 1997
[3]	FCC – Radio frequency radiation exposure limits	CFR Title 47 Part 1.1310	Feb 2022
[4]	Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)	RSS-102	Issue 5, March 2015
[5]	IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 300 GHz	IEEE Std C95.3	2021

Terms and Acronyms

Term / Acronym	*Definition*
BW	Bandwidth
EIRP	Effective Isotropic Radiated Power
EM	Electromagnetic
EMF	Electromagnetic Field
PAA	Phased-Array Antenna
mmWave	Millimetre-Wave
RF	Radio-Frequency
V2V	Vehicle-to-vehicle

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1. Overview

The TN201SC product delivers high bandwidth connectivity in two primary scenarios using mmWave technology in the 57-71 GHz radio band. The two scenarios are:

- For rail or transport use between a vehicle and static units, when combined with the trackside unit DN201SC. In this scenario, the TN201SC is part of the vehicle unit.
- For V2V scenarios, where TN201SC units are mounted on different vehicles.

The TN201SC comprises 2 major components, an antenna unit on the vehicle exterior and an NPU unit inside the vehicle, connected by a cable. The product as delivered consists of all 3 parts.

The TN201SC will be used in commercial and industrial applications, and may be installed and mounted on the rooftop of vehicles or other support structures. At all cases, the product will be out of reach to the general public.

The TN201SC product will be installed and maintained by professional operatives who are aware of the risks of Electromagnetic (EM) Fields, and an installation manual is supplied with instructions and safety notices.

The assessment takes into consideration all intended and foreseen operating conditions that were reasonably anticipated at the time of the assessment.

This document shows the calculations of the compliance distance for TN201SC product to meet the basic restrictions as defined in CFR Title 47 Part 1.1310 (referencing OET65 Edition 97-01) for FCC regulatory domain, and RSS-102 Issue 5 Sections 3 and 4 (referencing IEEE C95.3-2021 and Safety Code 6 – 2015, respectively) for ISED regulatory domain.

1.1 TN201SC equipment characteristics

Each TN201SC unit has:

- An antenna unit (TN201SP) which houses the modem and radios, and a NPU unit (TN001xC).
- The antenna unit has two integrated radios, each positioned in opposing sides of the product, and operating in the 60GHz band covering 57GHz – 71GHz (802.11ad channels 1 to 6), with a maximum of 2.16GHz channel BW.
- Each radio has one transmit phased-array antenna (PAA) and one receive PAA.
- The Tx PAA is a 16x4 array, made up of 16 Tx RF paths and 1x4 sub-arrays.
- The Rx PAA is a 16x4 array, made up of 16 Rx RF paths and 1x4 sub-arrays.
- Each radio has 13 levels of adaptive encoding, Modulation Coding Scheme (MCS) 0 to MCS12, as per 802.11ad.
- Multi-sector horizontal coverage of 180 degrees, with each beam having 7 degrees 3dB beamwidth, and 20 degrees vertical 3dB beamwidth (fixed coverage).

1.2 Maximum RF transmit output power

Each of the two radios on the TN201SC product have an electronically steerable beamforming PAA for transmission, with 23dBi of gain, resulting in the ability to achieve a maximum regulated transmitter power of 40dBm EIRP.

Transmitter power has been tested against CFR Title 47 Part 15.255 (Operation within the band 57-71 GHz), as well as RSS-210 Issue 10 Annex J (Devices operating in the band 57-71 GHz), with maximum transmitted power not exceeding 40dBm EIRP.

2. FCC regulatory domain – Electromagnetic fields exposure

The far field (spherical wave) calculation method, defined in OET65 (equation 6), was used to define the compliance boundary, using the maximum EIRP noted in section 1.2 of this document. This calculation yields a "truly worst-case" or conservative prediction of the near field (overestimation of the field strength), as well as accounting for 100% reflection on a nearby surface, as is referenced in OET65 (Section 2). Accounting for the nearby surface was deemed appropriate, given the likelihood of the product being mounted on the rooftop of vehicles, and those surfaces being of a metallic material or coating. Thus, the exposure at distances calculated below will be well within safe limits.

2.1 General Population/Uncontrolled Exposure

2.1.1 Compliance limits

The limit for general population/uncontrolled exposure according to CFR Title 47 Part 1.1310 (e)(1) (referencing OET65 Edition 97-01 Table 1B) is 1mW/cm^2 (10W/m^2).

2.1.2 Safe distance calculation

The two radios on the TN201SC unit are located in opposing sides of the chassis, the PAAs radiate towards distinct volumes, and the radiated signals are also uncorrelated. The maximum transmitted power level used in this calculation will be considered as that of a single radio, which is 40dBm (10W) EIRP.

Considering:

$S =$ power density (W/m^2) = 10W/m^2

$R =$ compliance boundary distance from the product (m)

$EIRP =$ effective isotropically radiated power (W) = 10W

With:

$$S = EIRP/(\pi R^2)$$

$$R = \sqrt{EIRP/(\pi S)}$$

Therefore:

$$R = \sqrt{10/(\pi \times 10)}$$

2.1.3 Required distance for general population exposure compliance

Product	*General population required distance*	*CFR Title 47 Part 1.1310 (e)(1) power density limit*
TN201SC	56.42cm	1mW/cm^2 (10W/m^2)

2.2 Occupational/Controlled exposure

2.2.1 Compliance limits

The TN201SC product will be installed and maintained by professional operatives who are aware of the risks of EM exposure. The limit for occupational/controlled exposure according to CFR Title 47 Part 1.1310 (e)(1) (referencing OET65 Edition 97-01 Table 1A) is 5mW/cm^2 (50W/m^2).

2.2.2 Safe distance calculation

The two radios on the TN201SC unit are located in opposing sides of the chassis, the PAAs radiate towards distinct volumes, and the radiated signals are also uncorrelated. The maximum transmitted power level used in this calculation will be considered as that of a single radio, which is 40dBm (10W) EIRP.

Considering:

$S =$ power density (W/m^2) = 50W/m^2

$R =$ compliance boundary distance from the product (m)

$EIRP =$ effective isotropically radiated power (W) = 10W

With:

$S = EIRP/(\pi R^2)$

$R = \sqrt{EIRP/(\pi S)}$

Therefore:

$R = \sqrt{10/(\pi \times 50)}$

2.2.3 Required distance for occupational exposure compliance

Product	*Workers required distance*	*CFR Title 47 Part 1.1310 (e)(1) power density limit*
TN201SC	25.23cm	5mW/cm^2 (50W/m^2)

3. ISED regulatory domain – Electromagnetic fields exposure

From RSS-102 Issue 5 Section 3, the RF exposure evaluations should be performed according to IEEE C95.3-2021. In accordance with IEEE C95.3-2021, section A.5.1, and assuming typical use cases for the TN201SC product (as previously described in this document), the source-environment plane regions considered for the compliance distance calculations may be $\mathrm{II}-0$, $\mathrm{II}-1$, $\mathrm{III}-0$ and $\mathrm{III}-1$. From Table D.1 in Annex D of the same document, it is determined the equations in Table D.2 and Table D.6 to be appropriate for the calculations, as it can be assumed worst-case scenario being exposed to EM fields along the main beam axis of the PAA radiating elements, as well as accounting for reflections in the surrounding environment. Additionally, the far field (spherical wave) calculation method used herein is considered to yield a conservative prediction of the near field (overestimation of the power density), as is indicated in section D.4.2 of IEEE C95.3-2021. Thus, the exposure at distances calculated below will be well within safe limits.

3.1 General Population/Uncontrolled Exposure

3.1.1 Compliance limits

The limit for general population/uncontrolled exposure according to RSS-102 Issue 5 Section 4 (referencing Safety Code 6 – 2015 Table 5) is 10W/m^2.

3.1.2 Safe distance calculation

The two radios on the TN201SC unit are located in opposing sides of the chassis, the PAAs radiate towards distinct volumes, and the radiated signals are also uncorrelated. The maximum transmitted power level used in this calculation will be considered as that of a single radio, which is 40dBm (10W) EIRP. For a theoretical worst case of a perfectly conducting ground plane, the reflection coefficient should be set to 1.

Considering:

S = power density including reflection (W/m^2) = 10W/m^2

S_d = power density of the direct ray (W/m^2)

$|\Gamma|$ = modulus of the absolute value of the reflection coefficient

S_{FF} = far-field power density (W/m^2)

$S_{FF} = S_d$

D = compliance distance from the product (m)

G_i = far-field antenna gain (power ratio)

P_{in} = power into the antenna (W)

$EIRP$ = effective isotropically radiated power (W)

Approximating:

$EIRP = G_i P_{in} = 10\text{W}$

With:

$S = (1 + |\Gamma|)^2 S_{FF}$

$S_{FF} = EIRP/(4\pi D^2)$

$D = \sqrt{EIRP/\left(4\pi(S/(1 + |\Gamma|)^2)\right)}$

Therefore:

$D = \sqrt{10/\left(4\pi \times (10/(1 + 1)^2)\right)}$

3.1.3 Required distance for general population exposure compliance

Product	*General population required distance*	*RSS-102 Issue 5 Section 4 power density limit*
TN201SC	56.42cm	10W/m^2

3.2 Occupational/Controlled exposure

3.2.1 Compliance limits

The TN201SC product will be installed and maintained by professional operatives who are aware of the risks of EM exposure. The limit for occupational/controlled exposure according to RSS-102 Issue 5 Section 4 (referencing Safety Code 6 – 2015 Table 6) is 50W/m^2.

3.2.2 Safe distance calculation

The two radios on the TN201SC unit are located in opposing sides of the chassis, the PAAs radiate towards distinct volumes, and the radiated signals are also uncorrelated. The maximum transmitted power level used in this calculation will be considered as that of a single radio, which is 40dBm (10W) EIRP. For a theoretical worst case of a perfectly conducting ground plane, the reflection coefficient should be set to 1.

Considering:

S = power density including reflection (W/m^2) = 50W/m^2

S_d = power density of the direct ray (W/m^2)

$|\Gamma|$ = modulus of the absolute value of the reflection coefficient

S_{FF} = far-field power density (W/m^2)

$S_{FF} = S_d$

D = compliance distance from the product (m)

G_i = far-field antenna gain (power ratio)

P_{in} = power into the antenna (W)

$EIRP$ = effective isotropically radiated power (W)

Approximating:

$EIRP = G_i P_{in} = 10\text{W}$

With:

$S = (1 + |\Gamma|)^2 S_{FF}$

$S_{FF} = EIRP/(4\pi D^2)$

$D = \sqrt{EIRP/\left(4\pi(S/(1 + |\Gamma|)^2)\right)}$

Therefore:

$D = \sqrt{10/\left(4\pi \times (50/(1 + 1)^2)\right)}$

3.2.3 Required distance for occupational exposure compliance

Product	*Workers required distance*	*RSS-102 Issue 5 Section 4 power density limit*
TN201SC	25.23cm	50W/m^2