Blu Wireless

Powering Connectivity

TN201SC - Human Exposure to RF EMF - FCC and ISED

Document Number: BW-008983-SD

Version Number: 2

Product Reference: TN201SC

Proprietary and Confidential

Blu Wireless Technology Limited.

One Castlepark, Tower Hill , Bristol BS2 0JA United Kingdom

www.bluwireless.com

Version History

Issue Number	Author(s)	Version Date	Summary & Comments
1	DF	2022-03-14	Approved version
2	DF	2023-04-06	Further description of equipment characteristics, and revision of exposure calculations

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

Contents

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 bandwidth.
- 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 PAA measures 37mm by 11mm.
- Each radio has 13 levels of adaptive encoding, Modulation Coding Scheme (MCS) 0 to MCS12, as per 802.11ad.
- Each radio has multi-sector horizontal coverage of 90 degrees, by means of 63 partially overlapping pencil beams, for a total coverage of 180 degrees when both radios are enabled. Each sector/beam has nominal 7 degrees 3dB horizontal beamwidth, and 20 degrees vertical 3dB beamwidth (fixed coverage).

The radio link between two mmWave TN201SC products is continuously and dynamically adjusting the sectors at each end of the link, with a periodicity in the order of milliseconds, such that it can achieve the best possible radio propagation channel characteristics.

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 up to 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 4), was used to define the compliance boundary, using the maximum EIRP noted in section 1.2 of this document. This calculation yields a generally accurate estimation in the far-field of the antenna, but will over-predict the power density in the near field (overestimation of the field strength) [2].

Considerations were given to the possibility of using equation 6 defined in OET65, which accounts for the potential doubling of predicted field strength, due to 100% reflection on rooftop scenarios or nearby reflectors. However, this possibility was discarded, as it would be overly pessimistic on multiple accounts:

- The dynamic behaviour of the wireless link described in the previous section, results in the inherent feature that any RF-opaque obstacle that presents itself in front of the radio link, will cause the system to steer away from it. Should the obstacle be sufficiently large, or close to the radio, preventing the radio link from being maintained, will result in a break of the wireless link. During re-association attempts, the transmission duty-cycle is significantly lower than that during typical operation, resulting in reduced exposure levels.
- The horizontal beamwidth of the PAA is very narrow, hence any obstacle that presents itself in the vicinity of the unit, but is not blocking the wireless link, will be exposed to a fraction of the power assumed in the below calculations.
- The vertical beamwidth of the PAA is substantially narrower to that of traditional antenna designs, and therefore, the power radiated towards surfaces parallel to the wireless link will be a fraction of that at the vertical-plane boresight.
- Should the RF-opaque obstacle be located sufficiently away from the radio, such that the wireless link does not steer away from it will, by definition, mean the exposure levels are also significantly lower than those in close proximity to the radio.
- The distances calculated in the following sub-sections are within the near-field region of the radio (see below), therefore, and as previously mentioned, should be considered a conservative estimation.

According to IEEE C95.3-2021 [5], the transition zone between near-field and far-field can be approximated by:

$$d = 2a^2/\lambda$$

Considering the largest dimension of the radio Tx PAA is 37mm, then:

$$a = 37mm$$

Therefore, the near-field to far-field transition at 57 and 71 GHz are approximately, 52 and 64.8 cm respectively.

Based on the above justifications, it can be considered that the distances calculated below are conservative, and the exposure levels will be 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. Therefore, 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:

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

$$R = \sqrt{EIRP/(4\pi S)}$$

Therefore:

$$R = \sqrt{10/(4\pi \times 10)}$$

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	28.21cm	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. Therefore, 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:

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

$R = \sqrt{EIRP/(4\pi S)}$

Therefore:

$R = \sqrt{10/(4\pi \times 50)}$

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	12.62cm	$5mW/cm^2$ ($50W/m^2$)

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 are II – 0, III – 0 and, to some extent, II – 1 and III – 1. From Table D.1 in Annex D of the same document, it is determined the equation in Table D.2 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, but not accounting for reflections in the surrounding environment. The reasoning for discarding the usage of source-environment II – 1 and III – 1 and, therefore, Table D.6, in the calculations of exposure has been presented in section 2, but is repeated for convenience:

- The dynamic behaviour of the wireless link described in the previous section, results in the inherent feature that any RF-opaque obstacle that presents itself in front of the radio link, will cause the system to steer away from it. Should the obstacle be sufficiently large, or close to the radio, preventing the radio link from being maintained, will result in a break of the wireless link. During re-association attempts, the transmission duty-cycle is significantly lower than that during typical operation, resulting in reduced exposure levels.
- The horizontal beamwidth of the PAA is very narrow, hence any obstacle that presents itself in the vicinity of the unit, but is not blocking the wireless link, will be exposed to a fraction of the power assumed in the below calculations.
- The vertical beamwidth of the PAA is substantially narrower to that of traditional antenna designs, and therefore, the power radiated towards surfaces parallel to the wireless link will be a fraction of that at the vertical-plane boresight.
- Should the RF-opaque obstacle be located sufficiently away from the radio, such that the wireless link does not steer away from it will, by definition, mean the exposure levels are also significantly lower than those in close proximity to the radio.
- The far field (spherical wave) 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. Considering the distances calculated in the following sub-sections are within the near-field region of the radio (see below), these should therefore be considered a conservative estimation.

According to IEEE C95.3-2021 [5], the transition zone between near-field and far-field can be approximated by:

$d = 2a^2/\lambda$

Considering the largest dimension of the radio Tx PAA is 37mm, then:

$a = 37mm$

Therefore, the near-field to far-field transition at 57 and 71 GHz are approximately, 52 and 64.8 cm respectively. Thus, it can be considered that the distances calculated below result in exposure levels that will be 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. Therefore, 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 including reflection (W/m^2) = 10W/m^2

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

$S_{FF} = S$

$D =$ 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:

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

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

Therefore:

$D = \sqrt{10/(4\pi \times 10)}$

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	28.21cm	$10W/m^2$

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. Therefore, 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 including reflection (W/m^2) = $50W/m^2$

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

$S_{FF} = S$

$D =$ 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:

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

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

Therefore:

$D = \sqrt{10/(4\pi \times 50)}$

3.2.3 Required distance for occupational exposure compliance

Product	***Workers required distance***	***RSS-102 Issue 5 Section 4 power density limit***
TN201SC	12.62cm	50W/m^2