

# **Tag Design with swarm bee LE**

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Chirp it.

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## 1. Introduction

The *swarm bee* CSS radio module is a fully integrated wireless node. The module works both in applications with collaborative location technology based on TOF (ranging) and fixed location technology based on TDOA (time difference of arrival) and supports concurrent communication. This application note describes the necessary steps to create tag designs utilizing the *swarm bee* LE module. It explains how to utilize nanotron's new *swarm bee* radio module to build smart tags with host controller and basic tags without host controller. Circuit diagrams for both architectures are shown and could easily be replicated by the user for rapid prototyping and quick time to market. Design recommendations are provided with regards to antenna design, power management and mechanical design. Calculation examples help to estimate battery life depending on application specific parameters like the location blink rate.

## 2. Tag Building Blocks

A *swarm bee* tag, as shown in Figure 2-1, mainly comprises the following blocks: antenna, transceiver, optional host, power supply and housing.

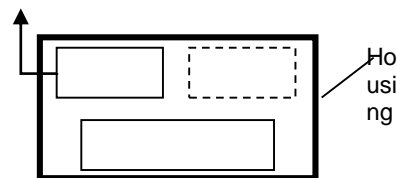


Figure 2-1 general building blocks of a *swarm bee* tag

### 2.1. Antenna

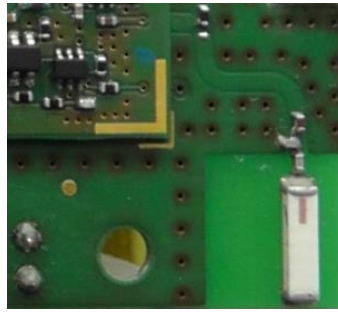
The *swarm bee* RF interface is a standard 50 Ohm RF-port which requires a 50 Ohm load for optimal RF performance. It is possible to connect antennas via RF connectors like U.FL as well as printed PCB antennas or chip antennas. The RF port is DC-decoupled.

#### 2.1.1. Chip Antenna

A chip antenna needs to create a 50 Ohm load impedance. The matching networks can be usually found in the data sheet of the chip antenna.

The design of the matching network mostly depends on the used carrier material of the PCB. It is recommended to measure the related parameters in a RF-Lab to get an optimized design result. The leading line to the antenna must have a 50 Ohm impedance.

There are a lot of manufacturers who can provide 2.4 GHz chip antenna, for example Antenova, Murata, Taiyo Yuden, TDK, Yageo, Johanson, etc. Figure 2-2 shows a chip antenna from Johanson, type 2450AT43A100.



**Figure 2-2 antenna on a two-layer PCB**

### 2.1.2. U.FL Standard Connector

Alternatively, an external antenna can be chosen for the *swarm bee* tag. It can be connected to *swarm bee* LE module through a 2.4 GHz RF-connector on the carrier board of the module. A widely used connector of this kind is a U.FL-R-SMT connector, for example from the company Hirose, see Figure 2-3. A proper RF-cable must be chosen to connect an antenna via U.FL connector.

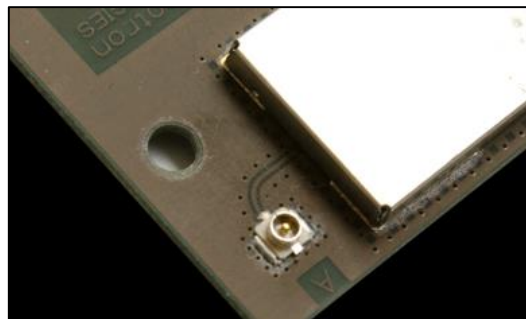


**Figure 2-3 U.FL-R-SMT connector for an external antenna**

Pay attention to the following during the use of U.FL connectors:

- The leading line from *swarm bee* LE module to U.FL connector must be as short as possible;
- The leading line must have a 50 Ohm impedance;
- The leading line must be embedded in GROUND;
- No signal lines shall run in the PCB layer directly under the connector;
- Adjacent ground planes in different PCB layers must be connected with as many vias as possible;
- The ground frames surrounding the U.FL connector must be at least 5 mm away from the via lines. The area of the layer directly under the U.FL connector must be designed as GROUND.

Figure 2-4 shows a U.FL connector with a curved leading line on a PCB.



**Figure 2-4 U.FL connector on a PCB**

## 2.2. Transceiver

In each *swarm bee* LE module, the key block of a *swarm bee* tag, there is a nanoLOC TRX transceiver chip based on nanotron's CSS (Chirp Spread Spectrum) technology. The nanoLOC integrated circuit operates in the freely accessible 2.4 GHz ISM band.

Please refer to [1] for more information about the nanoLOC transceiver.

## 2.3. Optional Host

The *swarm bee* LE module supports a number of basic tag functionalities like periodical transmission of a location broadcast. To utilize the basic tag functionality the module can be operated in stand-alone mode, as shown in figure 3-1. If extended tag functionality is required, *swarm bee* LE should be used in conjunction with a host microcontroller. Using a microcontroller also provides more flexibility to configuring the tag for different modes of operation. In most cases, the performance of a small low-power 8-bit controller will be sufficient. The configuration as a tag with or without controller is done by pulling pin 4 of *swarm bee* LE to ground or leaving it open (open is equal to pushing pin 4 to high) respectively. Please refer to figure 3-2.

### 2.3.1. Basic Tag Functionality

Tags based on a stand-alone *swarm bee* LE module are suitable for collaborative and fixed location applications. They are able to transmit location broadcasts and respond to ranging requests. Most recent readings from the on-board MEMs and temperature sensors are transmitted in each of the location broadcasts as payload. Please refer to [3] for a complete list of pre-set parameters. The tag can be powered down periodically by pulling MOD\_EN low (figure 3-1).

### 2.3.2. Extended Tag Functionality with a Host Microcontroller

Together with a host microcontroller the *swarm bee* LE module offers several location, communication and configuration options beyond the basic tag functionality. In this configuration a tag user interface – for instance a buzzer and/or push buttons – can be implemented.

## 2.4. Power Supply

*swarm bee* LE supports the supply voltage range between 3.0 V and 5.5 V. Direct supply from primary or rechargeable batteries is possible as well as external supply from a USB source.

### 2.4.1. Logic Levels

Regardless of the power supply voltages of *swarm bee* LE and host, the digital signal levels from host and module are subject to the following restrictions (relative to the *swarm bee* LE module):

- VIL (input voltage low): max. 0.7 V
- VIH (input voltage high): max. 2.8 V
- VOL (output voltage low): max. 0.45 V
- VOH (output voltage high): min. 2.15 V
- FT Input (five- volt tolerant input): max. 5.5 V

For pin configuration and supply voltage range of *swarm bee* LE please refer to [2]. If host and module work from different supplies level shifters might be necessary.

## 2.5. Housing

The *swarm bee* LE module together with an optional host is usually mounted onto a carrier board, which (including or excluding power supply) is then put into a housing to build a tag. Operating conditions such as temperature, humidity etc. must be taken into consideration to choose the right material of the housing.

## 3. Utilizing *swarm bee* as a Tag

According to requirements of an application, a *swarm bee* tag can be designed as a tag without host controller or as a smart tag with an external host controller.

### 3.1. Tag without Host Controller

Figure 3-1 shows a possible configuration of *swarm bee* tag for stand-alone operation with a (chip) antenna. When an external host is connected, i.e. for debugging purpose, the same signal level restrictions are valid as for Tag configuration with internal host.

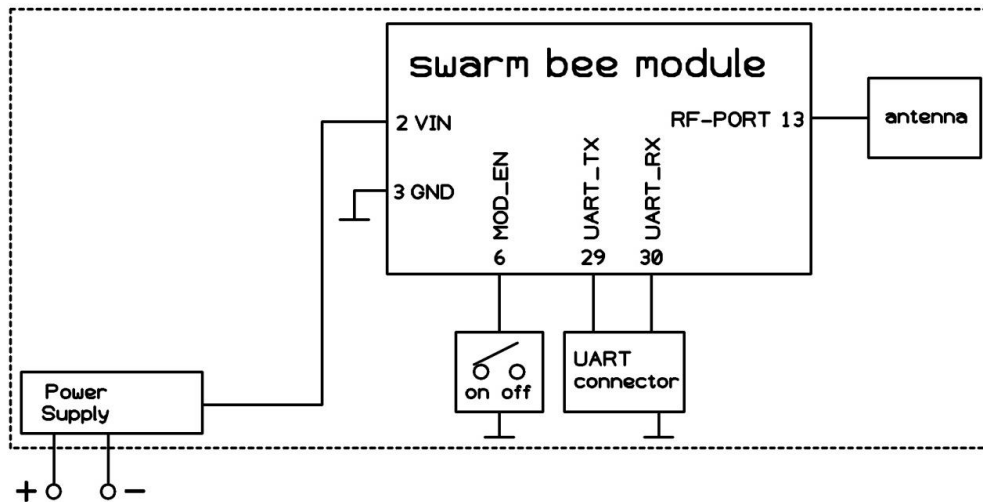


Figure 3-1 autonomous tag without host controller

### 3.2. Tag with Host Controller

Figure 3-2 shows a possible configuration of *swarm bee* as a tag with host. The power supply voltage range for *swarm bee* must be within 3 V ... 5.5 V. The host may have the same or a different power supply voltage. Important are the correct levels of digital signals between *swarm bee* and the host.

By pulling pin 6 (MOD\_EN) to logical LOW, the *swarm bee* LE module can be completely disabled. In this case, the module draw a current of less than 1uA. The *swarm bee* LE module can be enabled by leaving pin 6 open or setting it to HIGH with a level from 1.5 V to VDD of *swarm bee*.

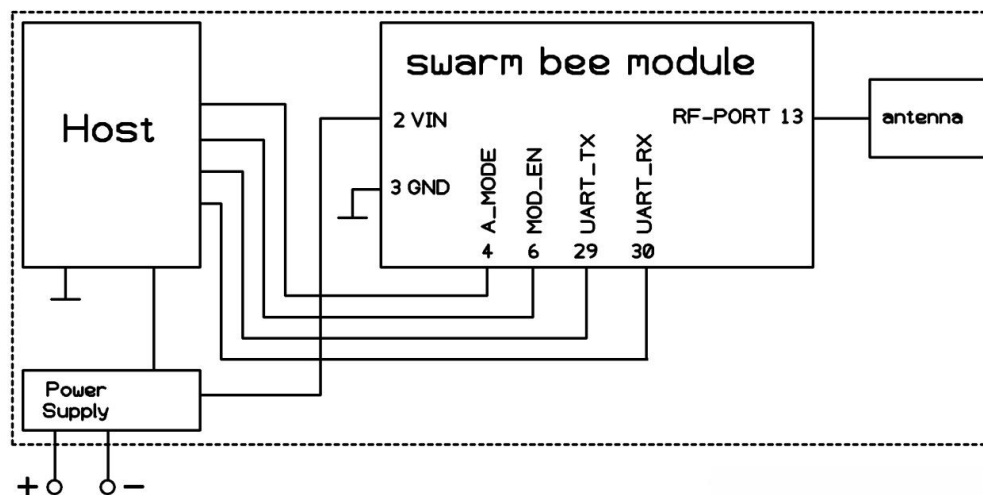


Figure 3-2 tag with host controller

## 4. Power Management

The *swarm bee* LE module could go to sleep and only wake up periodically for short periods of time in order to save battery power. The underlying power management concept enables cooperation between the radios of a larger *swarm* even if they sleep most of the time.

## 4.1. Power-saving Modes

Sleep modes or power-saving modes are specified in *swarm* API by the parameter TYPE in command group "SPSA (SetPowerSavingMode)".

**TYPE = 0 Power saving off, device is continuously receiving;**

**TYPE = 1 Power saving on, device makes full use of power saving features, receiver not continuously active;**

**TYPE = 2 Power saving on, wake up on interrupt.**

According to requirements of the application, the user can choose proper power-saving modes for the tag and configure it through *swarm* API commands. For a detailed description of the commands, please refer to [3].

## 4.2. Calculating Power Dissipation

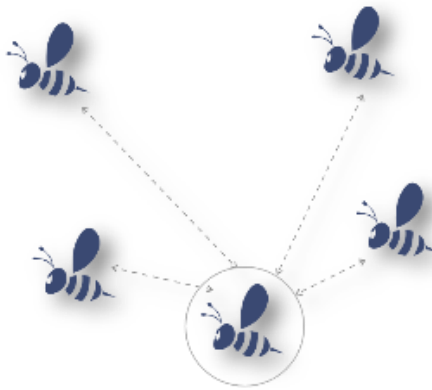
Power dissipation depends on the tag design, the use of power saving modes, the location update rate and the location method adopted. Power dissipation varies for different application scenarios.

## 4.3. Battery Lifetime

The battery lifetime of a stand-alone tag can be calculated when power dissipation is known and the battery capacity is given. In the following a sample calculation is shown for typical location sequences.

### 4.3.1. Collaborative Location (Ranging)

*swarm bee* tags can be used for collaborative location (shown in figure 4-1) where one moving tag ranges with one or more other moving or fixed tags in its neighbourhood. Local anchors which have received ranging results forward them to the location server which calculates the accurate location of the tag.



**Figure 4-1 collaborative location of *swarm bee* tags**

When a *swarm bee* tag only ranges to one other tag, the energy consumption for a ranging cycle has been measured as about 1200  $\mu$ As, when the board is working in 80MHz. If the ranging interval is 10 s, the battery capacity 1200 mAh and the battery efficiency 90%, the approximate battery lifetime  $T_1$  can be calculated as follows:

$$T_1 = \frac{1200 \text{ mAh} * 90 \%}{1200 \mu\text{As} / 10 \text{ s}} = 9000 \text{ h}$$

When a *swarm bee* tag ranges to more than one tags, the energy consumption for a ranging cycle would be increased by about 300  $\mu$ As per tag. If the other paramters are not changed, the approximate battery lifetime  $T_2$  for ranging to two tags can be calculated as follows:

$$T_2 = \frac{1200 \text{ mAh} * 90 \%}{(1200 + 300) \mu\text{As} / 10 \text{ s}} = 7200 \text{ h}$$



Similarly, the approximate battery lifetime  $T_3$  for ranging to three tags can be calculated as follows:

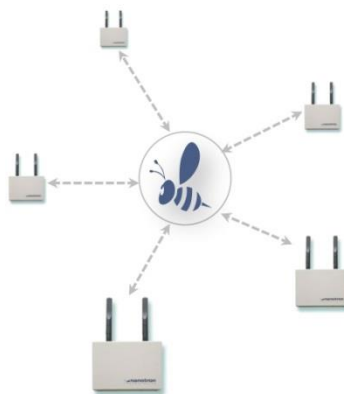
$$T_3 = \frac{1200 \text{ mAh} * 90 \%}{(1200 + 300 * 2) \mu\text{As} / 10 \text{ s}} = 6000 \text{ h}$$

Ranging with just one tag provides proximity information only, ranging values from two tags can be used to determine lateral location information and ranging with three reference tags allows to calculate a 2D location value.

Note: To simplify the approximate calculation, the power down dissipation has been neglected. For an accurate calculation of the battery lifetime, this parameter must be considered. Specifically for long ranging intervals this component might even dominate.

#### 4.3.2. Fixed Location (TDOA)

*swarm bee* tags can be used for fixed location as well, see figure 4-2. During fixed location, a moving tag sends out its node ID blink regularly. Anchors on fixed points receive the blinks and forward them to the location server which calculates the location of the tag based on TDOA (time difference of arrival).



**Figure 4-2 fixed location of a *swarm bee* tag**

For this application the power consumption of a tag mostly depends on the blink interval and it is much lower than in collaborative location. The measured value for each blink is about 900  $\mu\text{As}$ . If the blink interval is 1 s, the battery capacity 1200 mAh and the battery efficiency 90%, the approximate battery lifetime  $T_4$  can be calculated as follows:

$$T_4 = \frac{1200 \text{ mAh} * 90 \%}{900 \mu\text{As} / 1 \text{ s}} = 1200 \text{ h}$$

Note: To simplify the approximate calculation, the power down dissipation has been neglected. For an accurate calculation of the battery lifetime, this parameter must be considered. It dominates for long phases of sleep between blinks.

#### 4.3.3. Combined Location Modes

Depending on requirements of an application, *swarm bee* tags may be used for combined location modes, i.e. in areas where relative location information is needed between radio nodes, a tag must range with other tags in order to avoid collisions or dangers. In other areas, a tag may just need to send its own node ID blink so that the server can detect the position of this tag. In this case, the battery lifetime of a tag can be calculated combining parameters for both collaborative and fixed location.

## 5. Module Dimension & Soldering Information

### 5.1. Module Dimension

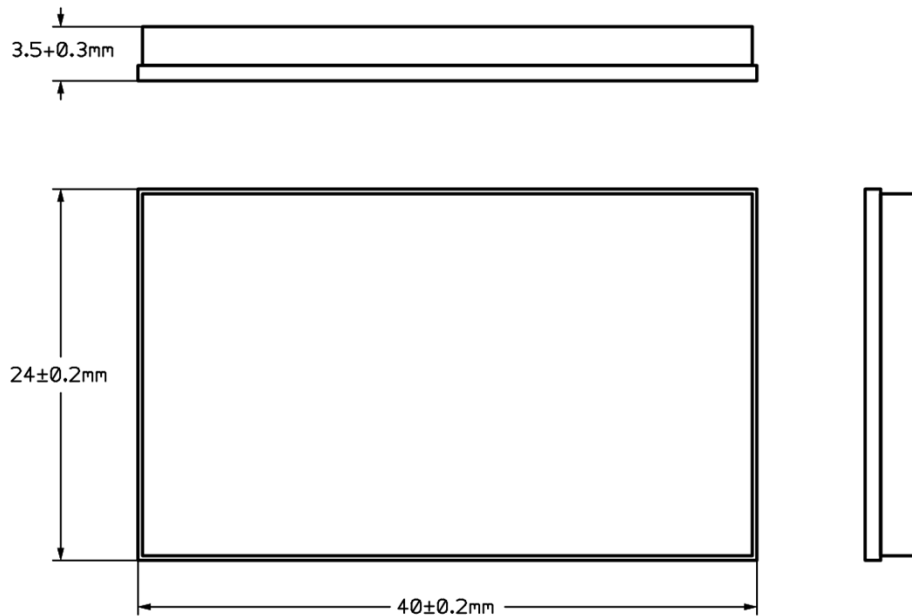


Figure 5-1 *swarm bee* LE module, dimensions

### 5.2. Footprint

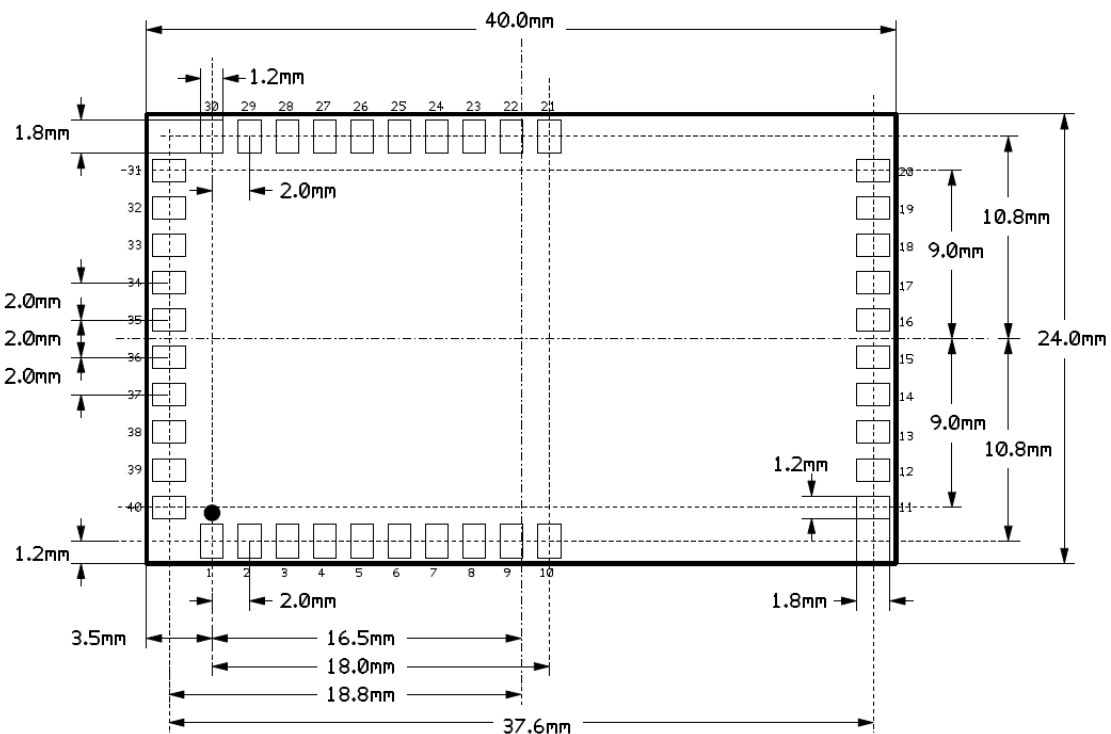


Figure 5-2 *swarm bee* LE module, footprint

### 5.3. Recommended Landing Pattern

The same dimensions for the solder paste screen are recommended, depending on the solder screen thickness.

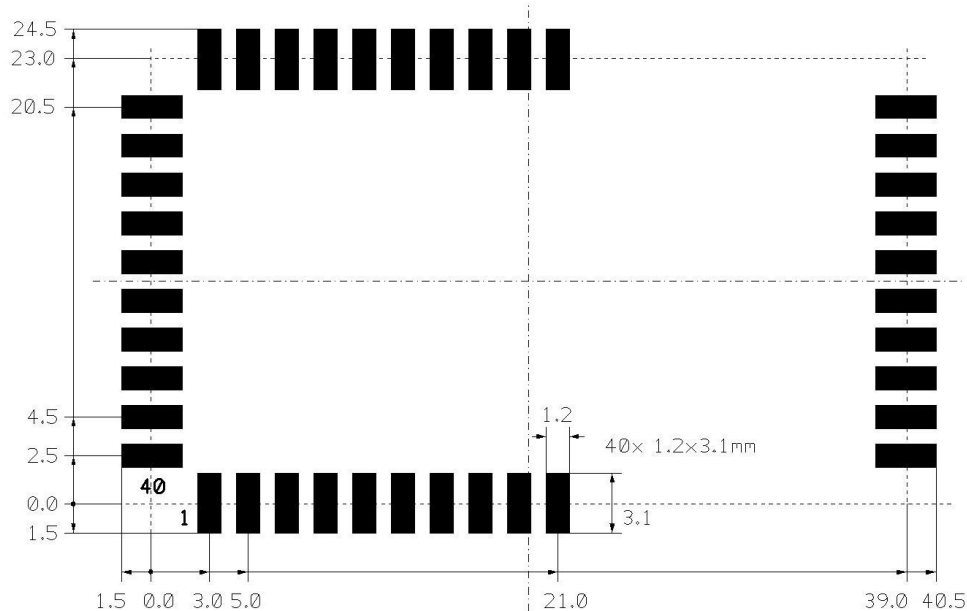


Figure 5-3 *swarm bee* LE module – footprint and landing pattern (top view)

### 5.4. Soldering Information

For lead-free reflow soldering, the follows conditions are recommended:

- max. Solder Peak Temperature: 200°C
- Solder Paste: for example ALPHA® CVP-520

## 6. Firmware Updates

The *swarm bee* LE module is delivered with the latest firmware. An update of the firmware is possible through the host interface, see [4] for more information.

## 7. References

- [1] nanoLOC Data Sheet, V2.01 as of 23.04.2008, Doc ID: NA-06-0230-0388-2.01
- [2] *swarm bee* Data Sheet, V1.0 (Preliminary) as of 27.02.2014 , Doc ID: NA-14-0267-0002-1.0
- [3] *swarm* API, V2.02 as of 18.03.2014, Doc ID: NA-13-0267-0003-2.02
- [4] *swarm bee* Firmware Update User Guide, V1.0 as of 01.07.2014, Doc ID: NA-14-0267-0011-1.0

End of Document

**Application Note**Tag Design with *swarm bee* LE

Version: AN0504 Author: Nanotron Technologies

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Date	Authors	Version	Description
30.09.2014	Nanotron Technologies GmbH	1.0	Application note on how to use swarm as a tag in a real time location system

## Application Note

Tag *Design* with swarm bee LE

Version: AN0504 Author: Nanotron Technologies



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**CAUTION - Electrostatic Sensitive Device!** Precaution should be used when handling the device in order to prevent permanent damage.

## FCC User Information

### *Statement according to FCC part 15.19:*

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

### *Statement according to FCC part 15.21:*

Modifications not expressly approved by this company could void the user's authority to operate the equipment.

### *RF exposure:*

The internal / external antennas used for this mobile transmitter must provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

### *Statement according to FCC part 15.105:*

This equipment has been tested and found to comply with the limits for a Class A and Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a resi-

dential installation and against harmful interference when the equipment is operated in a commercial environment.

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions as provided in the user manual, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his or her own expense.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures: (1) reorient or relocate the receiving antenna, (2) increase the separation between the equipment and receiver, (3) connect the equipment into an outlet on a circuit different from that to the connected equipment, and (4) consult the dealer or an experienced technician for help.

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Nanotron provides reliable loss protection technology and solutions that are used to protect people and animals. Energy efficient, battery-powered wireless nodes are the key building blocks. These small devices create a Virtual Safety Zone which protects tagged people and animals. Robust wireless Chirp technology underpins nanotron's offering of chips, modules and loss protection software for indoor and outdoor environments world wide.

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