

EnOcean Multisensor For IoT Applications

STM 550 / EMSI

24.06.2021



Observe precautions! Electrostatic sensitive devices!

Patent protected:

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STM 550 / EMSI – ENOCEAN MULTISENSOR FOR IOT APPLICATIONS

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1 General description

This user manual describes the functionality of the STM 550 EnOcean multisensor module, of the STM 550 Installation Kit and the EMSI Easyfit Multisensor in the following frequency variants:

- STM 550, STM 550 KIT and EMSIA using 868.3 MHz radio (main market Europe)
- STM 550U, STM 550U KIT and EMSIU using 902.875 MHz radio (main market US)
- STM 550J, STM 550J KIT and EMSIJ using 928.35 MHz radio (main market Japan)

The term “STM 550” is used throughout this user manual to describe all variants unless otherwise noted.

1.1 Basic functionality

STM 550 is a flexible self-powered multisensor module family capable of measuring temperature, humidity, illumination, magnet contact status and acceleration. It enables the realization of energy harvesting wireless sensors for light, building or industrial control systems communicating using the EnOcean radio standard.

STM 550 uses the same mechanical form factor as the industry standard PTM 21x modules from EnOcean.

STM 550 integrates the following sensors:

- Temperature
- Humidity
- Illumination
- Acceleration
- Magnet contact

STM 550 will report periodically (by default approximately every 60 seconds, configurable via NFC) the latest measurements of these sensors. In addition, STM 550 can also report its internal energy level and the amount of light available at the solar cell.

STM 550 will report immediately if the status (open / closed) of the magnet contact changes or if a change in acceleration measured by the acceleration sensor exceeds a user-defined threshold for the first time.

Radio telegrams transmitted by STM 550 can be encrypted and authenticated using AES-128 security based on a device-unique private key and a sequence counter in accordance to the EnOcean Alliance Security Specification. This ensures integrity, confidentiality and authenticity of the transmitted telegrams and prevents telegram replay (retransmission of previously transmitted telegrams).

STM 550 is self-supplied via an integrated solar cell which generates the energy required for its operation. For cases where ambient light is not sufficiently available, STM 550 provides the option to mount a CR1632 backup battery.

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1.2 Product variants

STM 550 is available in three different product and packaging variants:

- STM 550 is the multisensor module in original PTM module form factor intended for integration into OEM housings. It is provided in tray and box packaging of 100 units per box.
- STM 550 Installation Kit combines the STM 550 multisensor module with a wall mount, a design frame, a magnet (for magnet sensor functionality) and an adhesive mounting tape into a ready to use product. It is provided in tray and box packing of 100 units per box.
- EMSI Easyfit Multisensor contains the same components as STM 550 Installation Kit but is provided in single unit packaging with 10 single packaged units per box.

Figure 1 Figure 1 below shows the STM 550 module on the left and the finished product EMSI combining the STM 550 module with wall mount and design frame on the right.



Figure 1 – STM 550 module (left) and EMSI finished product (right)

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1.3 Technical data

Antenna	Integrated helix antenna
Transmission frequency / power	STM 550: 868.300 MHz / +5 dBm ⁽³⁾ STM 550U: 902.875 MHz / + 99 dBμV STM 550J: 928.350 MHz / 0 dBm
Transmission data rate	125 kbit/s
Communication range (for guidance only)	200 m free field 30 m indoor environment
Temperature measurement range / accuracy	-20 °C ... +60 °C / +- 0.3 K ⁽¹⁾
Humidity measurement range / accuracy	0 ... 100 % r.h. / +- 3% r.h. ⁽¹⁾
Illumination measurement range	0 ... 65000 lux
Acceleration measurement range	+ - 2 g (default, configurable via NFC)
Acceleration threshold for immediate report	0.03 g (default, configurable via NFC)
Update rate (excl. random offset)	Every 60 seconds (configurable via NFC)
Device configuration	LRN button and NFC interface
User notification	LED (red)
Supported EEP (selectable via NFC)	D2-14-41 (default) D2-14-40, A5-02-05, A5-04-01, A5-04-03 A5-06-02, A5-06-03, A5-14-05, D5-00-01
Power supply	Integrated solar cell
Minimum light level for self-supplied operation	200 lux for 6 hours per day ⁽²⁾
Operating time in darkness	4 days (after full charge)
Backup power supply (optional)	CR1632
Operation time with backup battery	Renata CR1632 (137 mAh)
Infrequent bright light (200 lux for 2 hrs per day)	7 years
Consistent low light (50 lux for 6 hrs per day)	6 years
Total Darkness	4.5 years
Dimensions (Module)	40 mm x 40 mm x 13 mm
Dimensions (Finished product)	49 mm x 49 mm x 13 mm

Note 1: STM 550 is designed for indoor use only and should only be used in the environmental conditions specified below

Note 2: Minimum light level required for self-supplied operation with the default product configuration. See chapter 3.2 for other scenarios

Note 3: Transmission power has been increased to +10 dBm starting with STM 550 product revision DB-06

1.4 Environmental conditions

Operating Temperature	-5 °C ... +45 °C (indoor use in dry rooms only)
Humidity	0% to 90% r.h. (non-condensing)

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1.5 Packaging information

1.5.1 STM 550

STM 550 is delivered in a box of 100 units packed onto 10 trays of 10 units each.

Packaging Unit	100 units
Packaging Method	10 modules per tray, 10 trays per box
Tray Dimensions	205 mm x 166 mm x 20 mm
Box Dimensions	205 mm x 176 mm x 174 mm

1.5.2 STM 550 installation kit

The STM 550 installation kit consists of one box with 100 units STM 550 modules (as described above) together with one box of 100 units of installation material.

Packaging Unit	100 units
Packaging Method	1 large outer box containing 2 smaller inner boxes Inner box 1: 100 units STM 550B (same as above) Inner box 2: 100 units installation material
Outer Box Dimensions	360 mm x 234 mm x 178 mm
Inner Box Dimensions	232 mm x 176 mm x 174 mm

1.5.3 EMSI

EMSI consists of one box with 10 single unit packages where each package contains one STM 550 module together with the installation material.

Packaging Unit	Individual unit packaging
Individual Unit Dimensions	75 mm x 75 mm x 28 mm
Packaging Method	10 individual unit packages within one box
Box Dimensions	300 mm x 90 mm x 90 mm

1.6 Ordering information

Product	Type	Ordering Code	Frequency
STM 550	Module only 100 unit packaging	S6201-K516	868.300 MHz
STM 550U		S6251-K516	902.875 MHz
STM 550J		S6261-K516	928.350 MHz
STM 550 KIT	Module with installation material 100 unit packaging	B6201-K516	868.300 MHz
STM 550U KIT		B6251-K516	902.875 MHz
STM 550J KIT		B6261-K516	928.350 MHz
EMSI	Module with installation material Single unit packaging	E6201-K516	868.300 MHz
EMSIU		E6251-K516	902.875 MHz
EMSIJ		E6261-K516	928.350 MHz

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2 Functional overview

2.1 Product overview

The energy-harvesting multisensor module STM 550 provides wireless sensing functionality without batteries.

STM 550 operates fully self-powered (no batteries required) when sufficient available ambient light (200 Lux for 6 hours per day) is available. The required energy for operation is harvested by an integrated solar cell. In this configuration, STM 550 operates fully maintenance-free.

For cases where sufficient ambient light is not available there is the option to mount a CR1632 backup battery.

STM 550 integrates high performance sensors to measure temperature, humidity, ambient light level, magnet contact status and acceleration. STM 550 periodically reports the status of these sensors using radio telegrams according to EnOcean Alliance radio specification.

Radio telegrams transmitted by STM 550 can be authenticated and encrypted using AES-128 security based on a device-unique private key and a sequence counter in accordance to the EnOcean Alliance Security Specification.

The user interface of STM 550 consists of one button for simple configuration tasks and one LED to provide user feedback. Configuration of STM 550 parameters is also possible via an integrated NFC (ISO 14443) interface.

2.2 Product interface

The STM 550 product interface consists of the following elements:

- LRN button and LED
- Solar cell harvesting energy from ambient light
- Ambient light sensor (co-located with the LED)
- Magnet contact sensor
- Ventilation slots to ensure airflow to the temperature and humidity sensor
- Backup battery slot for a CR1632 battery
- Backup battery ejector slot (on the back side)
- Product label (on the back side)

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2.2.1 Front side (STM 550)

Figure 2 below shows the external interfaces on the front side of the STM 550 module.

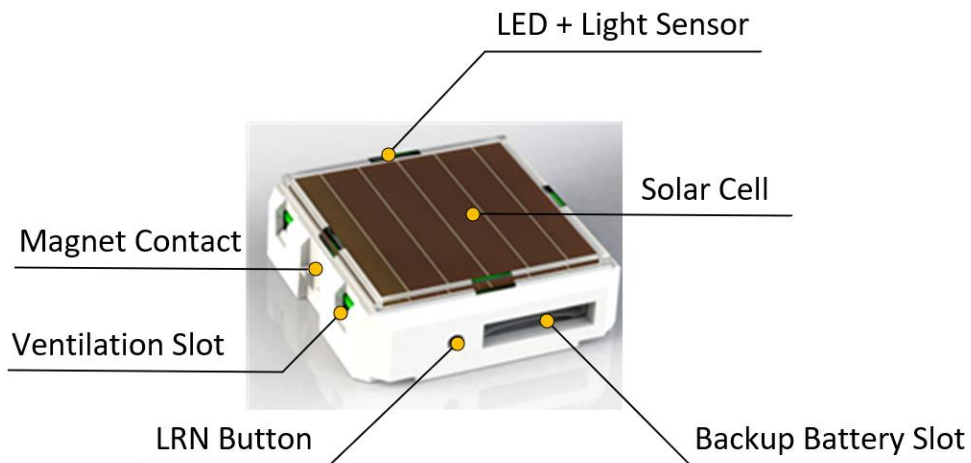


Figure 2 – STM 550 product interface (front side)

2.2.2 Front side (EMSI)

Figure 4 below shows the external interfaces on the front side of the EMSI product.

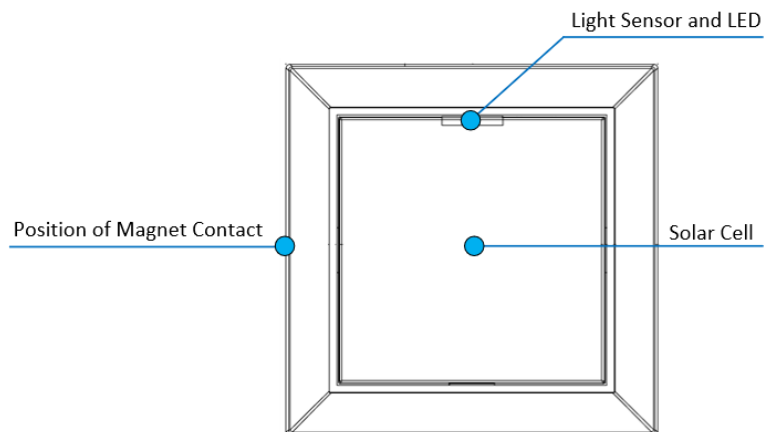


Figure 3 – EMSI product interface (front side)

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2.2.3 Back side (STM 550)

Figure 4 below shows the external interfaces on the back side of the STM 550 module. The orientation indicator points towards the side where the magnet contact is located.

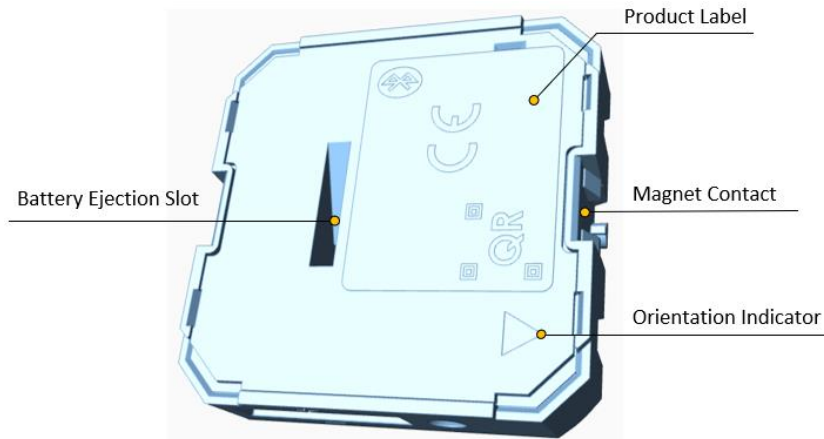


Figure 4 – STM 550 product interface (back side)

2.2.4 Back side (EMSI)

Figure 5 below shows the external interfaces on the back side of the EMSI finished product. The orientation indicator points towards the side where the magnet contact is located. The ventilation slots ensure air flow towards the temperature and humidity sensor and should not be obstructed.

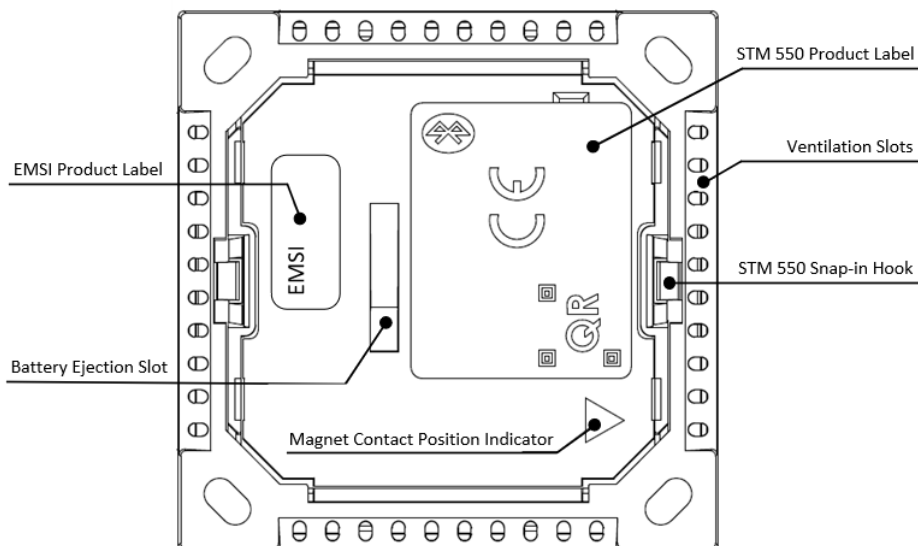


Figure 5 – EMSI product interface (back side)

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2.3 Functional modes

STM 550 supports seven functional modes:

- Standard operation mode
- Standby (Sleep) mode
- Learn mode
- Function test mode
- Illumination test mode
- Acceleration test mode
- Factory reset mode



Factory-new (out of the box) STM 550 are configured to be in standby mode to conserve energy during transport and storage.

Upon initial setup, STM 550 has to be set to standard operation mode by pressing the LRN button shortly as described in chapter 12.1 or via the NFC interface as described in chapter 10.5.11

2.3.1 Standard operation mode

During standard (normal) operation, STM 550 wakes up periodically and reports the current sensor status using data telegrams. The STM 550 wake-up timer is by default configured to wake-up STM 550 approximately every 60 seconds. The wake-up intervals are affected at random (meaning that a small random offset is added to the timing interval) to increase the robustness of the radio transmission and to comply with regulatory requirements.

If acceleration exceeding the configured threshold is detected for the first time after a period without exceeding this threshold, then STM 550 wakes up immediately (wake on acceleration event). Likewise, if the status of the magnet contact changes (from open to closed or vice versa) then this is reported immediately as well (wake on magnet contact event).

2.3.2 Standby (Sleep) mode

Standby (sleep) mode is the lowest power mode of STM 550 and is the out of the box state of STM 550 upon delivery. It is intended to be used during extended periods without operation such as device storage or transport. In standby mode, STM 550 stops operation and conserves as much energy as possible. All functionality – except those needed to return to standard operation mode – are disabled in this mode.

Standby mode can be selected using the LRN button as described in chapter 5.1 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 10.5.11. Upon entering standby mode, STM 550 will send a SIGNAL telegram of type 0x0E as described in chapter 6.2.7.

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2.3.3 Learn mode

In Learn mode, STM 550 will transmit a Teach-in telegram to communicate its source address (EURID), the EnOcean Equipment Profile (EEP) that it currently uses and – if applicable - security mode and security information to a receiver. After that transmission, STM 550 will return to standard operation mode.

Learn mode can be selected using the LRN button as described in chapter 5.1 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 10.5.11.

2.3.4 Function test mode

In Function Test mode, STM 550 will measure and report the status of the integrated sensors at the highest possible rate to verify the sensor functionality.

STM 550 can be set into function test mode via the LRN button as described in chapter 5.1 or via the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 10.5.11.

Function Test Mode will be stopped once the LRN button is pressed or the functional mode is changed via the NFC interface.

2.3.5 Illumination test mode

During installation, STM 550 can measure and report the amount of ambient light available at its solar cell in to select a suitable installation location as discussed in chapter 12.7.

Upon activation of illumination test mode, STM 550 will first wait for 15 seconds so that the installer can vacate the area in front of the sensor to ensure an accurate measurement result.

After that, STM 550 will take measurements of the ambient light level using its solar cell every 5 seconds for a period of one minute and compute the average illumination based on those measurements.

The computed average illumination is then available in the NFC register ILLUMINATION_TEST_RESULT as described in chapter 10.5.28.

Illumination test mode can be selected using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 10.5.11.

2.3.6 Acceleration test mode

During installation, STM 550 can visually indicate if detected acceleration exceeds the configured threshold. This provides quick visual feedback about the correct installation as discussed in chapter 12.5.

Upon activation of acceleration test mode, STM 550 will periodically (approximately every 3 seconds) measure acceleration vector changes and blink the LED whenever this change exceeds the threshold configured using the ACCELERATION_THRESHOLD register as described in chapter 10.5.21.

Acceleration test mode can be selected using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 10.5.11 or using the LRN button as described in chapter 5.2.

2.3.7 Factory reset mode

STM 550 can be reset to its standard settings using factory reset mode. Upon entering this mode, STM 550 will reset all configuration registers to their default settings and then restart operation in standard operation mode.

Factory reset mode can be selected using the LRN button as described in chapter 5.1 or using the MODE field of the FUNCTIONAL_MODE NFC register as described in chapter 10.5.11.

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2.4 Reporting interval

STM 550 will transmit its status as data telegram at a regular interval, the so-called reporting interval. By default, the reporting interval is 60 seconds, i.e. STM 550 will measure and report its status approximately once per minute.

STM 550 is designed to add a random timing offset of up to 10% to the configured reporting interval to increase transmission reliability and meet regulatory requirements.

If STM 550 is configured to report acceleration, then it will always report the initial acceleration detection after a period without detected acceleration immediately. Likewise, if STM 550 is configured to report magnet contact status, then it will report any change in the status of the magnet contact sensor (open -> closed or closed -> open) immediately.

2.4.1 Standard reporting interval

The standard reporting interval determines the default interval between two status updates of STM 550.

The standard reporting interval can be adjusted using the STANDARD_TX_INTERVAL NFC register as described in chapter 10.5.12. Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

The default setting for the standard reporting interval is one status update once every 60 seconds (1 minute).

Figure 6 below illustrates the use of the standard reporting interval.

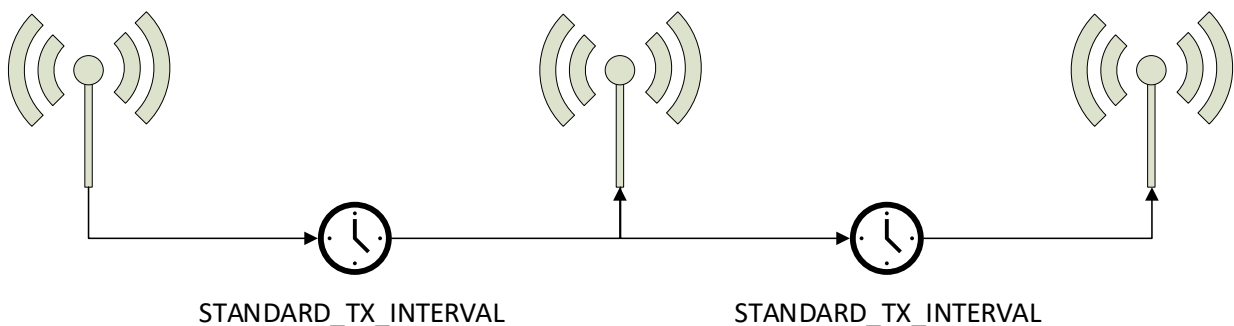


Figure 6 – Standard reporting interval

STM 550 can be configured to use a lower reporting interval, i.e. provide updates more often, based on certain conditions as described below.

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2.4.2 Illumination-controlled reporting interval

If sufficient ambient light is available, then it might be desirable to receive status updates more often. For this, there are typically two main use cases:

- Adjust the update rate based on the ambient light available for harvesting
- Report more often during daytime (or when an office is lit) and less often during night-time (or when an office is dark) to adapt the reporting to the usage pattern

In both cases, the higher update rate would be used whenever the ambient light level is above a certain threshold. Figure 7 below illustrated the use of the illumination-controlled reporting interval.

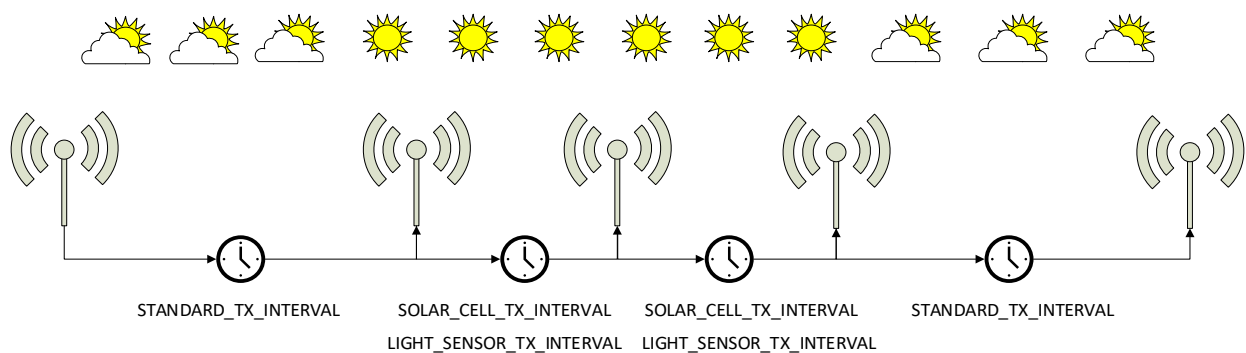


Figure 7 – Illumination-controlled reporting interval

STM 550 can use either the light level at the solar cell (harvested energy) or the light level at the ambient light sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Configure the desired light level threshold either for the solar cell or the ambient light sensor using either the `SOLAR_THRESHOLD` or `LIGHT_THRESHOLD` registers described in chapters 10.5.17 and 10.5.19 respectively
2. Configure the desired reporting interval using either the `SOLAR_TX_INTERVAL` or the `LIGHT_TX_INTERVAL` registers described in chapters 10.5.18 and 10.5.20 respectively
3. Enable the use of the defined parameters using the `SOLAR CELL` and `LIGHT SENSOR` bit fields in the `THRESHOLD_CFG1` register of the NFC interface as defined in chapter 10.5.13.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.3 Temperature-controlled reporting interval

In HVAC (heating, ventilation, air conditioning) applications it might be desirable to receive status updates more often if the measured temperature is significantly above or below the target value.

Figure 8 below illustrates the use of the temperature-controlled reporting interval.

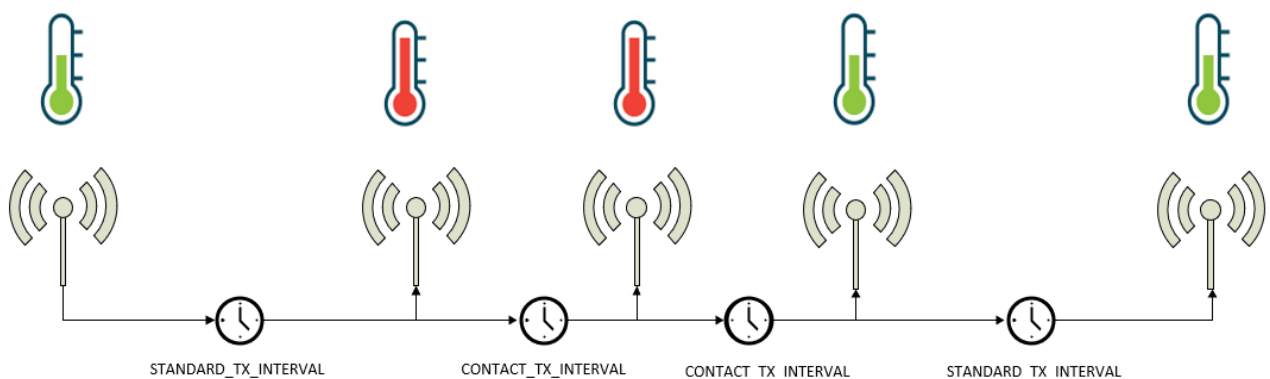


Figure 8 – Temperature-controlled reporting interval

STM 550 can use the temperature measured by the temperature and humidity sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 10.5.8 reports the measured temperature
2. Configure the desired temperature threshold using the `TEMPERATURE_THRESHOLD` register described in chapter 10.5.23
3. Configure the desired reporting interval using the `TEMPERATURE_TX_INTERVAL` register described in chapter 10.5.24
4. Enable the use of the defined parameters using the `TEMP SENSOR` bit field in the `THRESHOLD_CFG1` register of the NFC interface as defined in chapter 10.5.13.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.4 Humidity-controlled reporting interval

In HVAC (heating, ventilation, air conditioning) applications it might be desirable to receive status updates more often if the measured humidity is significantly above or below the target value.

Figure 9 below illustrates the use of the humidity-controlled reporting interval.

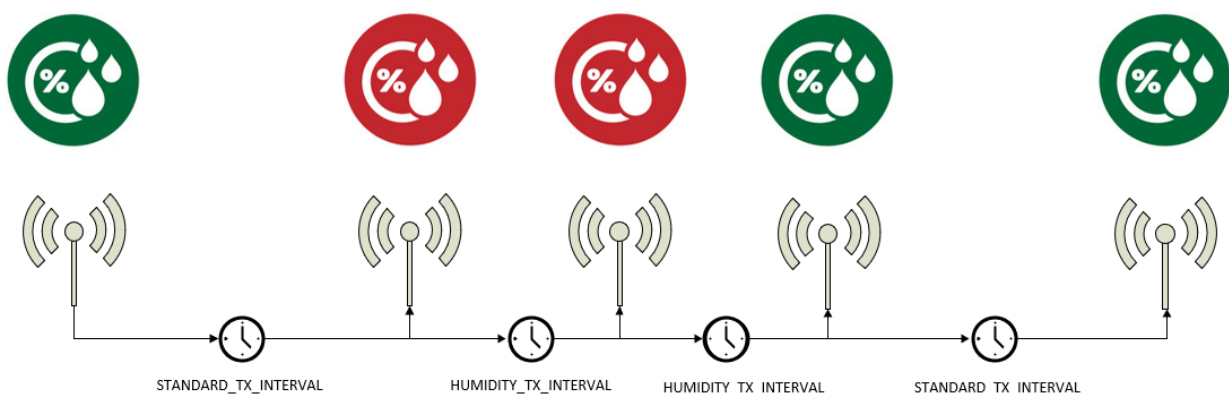


Figure 9 – Humidity-controlled reporting interval

STM 550 can use the humidity measured by the temperature and humidity sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 10.5.8 reports humidity
2. Configure the desired humidity threshold using the HUMIDITY_THRESHOLD register described in chapter 10.5.25
3. Configure the desired reporting interval using the HUMIDITY_TX_INTERVAL register described in chapter 10.5.26
4. Enable the use of the defined parameters using the HUMIDITY SENSOR bit field in the THRESHOLD_CFG1 register of the NFC interface as defined in chapter 10.5.13.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.5 Acceleration-controlled reporting interval

If an asset is in operation or it is being moved, then it might be desirable to receive status updates more often to determine its status or location.

Figure 10 below illustrates the use of the acceleration-controlled reporting interval.

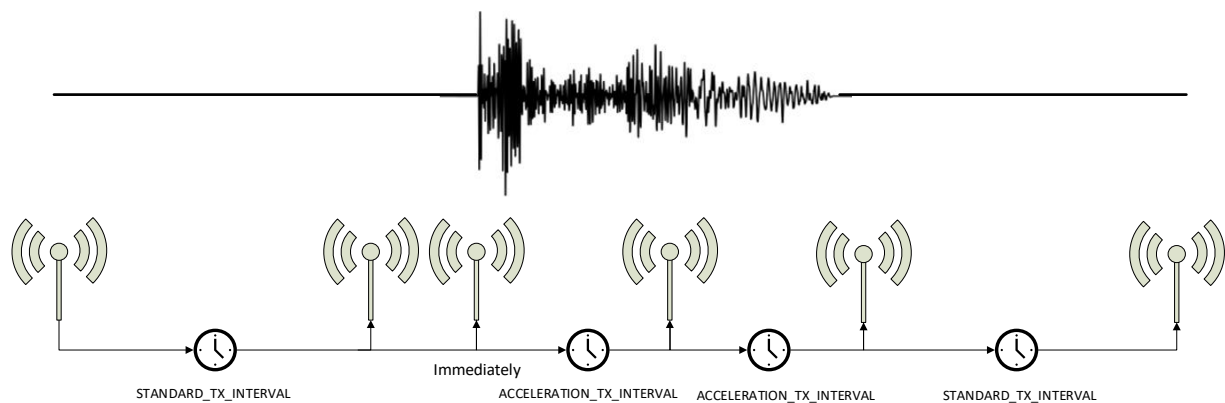


Figure 10 – Acceleration-controlled reporting interval

STM 550 can use acceleration events detected by the acceleration sensor to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 10.5.8 reports acceleration
2. Configure the acceleration sensor parameters (full scale value and sampling frequency) and enable the wake-on-acceleration feature using the ACC_SENSOR_CFG register described in chapter 10.5.16
3. Configure the desired acceleration threshold using the ACCELERATION_THRESHOLD register described in chapter 10.5.21
4. Configure the desired reporting interval using the ACCELERATION_TX_INTERVAL register described in chapter 10.5.22
5. Enable the use of the defined parameters using the ACCELERATION SENSOR bit field in the THRESHOLD_CFG2 register of the NFC interface as defined in chapter 10.5.14.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

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2.4.6 Magnet contact sensor-controlled reporting interval

If a door or a window is opened when it normally should be closed (or vice versa), then it might be desirable to receive status updates more often to monitor its status. STM 550 can therefore be configured to use a lower reporting interval, i.e. a higher update rate, for one of the two magnet contact sensor status options (open or closed).

Figure 11 below illustrates the use of the magnet contact sensor-controlled reporting interval.

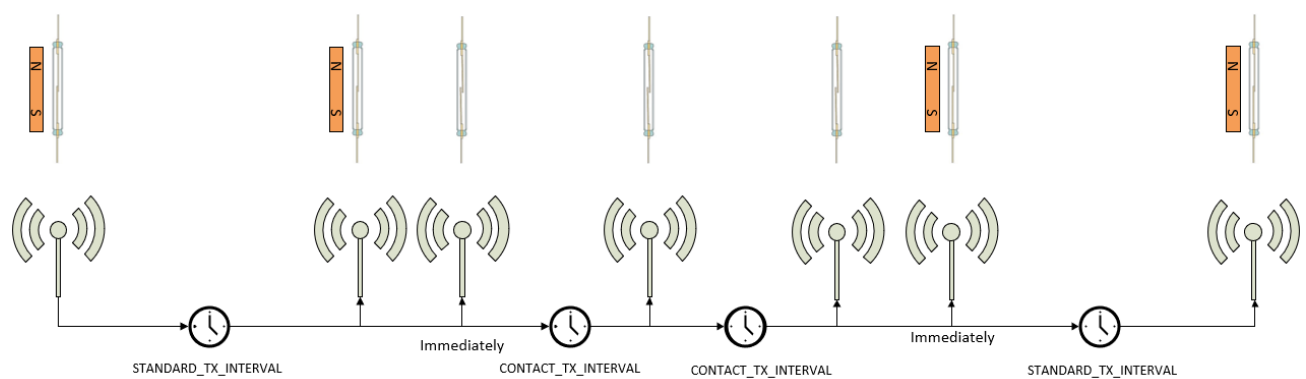


Figure 11 – Magnet contact sensor-controlled reporting interval

STM 550 can use the status of the magnet contact to trigger a higher update rate. To enable this feature, use the following steps:

1. Make sure that the EEP selected using the EEP register as described in chapter 10.5.8 reports the magnet contact status
2. Configure the desired reporting interval using the `MAGNET_CONTACT_TX_INTERVAL` register described in chapter 10.5.22
3. Select the state of the magnet contact (open or closed) where the lower update interval should be active using the `MC_SENSOR` bit field in the `THRESHOLD_CFG2` register as defined in chapter 10.5.14.

Consider the available energy before lowering the reporting interval as discussed in chapter 3.2.

2.4.7 Arbitration between reporting intervals

If more than one condition for a lower reporting interval applies – e.g. both an acceleration exceeding the acceleration threshold is detected and the room is brightly lit in excess of the light level threshold – then the lowest of the corresponding reporting intervals will be selected.

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3 Energy harvesting

Under normal operating conditions, STM 550 generates all energy required for its operation from available ambient light. Under these conditions, the amount of generated energy equals the amount of consumed energy; this state is called "energy balance". STM 550 is designed to achieve energy balance - i.e. to operate fully self-supplied - in its default configuration based on a light level of at least 200 lux available for at least 6 hours per day.

3.1 Energy generation

STM 550 generates energy from the ambient light using an integrated solar cell. The amount of generated by this solar cell energy depends on the ambient light level, the availability of the ambient light and – to a much lesser extend – also the type of light as described in the next chapters.

3.1.1 Light level

STM 550 uses an integrated solar cell which is optimized for indoor lighting conditions. It is designed to achieve best performance for light levels between 50 lux and 2000 lux.

Table 1 below provides a summary of the minimum required light level for typical work and school areas in Germany as a reference for typical light levels.

Area type	Required light level
Common office areas such as entrance halls, floors, break rooms, changing rooms, toilets and canteens Automated production areas without regular presence	200 lux
Work areas without special requirements School areas without special requirements Sales areas in stores	300 lux
Office work areas for reading, writing and data processing Specialized work areas for measuring, inspecting, testing and packaging Specialized school areas	500 lux
Quality inspection workplaces	1000 lux

Table 1 – Required lighting conditions for work and school areas

The actual ambient light level at an installation location can be determined by executing an illumination test as described in chapter 2.3.5.



STM 550 is intended for indoor use only. Operation in light levels above 10000 lux (outdoor operation, especially in direct sunlight) is not permitted. The solar cell performance might degrade after extended exposure to direct sunlight.

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3.1.2 Light availability

Light availability defines the amount of time for which a certain ambient light level is available.

Taking the example of a workplace, ambient light will usually be available for eight hours or more if the workplace is occupied during standard working hours. On the other hand, ambient light might not be available at all during the weekend if the interior lighting system is not in operation and the window shutters are closed.

The amount of generated energy is directly proportional to the availability of the light, meaning that for instance 200 lux of ambient light available for 12 hours per day will provide twice the amount of energy compared to 200 lux of ambient light available for 6 hours per day.

3.1.3 Light characteristics

STM 550 uses an integrated solar cell which is optimized for typical ambient indoor lighting over a wide spectral range. Energy will be generated both from artificial lighting (such as LED lighting) or from natural lighting (from the sun) with comparable efficiency.

Special windows (which protect against infrared ultraviolet radiation) will slightly reduce the amount of energy that is generated from the incoming natural light. This impact of this effect can however be neglected in relation the impact of changing light intensity or availability.

3.2 Energy consumption

STM 550 uses the generated energy for its operation; excess energy will be stored in the integrated energy storage element. Understanding the energy consumption is important to determine the energy balance.

The energy consumption of STM 550 is determined by two main contributors:

- **Static energy consumption**
The static energy consumption is independent of the measurement and transmission rate. Typical contributors are permanently active sensors (such as the acceleration sensor in STM 550) and current caused by inactive system (sleep current, self-discharge, etc)
- **Dynamic energy consumption**
The dynamic energy consumption depends on the measurement and transmission rate. Typical contributors are sensors that are active only upon measurement (such as the temperature, humidity and illumination sensor in STM 550), the microprocessor (when handling sensor data and formatting the radio telegram) and the radio transmitter (when transmitting the radio telegram)

The total energy consumption is the sum of these two contributors.

3.2.1 Static energy consumption

Static energy consumption is the part of the energy consumption that is independent of the operation (meaning the regular sensor measurements and data transmissions) of the device. It is caused by permanently active consumers such as permanently active sensors or other functional units such as the internal timer.

To minimize the static energy consumption – and thereby optimize the energy balance – it is recommended to disable the acceleration sensor (with the permanently wake-on-acceleration functionality) if this functionality is not required. The acceleration sensor can be disabled by selecting an EnOcean Equipment Profile (EEP) that does not include acceleration sensor data..

3.2.2 Dynamic energy consumption

Dynamic energy consumption is the part of the energy consumption that is dependent of the operation (meaning the regular sensor measurements and data transmissions) of the device. As discussed above, the update rate – meaning the rate at which STM 550 measures and reports the sensor status – is the main parameter defining the dynamic energy consumption of STM 550.

It is important to understand that a change in the update rate will usually not result in a proportional change of the energy consumption. Decreasing the update rate by factor two will in most cases not decrease the energy consumption by factor two. Likewise, providing twice as much energy will not allow to increase the update rate by factor two.

As a guidance, Table 2 below provides a summary of minimum supported update intervals for self-supplied operation based for different scenarios of light intensity and light availability. Sufficient margin should be added to these minimum values to account for possible changes in the ambient light level.

	6 hrs / day	8 hrs / day	10 hrs / day	12 hrs / day
100 lux	360 s	150 s	90 s	60 s
200 lux	60 s	45 s	45 s	30 s
300 lux	45 s	30 s	30 s	20 s
400 lux	30 s	25 s	25 s	15 s
500 lux	25 s	20 s	20 s	15 s

Table 2 – Minimum update rates for self-supplied operation

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3.3 Energy storage

STM 550 is designed to operate for one full day (24 hours) based on 200 lux of ambient light available for 6 hours. This means that 6 hours of available light will provide enough energy for 24 hours (6 hours with light, 18 hours without light) of operation.

If ambient light is available for more than 6 hours per day, then STM 550 will accumulate the additional energy so that it can operate for more than 18 hours without light. STM 550 can accumulate energy for up to 14 days of operation without light.

Table 3 below lists the operation time without light and the accumulated additional operation time (if the same lighting conditions apply every day).

Light availability	Light level	Operating time without light	Accumulated additional operation time
6 hours of per day	200 lux	18 hours	0 hours per day 0 hours per 5 day work week
8 hours per day	200 lux	24 hours	8 hours per day 40 hours per 5 day work week
10 hours per day	200 lux	30 hours	16 hours per day 80 hours per 5 day work week
6 hours of per day	400 lux	36 hours	18 hours per day 90 hours per 5 day work week
8 hours per day	400 lux	48 hours	32 hours per day 160 hours per 5 day work week
10 hours per day	400 lux	60 hours	46 hours per day 230 hours per 5 day work week

Table 3 – Operation time based on available light

As shown in Table 3 above, available ambient light of 200 lux for 6 hours per day will result in a neutral energy balance meaning that the amount of generated energy and the amount of consumed energy will be the same.

The installation location of STM 550 should be chosen to provide sufficient margin to account for variations in the available ambient light, variations in the operation pattern (e.g. additional event-based transmissions when used as magnet contact or acceleration sensor, use of high security functionality etc) and to allow accumulation of energy to cover periods without available ambient light.

It is suggested to select an installation location which provides at least 25% margin (e.g. 250 lux instead of 200 lux for 6 hours per day or 200 lux for 8 hours per day) to account for these factors. As reference, the required minimum light level at most working places is more than 300 lux.

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4 Sensor functionality

STM 550 integrates a set of sensors used to measure environmental parameters. The following chapters described their characteristics in detail.

4.1 Light level sensor

STM 550 integrates a dedicated light level sensor with narrow aperture and a spectral response optimized to mimic the human eye's perception of ambient light. This light sensor reports the light level directly in front of the sensor (spot measurement with narrow aperture).

Figure 12 shows the spectrum response of the STM 550 illumination sensor compared to that of the human eye.

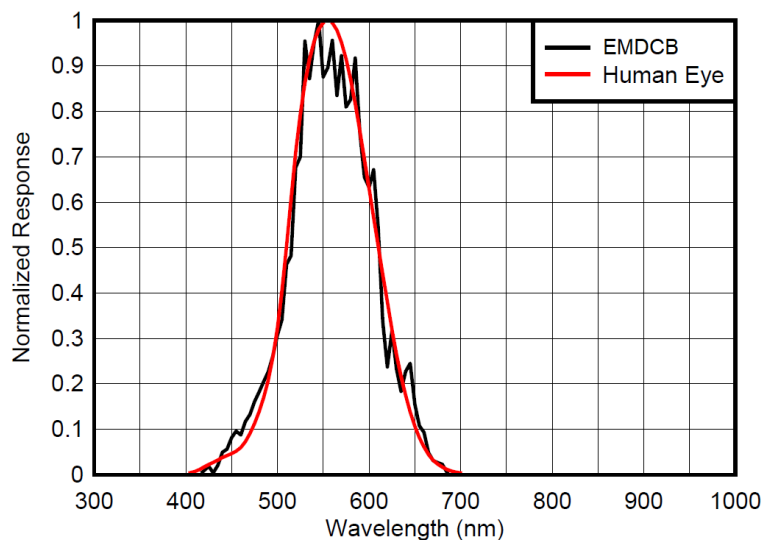


Figure 12 – Spectrum response of the light level sensor

4.2 Solar cell

STM 550 can use SIGNAL telegrams - as described in chapter 6.2.7 - to report the energy generated by the solar cell. Reporting of the solar cell energy generation level can be enabled and disabled via the SIGNAL register of the NFC interface as described in chapter 10.5.9. By default, the reporting is disabled.

In addition, STM 550 provides the option to use the calibrated solar cell response to report wide area illumination instead of the narrow angle spot measurement of the ambient light level sensor. This can be selected using the LIGHT_SENSOR_CFG register of the NFC interface as described in chapter 10.5.15.

Refer to Chapter 12.6 for a discussion about the respective benefits of the two options.

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4.3 Temperature sensor

STM 550 integrates a high-performance temperature sensor achieving accuracy of better than ± 0.3 °C throughout the entire operation temperature range and an accuracy of better than ± 0.2 °C for the typical indoor temperature range. Figure 13 below shows the typical accuracy of the STM 550 temperature sensor as a function of the ambient temperature.

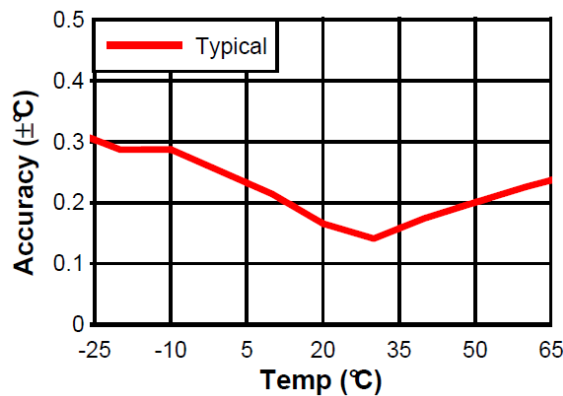


Figure 13 – Temperature sensor accuracy

To determine the overall system accuracy, the quantization error (reporting step size) determined by the selected EnOcean Equipment Profile (EEP) has to be added to this value.

4.4 Humidity sensor

STM 550 integrates a high-performance humidity sensor achieving accuracy of better than ± 3 % r.h. throughout the entire operation temperature range and an accuracy of better than ± 2 % r.h. for the typical indoor humidity range. Figure 14 below shows the typical accuracy of the STM 550 humidity sensor as a function of the ambient humidity.

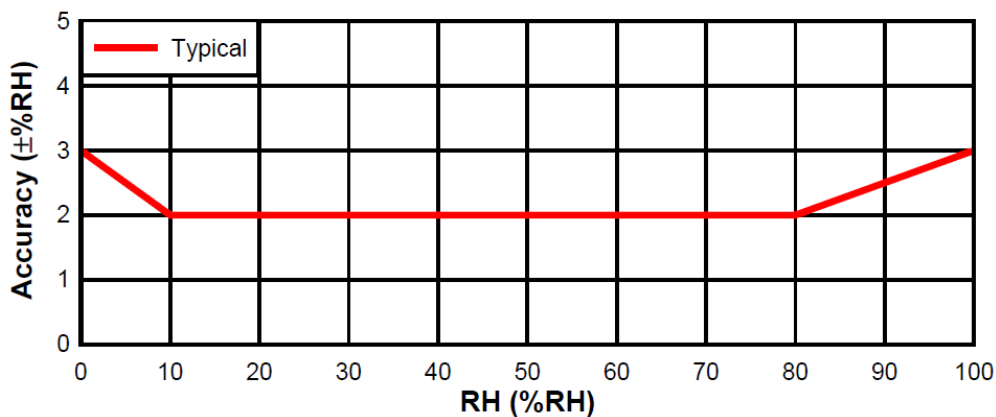


Figure 14 – Humidity sensor accuracy

To determine the overall system accuracy, the quantization error (reporting step size) determined by the selected EnOcean Equipment Profile (EEP) has to be added to this value.

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4.5 Acceleration sensor

STM 550 integrates an acceleration sensor which provides two types of data:

- Acceleration vector orientation
This allows determining the direction into which STM 550 is either accelerated (moved) or permanently oriented (positioned relative to the earth gravity vector). See Chapter 12.5.1 for an example.
- Acceleration vector change
This allows determining if STM 550 is moved or shaken

The second case (acceleration vector change) can be used to determine the presence or absence of small vibrations (acceleration vector changes). Examples use cases causing such small vibrations include asset utilization (e.g. a motor to which STM 550 is attached is running) or asset movement (e.g. an asset to which STM 550 is attached changes its location).

If such change in acceleration is above a certain threshold, then this will be reported as part of the regular data telegram. If the acceleration exceeds this threshold for the first time, then this will be reported immediately (wake-on-acceleration).

Figure 15 below shows the orientation of the acceleration vector relative to STM 550.

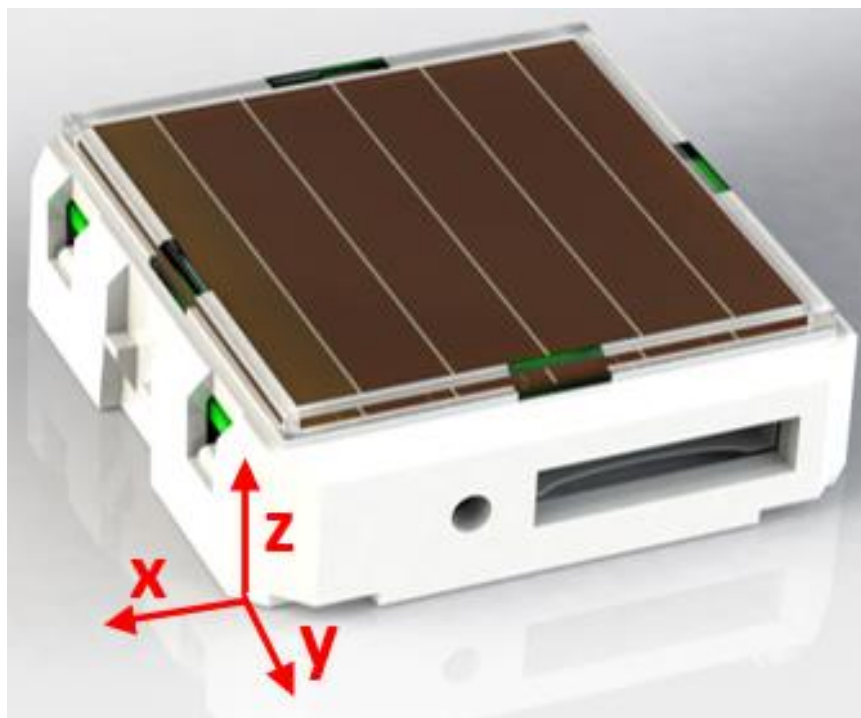


Figure 15 – Acceleration sensor orientation

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4.5.1 Wake on acceleration

If acceleration exceeding the configured threshold is detected for the first time after a period without exceeding this threshold, then STM 550 wakes up immediately (wake on acceleration event).

Wake-on acceleration can be used to immediately trigger the transmission of a message when an item is moved or starts to vibrate. The threshold for the wake on acceleration feature is adjustable as described below.

4.5.2 Acceleration sensor parameters

The acceleration sensor integrated in STM 550 allows configuring the following parameters:

- Full-scale magnitude
The full-scale magnitude determines the maximum acceleration magnitude that will be reported. Higher settings allow reporting higher magnitudes but will result in less resolution and thereby less sensitivity. The default full scale magnitude of $\pm 2g$ should be appropriate for most use cases.
- Acceleration threshold
The acceleration threshold determines the threshold of acceleration vector change required to trigger a wake-on vibration event as described above or to reduce the transmission interval as described in chapter 2.4.5. Setting a lower acceleration threshold results in a higher sensitivity to acceleration vector changes. STM 550 uses by default the minimum possible threshold corresponding to $1/64$ of its full-scale magnitude.
- Sampling rate
The sampling rate determines how often the acceleration vector will be measured. Higher sampling rates allow detecting shorter vibrations but require more energy to do so. Higher sampling rates should only be used if minor vibrations are not detected when using the minimum acceleration threshold.

Table 4 below shows the supported configuration options for each of these parameters and their default settings in STM 550.

Parameter	Supported Options (bold = default)
Full-scale magnitude	$\pm 2g$, $\pm 4g$, $\pm 8g$, $\pm 16g$
Acceleration threshold	$1/64$... $63/64$ of full scale
Sampling rate	1.6 Hz , 12.5 Hz , 25 Hz , 50 Hz
Measurement resolution	10 bit for each (x, y, z) direction

Table 4 – Acceleration sensor parameters



Note that increasing the sampling rate will proportionally increase the power consumption of STM 550. The sampling rate should only be increased if sufficient ambient light is available or if a backup battery is used.

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4.6 Magnet contact sensor

STM 550 integrates a magnet contact sensor detecting presence or absence of a magnetic field in the proximity of the it. Refer to Chapter 2.2 for the location of the magnet contact sensor within STM 550 and to Chapter 12.7 for mounting instructions.

EMSI product packaging includes a block magnet suitable for use with its magnet contact sensor. Figure 16 shows the outer appearance of this magnet.

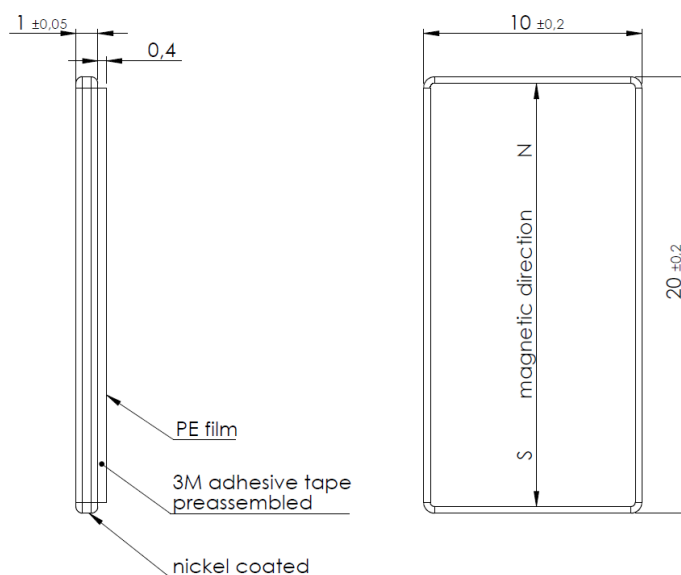


Figure 16 – Magnet outline

The magnet is made from N35 grade Neodymium material. Table 5 below lists the key parameters of this material for reference if use of alternative magnets is planned.

	Br		Hcb		Hcj		(BH) _{max}		TW
	T	KGs	KA/m	KOe	KA/m	KOe	KJ/m ³	MGOe	°C
N35	1.17-1.21	11.7-12.1	876-899	11.0-11.3	≥955	≥12	263-279	33-35	≤80

Table 5 – N35 material parameters

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5 User interface

The STM 550 product interface contains an LED, a LRN button and a backup battery interface as described in chapter 2.2.

5.1 LED

STM 550 contains an indication LED used to provide user feedback. By default, the LED will blink shortly whenever a telegram is transmitted. This indication can be disabled using the LED_MODE register of the NFC interface as described in chapter 10.5.10. In addition to that, the LED provides a response to LRN button inputs as described below.

5.2 LRN button

Most STM 550 device parameters can be configured using the NFC interface as described in chapter 10. Some of the most common parameters or states can additionally be configured using the LRN button. Table 6 below lists those LRN button actions with the corresponding STM 550 response and LED feedback.

Type	LRN Button Action	STM 550 Response	LED Feedback
1 x Short	< 1s Press	Exit from Sleep Mode Send Learn Telegram	Success: 1 short blink Error: No feedback
2 x Short	< 1s Press,	Start Function Test (End after 2 min or upon any button press)	Sensor status is transmitted with higher update rate, LED blinks for every transmission
	< 1s Release,		
	< 1s Press		
3 x Short	< 1s Press,	Toggle LED indication	LED enabled: 2 short blinks LED disabled: No feedback
	< 1s Release,		
	< 1s Press,		
	< 1s Release,		
	< 1s Press		
4 x Short	< 1s Press,	Start Acceleration Test	1 short blink during test interval if acceleration above threshold is detected
	< 1s Release,		
	< 1s Press,		
	< 1s Release,		
	< 1s Press		
	< 1s Release,		
	< 1s Press		
1 x Long	3s < Press < 5s	Enter Sleep Mode (Disable LED and Radio)	Success: 3 short blinks Error: No feedback
2 x Long	3s < Press < 5s,	Enter High Security Mode (Encrypt and authenticate)	Success: 2 short blinks Error: No feedback
	< 1s Release,		
	3s < Press < 5s		
Very Long	> 8s Press	Factory Reset	Success: 5 short blinks Error: No feedback

Table 6 – STM 550 user interface actions

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5.3 Backup battery

STM 550 provides a backup battery interface to mount a CR1632 battery for cases with insufficient ambient light. The backup battery has to be installed with the negative pole pointing upwards (i.e. towards the side of the solar cell). Check the '+' and '-' polarity markings on the housing for correct battery orientation as shown in Figure 17 below.

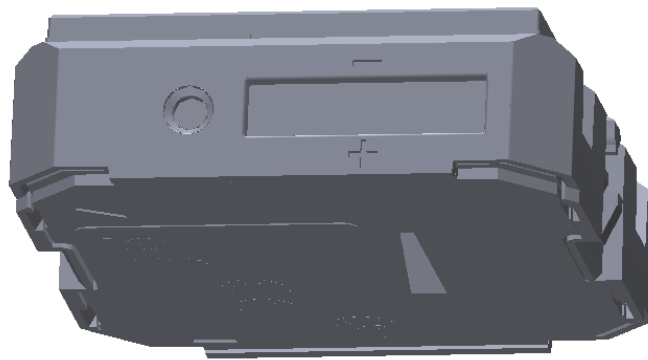


Figure 17 – Backup battery slot with polarity markings

EnOcean recommends Renata CR1632 due to its low self-discharge and high capacity. Gloves should be used when installing a backup battery to avoid contamination of the isolation area between the contacts that could lead to a higher self-discharge.

The backup battery can be removed (ejected) by using a small, non-conductive item (e.g. wooden toothpick) to push the battery out via the battery ejector slot on the back side of STM 550 as shown in chapter 2.2.

5.3.1 Safety remarks

Please familiarize yourself with the following safety remarks before using a backup battery:



Do not insert any tools into the battery slot or the battery ejection slot. Doing so could create a short circuit or damage the PCB resulting in permanent damage.



CAUTION: Risk of damage or explosion if a battery of incorrect type is used.



This product can contain a coin/button cell battery. If the coin/button cell battery is swallowed, it can cause severe internal burns in just 2 hours and can lead to death.



Keep new and used batteries away from children.

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5.4 Product label

5.4.1 STM 550

Each STM 550 module contains a product label with a commissioning QR code. Figure 18 shows the STM 550 product label. STM 550U and STM 550J use the same label structure. Note the commissioning QR code (described in chapter 8.2) on the bottom left side.

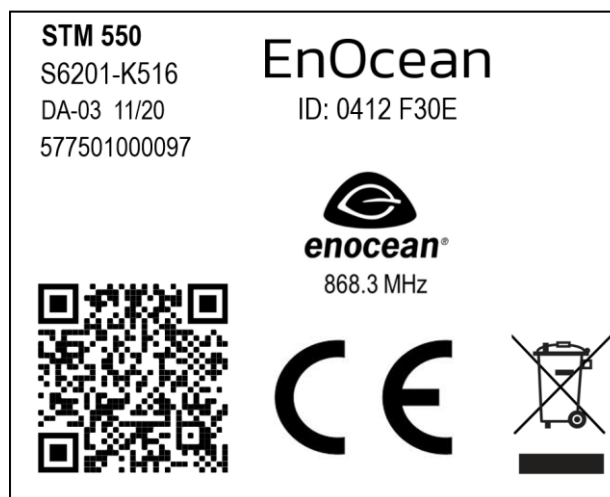


Figure 18 – STM 550 product label

5.4.2 EMSI

EMSI products integrated the STM 550 module into a housing as discussed in chapter 1.2. Each EMSI product contains an additional label shown in Figure 19 below in addition to the STM 550 product label.

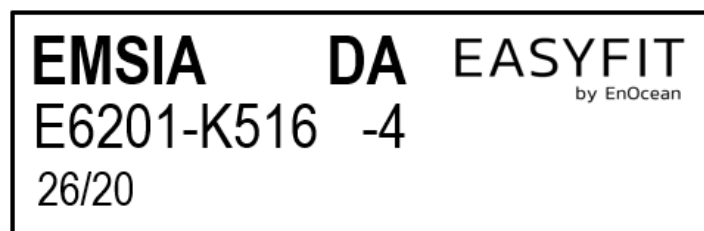


Figure 19 – Additional EMSI product label

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6 Radio communication

STM 550 devices communicate using radio telegrams encoded according to the EnOcean Equipment Profile (EEP) specification and the EnOcean Alliance Signal Telegram specification on a radio link according to the EnOcean Alliance Radio Protocol (ERP).

STM 550 uses the ERP1 standard (ISO 14543-3-10) while STM 550U and STM 550J use the ERP2 (ISO 14543-3-11) standard.

6.1 Radio Frame format

As described above, STM 550 uses ERP1 as radio link while STM 550U and STM 550J use ERP2.

Note that EnOcean radio transceivers such as TCM 310 or TCM 515 will convert both ERP1 and ERP2 into the same EnOcean Serial Protocol (ESP3) format so that this difference is normally not noticeable.

6.1.1 ERP1 frame format

The ERP1 radio frame format is shown in Figure 20 below.

RORG	DATA	SENDER EURID	STATUS	CRC
------	------	--------------	--------	-----

Figure 20 – ERP1 Frame Format

The most relevant fields of the ERP1 frame are the following:

- RORG (containing the EEP or SIGNAL RORG)
- SENDER EURID (Device address of the sender)
- DATA (Telegram payload containing the EEP)

6.1.2 ERP2 frame format

The ERP2 radio frame format is shown in below.

LENGTH	HEADER	EXT_HEADER	SENDER EURID	DATA	CRC
--------	--------	------------	--------------	------	-----

Figure 21 – ERP2 Frame Format

The most relevant fields of the ERP2 frame are the following:

- HEADER (including the EEP or SIGNAL RORG)
- SENDER EURID (Device address of the sender)
- DATA (Telegram payload containing the EEP)

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6.2 EnOcean Equipment Profiles (EEP) and SIGNAL telegrams

The data section within EnOcean radio telegrams uses one of the EnOcean Equipment Profiles (EEP) or one of the SIGNAL telegram types defined by EnOcean Alliance to encode sensor information. The EEP used is selected by the sender and must be supported by the receiver.

6.2.1 STM 550 supported EEP

STM 550 supports a wide range of EEP suitable for different use cases. Table 7 below lists the supported EEP.

Profile	Type	Reported Parameters	Parameter Range	Size / Resolution
D5-00-01	1BS	Magnet Contact	Open / Closed	1 Bit
A5-02-05	4BS	Temperature	0°C ... 40°C	8 bit
A5-04-01	4BS	Temperature	0°C ... 40°C	8 Bit
		Humidity	0% ... 100% r.h.	8 Bit
A5-04-03	4BS	Temperature	-20°C ... 60°C	10 Bit
		Humidity	0% ... 100% r.h.	8 Bit
A5-06-02	4BS	Light Sensor	0 lx ... 1020 lx	8 Bit
A5-06-03	4BS	Light Sensor	0 lx ... 1000 lx	10 Bit
A5-14-05	4BS	Vibration Detector	Above / Below threshold	1 Bit
D2-14-40	VLD (9 Byte)	Temperature	-40°C ... 60°C	10 Bit
		Humidity	0% ... 100% r.h.	8 Bit
		Illumination	0 ... 100000 lx	17 Bit
		Acceleration x-axis	+/- 2.5g	10 Bit
		Acceleration y-axis	+/- 2.5g	10 Bit
		Acceleration z-axis	+/- 2.5g	10 Bit
		Acceleration Status	Above / Below threshold	2 Bit
D2-14-41 (Default)	VLD (9 Byte)	Temperature	-40°C ... 60°C	10 Bit
		Humidity	0% ... 100% r.h.	8 Bit
		Illumination	0 ... 100000 lx	17 Bit
		Acceleration x-axis	+/- 2.5g	10 Bit
		Acceleration y-axis	+/- 2.5g	10 Bit
		Acceleration z-axis	+/- 2.5g	10 Bit
		Acceleration Status	Above / Below threshold	2 Bit
		Magnet Contact	Open / Closed	1 Bit

Table 7 – Supported EEP

The default EEP used by STM 550 is D2-14-41 (VLD with 9 byte payload). It is possible to select another one of the supported EEP via the EEP register of the NFC configuration interface described in chapter 10.5.8.

For details about the EEP content, see <http://tools.enocean-alliance.org/EEPViewer/#1>

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6.2.2 EEP structure

Each EEP is identified using three fields:

- **RORG**
RORG identifies the high-level telegram type, e.g. rocker switch telegram (RPS), one-byte sensor telegram (1BS), four-byte sensor telegram (4BS), variable length telegram (VLD), Universal Teach-in with EEP (UTE), etc.
- **FUNC**
FUNC identifies the function group to which this telegram belongs, e.g. the function group of temperature sensors within the four-byte sensor telegram type
- **VARIANT (or TYPE)**
VARIANT (which is confusingly also called TYPE) identifies the exact sensor variant within the function group, e.g. a 0 °C – 40 °C temperature sensor that is defined within the function group of temperature sensors

Figure 22 below shows the structure of the EEP identifier.

RORG	FUNC	VARIANT
0x00 ... 0xFF	0x00 ... 0x3F	0x00 ... 0x7F
8 bit	6 bit	7 bit

Figure 22 – EEP identifier structure

The EEP identifier is typically only transmitted during the initial teach-in (paring) between devices. For special cases (e.g. devices using more than one EEP), data telegrams might specify the EEP that is used.

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6.2.3 1BS telegram

1 Byte Sensor (1BS) telegrams are identified by the RORG field being set to 0xD5 which is followed by one byte of payload (Bit0 ... Bit7). 1BS telegrams are used exclusively to encode the status (open / closed) of a binary contact (typically a magnet contact)

The payload of 1BS telegrams encodes either the contact status (1BS Data Telegram) during normal operation or identifies a teach-in telegram (1BS Teach-in Telegram).

The distinction between data and teach-in telegrams is made based on the status of Bit4. If this bit is set to 0 then the telegram is a 1BS Teach-in Telegram; if this bit is set to 1 then the telegram is a 1BS Data Telegram.

6.2.4 4BS telegram

4 Byte Sensor (4BS) telegrams are identified by the RORG field being set to 0xA5 which is followed by four bytes of payload (Bit0 ... Bit31).

The payload of 4BS telegrams encodes either the sensor status (4BS Data Telegram) during normal operation or identifies EEPROM and manufacturer of the device during teach-in (4BS Teach-in Telegram).

The distinction between data and teach-in telegrams is made based on the status of Bit28. If this bit is set to 0 then the telegram is a 4BS Teach-in Telegram; if this bit is set to 1 then the telegram is a 4BS Data Telegram.

6.2.5 VLD telegram

Variable Length Data (VLD) telegrams are identified by the RORG field being set to 0xD2. They carry a variable length payload which can be between 1 and 14 byte long.

6.2.6 UTE (Universal Teach-in) telegram

Variable Length Data (VLD) telegrams carry a variable length payload, therefore it is not possible to use one bit at a pre-defined location to distinguish between data and teach-in telegrams.

Devices communicating using VLD data telegrams therefore use the generic Universal Teach-in with EEPROM (UTE) format when transmitting a teach-in telegram. The format of such UTE telegram is shown in Figure 23 below.

UTE RORG	UTE DATA						
BYTE0	BYTE0	BYTE1	BYTE2	BYTE3	BYTE4	BYTE5	BYTE5
0xD4	CTRL	CHANNEL	MANUFACTURER_ID	FUNC	TYPE	RORG	

Figure 23 – UTE Telegram Structure

6.2.7 Signal telegram

SIGNAL telegrams are used to encode generic system conditions independent of specific sensor functionality of the device. Examples of such system conditions are internal energy level, available ambient energy and backup battery status.

SIGNAL telegrams are identified by having the RORG field of the data telegram set to 0xD0. After that, the SIGNAL type (what is reported) is identified by the 1 byte long MID field which is followed by the data corresponding to this SIGNAL type. Figure 24 below shows the structure of a SIGNAL telegram.

SIGNAL RORG	SIGNAL Type (MID)	SIGNAL Data
0xD0	0x00 ... 0xFF	Depending on SIGNAL Type

Figure 24 – SIGNAL Telegram Structure

Table 8 below lists the SIGNAL types supported by STM 550 together with their reported data.

MID	Content	Data
0x06	Energy status (remaining energy)	1 byte integer value (expressing %) Valid values: 0 ... 100
0x0D	Energy delivery of the harvester	1 byte Enumeration Valid values: 0x00 (best) ... 0x04 (worst)
0x0E	Radio disabled	Transmitted upon entering standby mode No additional data
0x10	Backup battery status	1 byte integer value (expressing %) Valid values: 0 ... 100

Table 8 – Supported SIGNAL Types

The transmission of each supported SIGNAL telegram can be individually enabled and disabled using the via the SIGNAL configuration register of the NFC interface as described in chapter 10.5.9.

STM 550 will transmit each of the enabled SIGNAL telegram types once for every *n* EEP (data) telegrams with *n* being a configurable parameter that can be set via the SIGNAL configuration register of the NFC interface as described in chapter 10.5.9.

The default setting is that each enabled SIGNAL telegram type will be transmitted once every 32 EEP (data) telegrams, i.e. STM 550 will provide an update about the enabled internal parameters approximately once every 32 minutes.

7 Security

STM 550 implements the security handling functions as specified in the EnOcean security specification: <https://www.enocean-alliance.org/sec/>

7.1 Basic concepts

Security for radio transmission addresses two main issues:

- Unauthorized interception (reception and correct interpretation) of transmitted data
In doing so, a third (unauthorized) party is able to understand the content of a received content.
- Unauthorized transmission of radio telegrams
In doing so, a third (unauthorized) party is able to transmit a radio telegram that is treated by a receiver as valid request.

Somewhat loosely speaking, the goal of security has to be preventing an unauthorized person (often referred to as an *Attacker*) both from learning about the current state of a system and from actively changing it.

These goals can be achieved via techniques such as telegram encryption, telegram authorization and dynamic security key modification. All three techniques will be reviewed in the subsequent chapters for reference.

7.1.1 Telegram encryption

The goal of telegram encryption is to prevent unauthorized receivers from correctly interpreting the content of a telegram. To do so, the original (plain text) data is *encrypted* with a *security key* thus transforming it into encrypted, unreadable data. Only when the correct key is known it is possible to transform – *decrypt* – the encrypted data into readable data again.

Figure 25 below shows the concept.

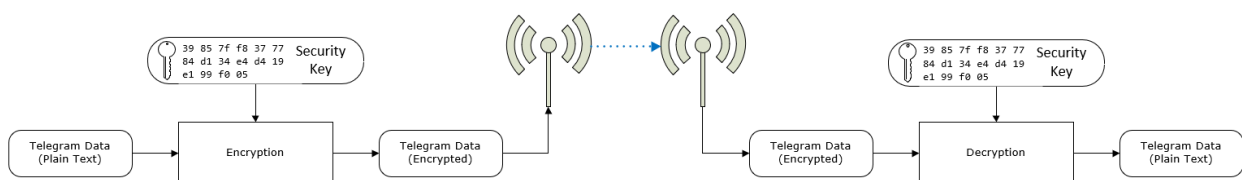


Figure 25 – Telegram encryption

If the same security key is used for encryption at the sender and decryption at the receiver then this is called a *symmetric* key algorithm. AES (AES128 / AES256) and DES / 3DES algorithms are typical examples of this category. TCM 515 uses this approach.

7.1.2 Telegram authentication

The goal of telegram authentication is to prevent unauthorized senders to transmit apparently valid commands causing the receiver to perform unauthorized actions. Telegram authentication is typically used in conjunction with telegram encryption.

Telegram authentication works by creating a *signature* (often called *Cipher-based Message Authentication Code* or *CMAC* in short) based on the content of the telegram and the security key.

Essentially, the telegram data is transformed via a defined algorithm using the security key into a unique, fixed size signature (where typical signature lengths include 24 bit, 32 bit, 512 bit and 1024 bit) which identifies this specific message.

For an optimal signature algorithm, the likelihood of two different telegrams creating the same telegram signature should be inversely proportional to the signature size, so for instance for 24 bit signatures the likelihood should be one in 16 million and for 32 bit signatures it should be one in 4 billion.

Conceptually the correspondence between telegram content and telegram signature is like the one between a person and a fingerprint:

- Each person has a unique fingerprint. Based on a given person one can determine her or his fingerprint
- Based on a given fingerprint one can check if it originated from a given person
- Based on the fingerprint one cannot determine any other properties of the person

For telegram authentication purposes, the telegram signature (CMAC) is usually appended to the telegram content so that the telegram content and the telegram signature are transmitted together.

When the receiver receives such a telegram, it will itself calculate the telegram signature (CMAC) based on the security key and the telegram content. The receiver then compares the signature that it calculated with the signature it received as part of the telegram.

If both signatures are the same, then the receiver can establish two important facts:

1. The telegram originates from a sender knowing the security key
2. The content of the telegram has not been modified after the sender added the signature to it

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Figure 26 below illustrates the concept of telegram authorization via a telegram signature.

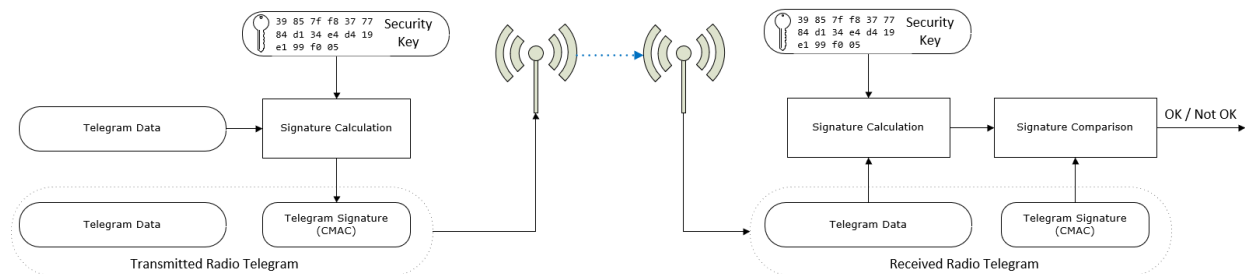


Figure 26 – Telegram authentication via telegram signature

One fundamental problem with both telegram encryption and telegram authorization is that using the same input data (plain text) with the same security key will always result in the same encrypted data and the same signature. This enables attacks based on monitoring previous system behaviour. If an attacker has observed that a certain data telegram results in a certain light being turned on, then he could use this information to identify - or even actively send - similar telegrams in the future. This type of attack is often called *Replay Attack* since it works by reusing (replaying) previously transmitted (valid) data telegrams.

In order to prevent this type of attack, either the telegram data or the security material (e.g. the security key or the initialization vector / nonce) must change to ensure that identical input data does not create identical encrypted radio telegrams.

The change of telegram data or security material is done based on a sequence of values that are guaranteed to be unique so that the same value will not be used twice. This sequence of changing values is often referred to as *Rolling Code* or *RLC* in short.

In order to prevent replay of an already received message, the receiver will keep track of the latest received RLC value and will only accept telegrams with an RLC value that comes later (after the last received RLC value) in the sequence.

Both sender and receiver have to know the mechanism how to generate the next RLC (the next value in the sequence) based on the current RLC (the current value of the sequence). The easiest - and most common - approach for that is to use the value of a monotonously incrementing counter that is incremented for each telegram.

Such counter is often referred to as *Sequence Counter*; the current value of the sequence counter is the RLC.

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Figure 27 below shows the concept of adding an RLC to the telegram data.

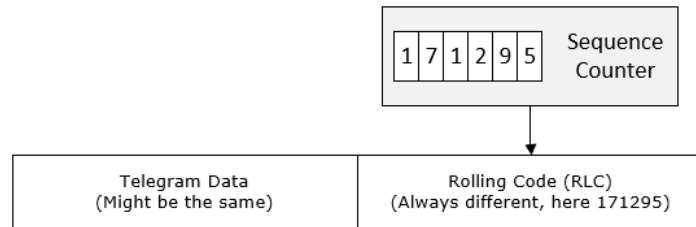


Figure 27 – Addition of an RLC to the telegram data

EnOcean radio systems use an approach where the RLC is used to change the security material (specifically, the initialization vector – often called *Nonce* - used by the security algorithms together with the security key) to ensure that the encrypted telegram payload and the telegram signature change even when the content of the telegram itself stays the same.

Figure 28 below illustrates this approach.

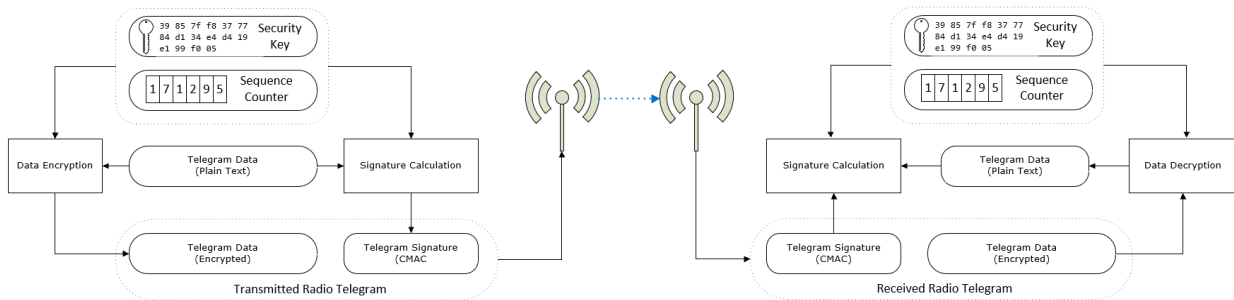


Figure 28 – Encryption and authentication in EnOcean radio systems

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7.2 Security parameters

The following security parameters are used to define secure communication based on EnOcean Alliance security specification between a sender and a receiver:

- EURID (Device ID of the sender)
- Rolling code size and current value
- Signature (MAC) size
- Security algorithm

Those parameters are communicated from STM 550 to the receiver during teach-in either via a secure teach-in telegram, via NFC configuration or via the QR code of STM 550.

7.2.1 EURID

The EURID identifies the sender of each radio telegram using a unique 6 byte value. The EURID of an EnOcean device is assigned at manufacturing and cannot be changed.

7.2.2 Security key

The security key is a random 128 Bit (16 byte) value that is known only to the sender and the receiver(s). It is the basis for encryption, decryption and authentication of telegrams.

7.2.3 Rolling code

The rolling code is a monotonously incrementing counter used to modify the content of encrypted secure telegrams as described in chapter 7.1. The rolling code is generated by the sender and monitored by the receiver.

STM 550 uses by default a 32 bit rolling code counter which will be initialized to 0 at the time of production and increment whenever a telegram is transmitted.

The receiver will store the most recently received rolling code value and only accept telegrams with higher rolling code values to avoid retransmission of previously transmitted messages.

7.2.4 Security algorithm

STM 550 uses variable AES based on AES-128 to encrypt and authenticate its telegrams.

7.3 STM 550 security implementation

STM 550 supports both standard and high security modes as defined by EnOcean Alliance. The security mode can be selected both via the LRN button and via the NFC interface.

For high security mode, the default security level format (SLF) is set to use a 4 byte sequence counter to generate a 4 byte signature.

For backwards compatibility with legacy systems, it is possible to select via NFC a legacy mode using a 3 byte sequence counter to generate a 3 byte signature.

STM 550 will use secure chained telegrams (SEC_CDM) if high security mode is used and the telegram payload (including rolling code and CMAC) exceeds 14 byte.

8 Commissioning

Commissioning is the process by which STM 550 is learned into a receiver (actuator, controller, gateway, etc.).

The following two tasks are required in this process:

- **Device identification**
The receiver needs to know how to uniquely identify this specific STM 550 device. This is achieved by using a unique 48 Bit ID (Source Address) for each STM 550 device.
- **Security parameter exchange**
The receiver needs to be able to authenticate radio telegrams from STM 550 in order to ensure that they originate from this specific device and have not been modified. This is achieved by exchanging a 128 Bit random security key used by STM 550 to authenticate its radio telegrams.

STM 550 provides the following options for these tasks:

- **Radio-based commissioning**
STM 550 can communicate its parameters via special radio telegrams (teach-in telegrams) to the intended receiver. Transmission of such telegrams can be triggered by using the LRN button.
- **QR code commissioning**
Each STM 550 device contains an optically readable Quick Response (QR) Code which identifies its ID and its security key. This QR code can be read by a suitable commissioning tool (e.g. smartphone) which is already part of the network into which STM 550 will be commissioned. The commissioning tool then communicates these parameters to the intended receiver of STM 550 radio telegrams.
- **NFC commissioning**
Each STM 550 device contains an NFC interface allowing to read device parameters and to configure a user-defined security key.

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8.1 Radio-based commissioning

Radio-based commissioning is used to associate STM 550 with other devices by sending a dedicated radio telegram (a so-called commissioning telegram).

To do so, STM 550 can transmit a dedicated teach-in telegram identifying its relevant parameters as discussed in chapter 6.2. Transmission of the teach-in telegram is triggered by pressing the LRN button or via the NFC interface by setting the function mode to Learn Mode as described in chapter 10.5.11.

Radio-based commissioning mode is intended for applications where NFC commissioning cannot be used. Radio-based commissioning can be disabled via NFC if the device is operating in high security mode to prevent transmission of the security key over the air.

8.2 QR code commissioning

QR code-based commissioning reads the required parameters from a dedicated QR code in the product label (described in chapter 5.4). The parameters are encoded according to the ANSI/MH10.8.2-2013 industry standard.

The QR code on the product label in chapter 5.4 encodes the following string:

```
30S0412F30E+1P000B0000004C+13ZF9714BC5E8345CA72DFC78DB7514624F+30PS6201-K516
+2PDA03+S01577501000097
```

Identifier	Length of data (excluding identifier)	Value
30S	8 characters	EURID (hex)
13Z	32 characters	Security Key (hex)
30P	Up to 10 characters	Ordering Code (E6201-K516)
2P	4 characters	Step Code - Revision (CA-01)
S	14 characters	Serial Number

Table 9 – QR code format

From this content, it is possible to extract the device address (000012345678) and the security key (0123456789ABCDEF0123456789ABCDEF) which can then be used to commission STM 550 into a receiver and to decrypt and authenticate STM 550 data telegrams as described in chapter 7.

8.3 Commissioning via NFC interface

STM 550 implements NFC Forum Type 2 Tag functionality as specified in the ISO/IEC 14443 Part 2 and 3 standards.

This NFC functionality can be used to read the device address and to configure the security key of STM 550 as described in chapter 10.

9 NFC interface

STM 550 implements an NFC configuration interface that can be used to access (read and write) the STM 550 configuration memory and thereby configure the device as described in the following chapters.

NFC communication distance is for security reasons set to require direct contact between the NFC reader and the STM 550 device.



Note that STM 550 temporarily stops operation to ensure configuration data integrity while the NFC reader is connected to the NFC interface of STM 550.

STM 550 will automatically resume operation approximately 5 seconds after the NFC reader has been disconnected.

Care has to be taken not to configure unsupported values as product behavior is undefined in that case.

9.1 NFC interface parameters

The NFC interface of STM 550 uses NFC Forum Type 2 Tag functionality as specified in the ISO/IEC 14443 Part 2 and 3 standards. It is implemented using an NXP NT3H2111 Mifare Ultralight tag.

9.2 NFC access protection

Protected data access is only possible after unlocking the configuration memory with the correct 32 bit PIN code. By default, the protected area is locked and the default pin code for unlocking access is `0x0000E500`.

The default pin code shall be changed to a user-defined value as part of the installation process. This can be done by unlocking the NFC interface with the old PIN code and then writing the new PIN code to page `0x4B`.

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9.3 Using the NFC interface

Using the NFC interface requires the following:

- NFC reader
This can be either a USB NFC reader connected to a PC or a suitable smartphone with NFC functionality
- NFC SW with read, write, PIN lock, PIN unlock and PIN change functionality
This can be either a PC application or an Android / iOS app

These options are described in more detail below.

9.3.1 PC with dedicated NFC reader

For PC-based applications, EnOcean recommends the TWN4 Multitech 2 HF NFC Reader (order code T4BT-FB2BEL2-SIMPL) from Elatec RFID Systems (sales-rfid@elatec.com).

This reader is shown in Figure 29 below.



Figure 29 – Elatec TWN4 MultiTech Desktop NFC Reader

9.3.2 Android or iOS smartphone with NFC

NFC functionality is available in certain Android (e.g. Samsung Galaxy S7 / S8 / S9 / S10) and iOS (iPhone7 or newer, firmware version 13 or newer) smartphones.

EnOcean provides the configuration app “EnOcean Tool” for these devices which can be downloaded directly from the respective app store.

At the time of writing, the tool was available from the Google Play Store using this link: <https://play.google.com/store/apps/details?id=de.enocean.easytool&hl=en>

Likewise, the tool was available from the Apple Store using this link: <https://apps.apple.com/de/app/enocean-tool/id1497283202>

9.4 NFC interface functions

For a detailed description about the NFC functionality, please refer to the ISO/IEC 14443 standard.

For specific implementation aspects related to the NXP implementation in NT3H2111, please refer to the NXP documentation which at the time of writing was available under this link:

https://www.nxp.com/docs/en/data-sheet/NT3H2111_2211.pdf

The following chapters summarize the different functions for reference purposes.

9.4.1 NFC interface state machine

Figure 30 below shows the overall state machine of the NFC interface.

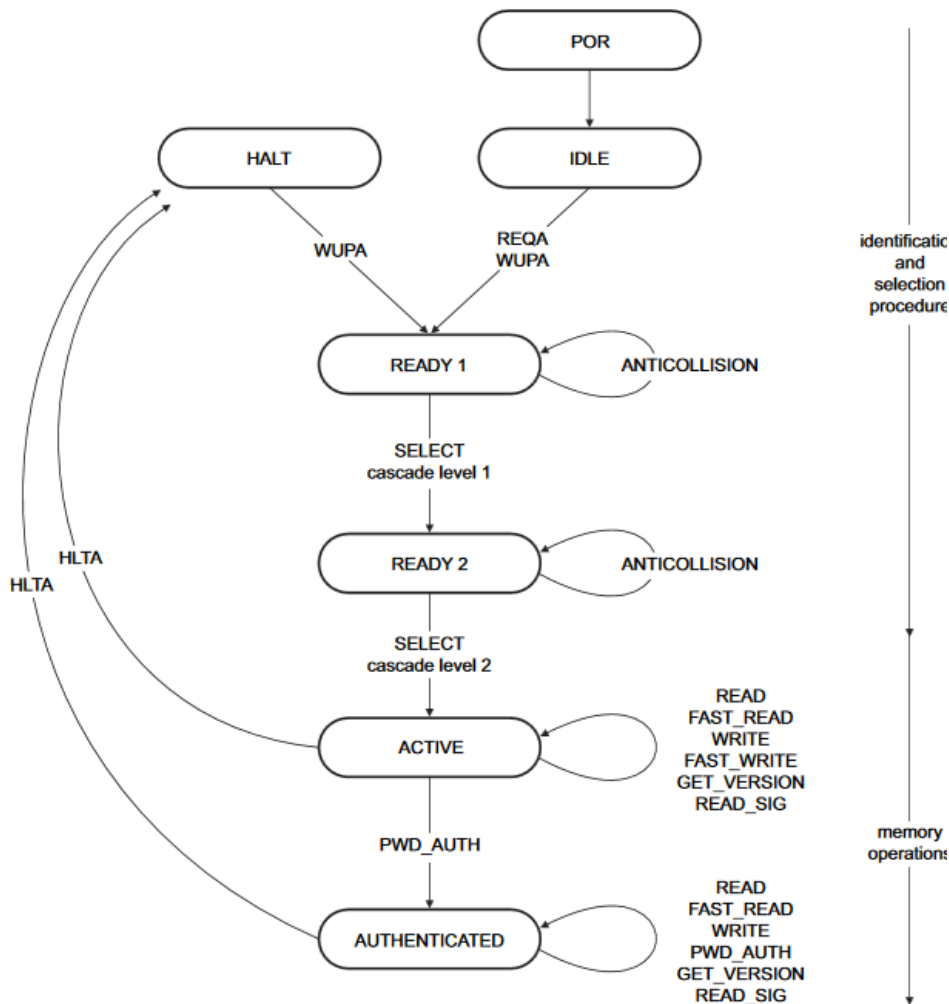


Figure 30 – NFC interface state machine

9.4.2 IDLE state

IDLE is the waiting state after a Power-On Reset (POR), i.e. after the NFC tag has been introduced into the magnetic field of the NFC reader.

The NFC tag exits the IDLE state towards the READY 1 state when either a REQA or a WUPA command is received from the NFC reader. REQA and WUPA commands are transmitted by the NFC reader to determine whether any cards are present within its working range.

Any other data received by the NFC tag while in IDLE state is discarded and the NFC tag will remain in IDLE state.

9.4.3 READY 1 state

READY 1 is the first UID resolving state where the NFC tag resolves the first 3 bytes of the 7 byte UID using the ANTICOLLISION or SELECT commands for cascade level 1.

READY 1 state is exited after the SELECT command from cascade level 1 with the matching complete first part of the UID has been executed. The NFC tag then proceeds into READY 2 state where the second part of the UID is resolved.

9.4.4 READY 2 state

READY 2 is the second UID resolving state where the NFC tag resolves the remaining 4 bytes of the 7 byte UID using the ANTICOLLISION or SELECT commands for cascade level 2.

READY 2 state is exited after the SELECT command from cascade level 2 with the matching complete part of the UID has been executed. The NFC tag then proceeds into ACTIVE state where the application-related commands can be executed.

9.4.5 ACTIVE state

ACTIVE state enables read and write accesses to unprotected memory.

If access to protected memory is required, then the tag can transition from the ACTIVE state to AUTHENTICATED state by executing the PWD_AUTH command in conjunction with the correct 32 bit password.

9.4.6 Read command

The READ command requires a start page address, and returns the 16 bytes of four NFC tag pages (where each page is 4 byte in size).

For example, if the specified address is 03h then pages 03h, 04h, 05h, 06h are returned. Special conditions apply if the READ command address is near the end of the accessible memory area.

Figure 31 below shows the read command sequence.

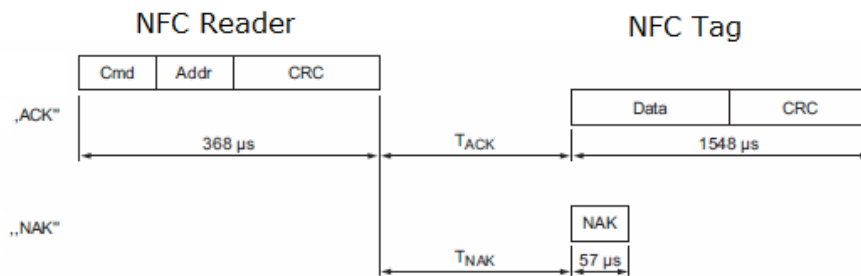


Figure 31 – NFC read command sequence

9.4.7 Write command

The WRITE command requires a start page address and returns writes 4 bytes of data into that page.

Figure 32 below shows the read command sequence.

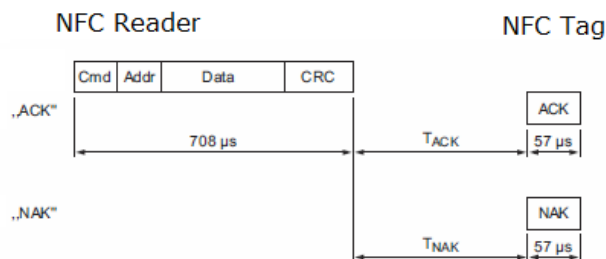


Figure 32 – NFC write command sequence

9.4.8 Password authentication (PWD_AUTH) command

The protected memory area can be accessed only after successful password verification via the PWD_AUTH command.

The PWD_AUTH command takes the password as parameter and, if successful, returns the password authentication acknowledge, PACK.

Figure 33 below shows the password authentication sequence.

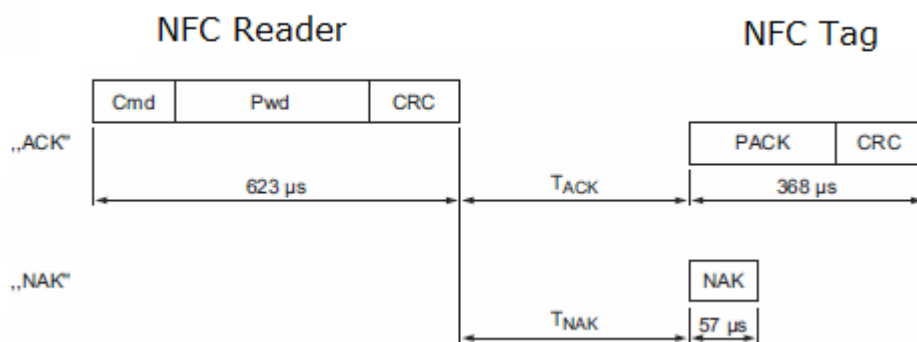


Figure 33 – Password authentication sequence

After successful authentication, the password can be changed by writing the new password to memory page 0x4B.

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10 NFC registers

The NFC memory is organized in pages (smallest addressable unit) where each page contains 4 byte of data. Several pages with similar functionality form an NFC memory area.

10.1 NFC memory areas

These NFC pages are allocated into the following areas:

- Device Identification NDEF string (Public read-only access; no PIN required)
This area contains an NDEF string identifying key device parameters
- User Information NDEF string (Public read / write access; no PIN required)
This area allows any user to read or write information about the device such as the intended installation location or additional instructions
- PUBLIC INFO (Public read-only access; no PIN required)
This area contains key device parameters in binary format
- NFC HEADER (Public read-only access; no PIN required)
This area contains information about the NFC revision
- INTERNAL DATA (Non-accessible)
This area contains calibration values and internal parameters and cannot be used
- CONFIGURATION (Read and Write access, PIN required)
This area contains device configuration registers
- USER DATA (Read and Write access, PIN required)
This area allows the user to store up to 64 byte of data such as information about the installation or any other data that the user deems relevant.
STM 550 does not use this area and does not interpret its content in any way.

The organization of the STM 550 NFC memory map is shown in Table 10 below.

NFC Address	Memory Area	Content
0x00 ... 0x1D	PRODUCT NDEF	Device identification NDEF string (read-only)
0x1E ... 0x30	USER NDEF	User information NDEF string (read / write access)
0x31 ... 0x33	NFC HEADER	NFC memory revision (read-only)
0x34 ... 0x3F	INTERNAL DATA	Internal data (Do not use)
0x40 ... 0x54	CONFIGURATION	Configuration registers (Read / Write, PIN protected)
0x55 ... 0xCF	INTERNAL DATA	Internal data (Do not use)
0xD0 ... 0xDF	USER DATA	User data (64 byte read / write access, PIN protected)
0xE0 ... 0xEB	INTERNAL DATA	Internal data (Do not use)

Table 10 – STM 550 NFC memory areas

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10.2 Device identification NDEF

The NDEF area contains a device identification string using the NDEF (NFC Data Exchange Format) standard that is readable by most NFC-capable reader devices (including smartphones).

An example device identification string from the NDEF area of STM 550 could be:

```
6PEN0+30S000012345678+1P000B0000004C+30PS6221-K516+2PDB06+12Z01234567891234
+3C31+01000000
```

This NDEF string encodes the parameters shown in Table 11 below.

Identifier	Length of data (excl. identifier)	Value
6P	3 characters	Standard: "ENO"
30S	12 characters	EURID (6 byte, variable)
1P	12 characters	EnOcean Alliance Product ID STM 550: „000B0000004C“ STM 550U: „000B0000004D“ STM 550J: „000B0000004E“
30P	10 characters	Ordering Code STM 550: "S6201-K516" STM 550U: "S6251-K516" STM 550J: "S6261-K516"
2P	4 characters	Step Code and Revision ("DB06")
12Z	14 characters	NFC UID (14 byte, globally unique)
3C	2 characters	Header Start Address ("31" = 0x31)
16S	8 characters	SW Version Example: 01000000 = 01.00.00.00

Table 11 – NDEF Parameters

10.3 User information NDEF

The NDEF area allows the user to store a string of up to 64 characters starting at page 0x20 and ending at page 0x2F. The remaining pages in this area (0x1E, 0x1F, 0x30) provide the required NDEF formatting information and cannot be changed by the user.

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10.4 NFC HEADER

The NFC HEADER area contains information about the NFC memory structure and can therefore be used to distinguish between different NFC memory layouts.

10.4.1 NFC HEADER area structure

The structure of the NFC HEADER area is shown in Figure 34 below.

NFC Address	Content			
	Byte 0	Byte 1	Byte 2	Byte 3
0x31	START (0xE0)	LENGTH (0x0A)	VERSION (0x01)	OEM MSB (0x00)
0x32	OEM LSB (0x0B)	DEVICE_IDENTIFIER (0x000003)		
0x33	REVISION (0x03)	END (0xFE)	UNUSED (0x0000)	

Figure 34 – NFC HEADER area structure

The NFC HEADER contains the following fields:

- **START**
This field identifies the start of the NFC header and is always set to 0xE0
- **LENGTH**
This field identifies the length of the NFC header.
For STM 550, this field is set to 0x0A since the header structure is 10 bytes long
- **VERSION**
This field identifies the major revision and is set to 0x01 currently
- **OEM**
The 16 bit OEM field identifies the manufacturer of the device so that manufacturer-specific layout implementations can be determined.
For EnOcean GmbH this field is set to 0x000B
- **DEVICE_IDENTIFIER**
The 24 bit DEVICE_IDENTIFIER field identifies an individual device from the range of devices manufactured by the manufacturer specified in the OEM field.
For STM 550, the DEVICE_IDENTIFIER is set to 0x000003
- **REVISION**
The REVISION field identifies the exact revision of the NFC layout. This REVISION will be incremented whenever a change to the NFC layout is made.
- **END**
The END field identifies the end of the NFC header and is always set to 0xFE. The number of bytes from START to END must equal LENGTH, otherwise the NFC header is invalid.

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10.5 CONFIGURATION

The CONFIGURATION area allows configuring the device parameters and is therefore the most important part of the NFC memory. Configuration registers larger than 8 bit use big endian format, i.e. the most significant byte comes first.

Read or write access to the CONFIGURATION area is only possible after issuing a PWD_AUTH command as described in chapter 9.4.8 using the correct 32 bit PIN code.

10.5.1 Using the NFC configuration functionality

Before making any changes to the default configuration, be sure to familiarize yourself with the functionality of the device and the effect of the intended changes. STM 550 will not accept the setting of non-valid values for its parameters. If any parameter is non-valid then all changes made will be rejected and the previous configuration will be restored.

10.5.2 CONFIGURATION area structure

The structure of the CONFIGURATION area is shown in Figure 35 below.

NFC Address	Content			
	Byte 0	Byte 1	Byte 2	Byte 3
0x40	PRODUCT_ID (as characters in ASCII format) Will be copied to NDEF Header			
0x41				
0x42				
0x43	RFU			
0x44	USER_KEY (128 Bit) (Write Only - Will be reset to zero after it has been copied to internal memory) Can be used as alternative security key instead of FACTORY_KEY			
...				
0x47				
0x48	SECURITY_KEY_MODE	SECURITY_CFG	RFU	
0x49	EEP	SIGNAL	LED_MODE	FUNCTIONAL_MODE
0x4A	STANDARD_TX_INTERVAL		RFU	
0x4B	NFC_PIN_CODE			
0x4C	THRESHOLD_CFG1	THRESHOLD_CFG2	LIGHT_SENSOR_CFG	ACC_SENSOR_CFG
0x4D	SOLAR_THRESHOLD		SOLAR_TX_INTERVAL	
0x4E	LIGHT_THRESHOLD		LIGHT_TX_INTERVAL	
0x4F	ACCELERATION_THRESHOLD		ACCELERATION_TX_INTERVAL	
0x50	TEMPERATURE_THRESHOLD		TEMPERATURE_TX_INTERVAL	
0x51	HUMIDITY_THRESHOLD		HUMIDITY_TX_INTERVAL	
0x52	RFU		MAGNET_CONTACT_TX_INTERVAL	
0x53	RFU		RFU	
0x54	LIGHT_TEST_RESULT		RFU	

Figure 35 – CONFIGURATION area structure

10.5.3 NFC_PIN_CODE

The PIN code used to protect access to the NFC CONFIGURATION memory area should be changed from the default value to a user-specific value to avoid unauthorized access to the device configuration.

To do so, first authenticate with the current PIN code and then write the new PIN code (32 bit value) to the NFC_PIN_CODE register.

10.5.4 PRODUCT_ID

The EnOcean Alliance Product ID uniquely identifies each product within the EnOcean Alliance ecosystem. The Product ID consists of a 2 byte manufacturer identification code (assigned by EnOcean Alliance) and a 4 byte product identification code (assigned by the manufacturer).

EnOcean has been assigned the manufacturer identification code 0x000B. EnOcean has assigned the following product identification codes to STM 550:

```
STM 550: 0000004C
STM 550U: 0000004D
STM 550J: 0000004E
```

The PRODUCT_ID register contains the Product ID in ASCII format (12 characters) and allows changing both manufacturer and product identification. Changing the PRODUCT_ID will also cause the PRODUCT ID field in the NDEF string (described in chapter 10.2) to be updated.

Figure 36 below shows the structure of the PRODUCT_ID register. This register contains the sequence of 12 ASCII characters (1 byte each) starting with CH0 and ending with CH11.

PRODUCT_ID											
CH0	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH11
Manufacturer ("000B")				Product ID ("0000004C", "0000004D" or "0000004E")							

Figure 36 – PRODUCT_ID

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10.5.5 USER_KEY

Each STM 550 module is pre-programmed at the factory with a randomly generated 128 bit security key (FACTORY_KEY). This key will by default be used to encrypt and authenticate STM 550 radio telegrams when operating in high security mode.

In certain applications it might be desirable to assign a different (user-defined) security key (USER_KEY) during commissioning to STM 550. This can be done by writing the user-defined security key to the USER_KEY register and setting KEY SELECTION field of the SECURITY_KEY_MODE to 0b01 as described below.

Note that the USER_SECURITY_KEY register is a write-only register meaning that it is not possible to read back a user-defined security key.

10.5.6 SECURITY_KEY_MODE

The register SECURITY_KEY_MODE allows selecting if FACTORY_KEY or USER_KEY should be used to encrypt and authenticate STM 550 radio telegrams in high security mode. In addition, it allows disabling the transmission of Secure Teach-in telegrams in order to protecting the security key.

Note that if the transmission of a secure teach-in telegram has been disabled and is subsequently re-enabled then USER_KEY will be reset to FACTORY_KEY.

Figure 37 below shows the structure of the SECURITY_KEY_MODE register.

SECURITY_KEY_MODE (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				SECURE LRN TELEGRAM		KEY SELECTION	

Figure 37 – SECURITY_KEY_MODE register

The encoding for the KEY SELECTION bit field is shown in Table 12 below.

KEY SELECTION	Security key used
0b00 (Default)	FACTORY_KEY is used
0b01	USER_KEY is used
0b10, 0b11	Reserved, do not use

Table 12 – KEY SELECTION bit field encoding

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The encoding for the SECURE LRN TELEGRAM bit field is shown in Table 13 below.

SECURE LRN TELEGRAM	Secure LRN telegram
0b00 (Default)	Secure LRN Telegram (containing security key) enabled
0b01	Secure LRN Telegram (containing security key) disabled
0b10, 0b11	Reserved, do not use

Table 13 – SECURE LRN TELEGRAM bit field encoding

10.5.7 SECURITY_MODE

The register SECURITY_MODE identifies the security settings used by STM 550. Figure 38 below shows the structure of the SECURITY_MODE register.

SECURITY_MODE (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				SECURITY FORMAT		SECURITY MODE	

Figure 38 – SECURITY_MODE register

The encoding for the SECURITY MODE bit field is shown in Table 14 below.

SECURITY MODE	Security Mode
0b00 (Default)	Standard, can be changed by the user with the LRN button
0b01	High Security, can be changed by the user with the LRN button
0b10	Standard, cannot be changed by the user with the LRN button
0b11	High Security, cannot be changed by the user with the LRN button

Table 14 – SECURITY MODE bit field encoding

The encoding for the SECURITY FORMAT bit field is shown in Table 15 below.

SECURITY FORMAT	Advertising Interval
0b00 (Default)	32 bit RLC and 32 bit CMAC
0b01	24 bit RLC and 24 bit CMAC
0b10, 0b11	Reserved, do not use

Table 15 – SECURITY FORMAT bit field encoding

10.5.8 EEP

The EEP register determines the EnOcean Equipment Profile (EEP) used by STM 550 for the transmission of data telegrams. Figure 39 below shows the structure of the EEP register.

EEP (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				EEP			

Figure 39 – EEP register

The encoding used by the SIZE bit field is shown in Table 16 below.

EEP	EnOcean Equipment Profile
0b0000 (Default)	D2-14-41
0b0001	D2-14-40
0b0010	A5-02-05
0b0011	A5-04-03
0b0100	A5-06-03
0b0101	A5-06-02
0b0110	D5-00-01
0b0111	A5-14-05
0b1000	A5-04-01
Others	Reserved, do not use

Table 16 – EEP bit field encoding

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10.5.9 SIGNAL

STM 550 supports reporting its energy status, the current energy delivery of the harvester and the backup battery status via SIGNAL telegrams as described in chapter 6.2.7.

The type and the transmission rate of SIGNAL telegrams is controlled by the SIGNAL register shown in Figure 40 below.

SIGNAL (Default: 0x31)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TRANSMISSION RATE				RFU	BACKUP BATTERY	ENERGY DELIVERY	ENERGY STATUS

Figure 40 – SIGNAL register

STM 550 supports the following SIGNAL types:

- ENERGY STATUS (MID 0x06)
- ENERGY DELIVERY (MID 0x0D)
- BACKUP BATTERY STATUS (MID 0x10)

Transmission of these supported SIGNAL types can be enabled by setting the associated configuration bit in the SIGNAL register to 0b1 and disabled by setting the associated configuration bit to 0b0.

By default, the reporting of the energy status (MID 0x06) is enabled while the reporting of energy delivery (MID 0x0D) and backup battery status (MID 0x10) is disabled.

STM 550 allows additionally to configure at what rate each enabled SIGNAL telegram will be sent using the TRANSMISSION RATE bit field as shown in Table 17 below. If more than one SIGNAL telegram is enabled, then this rate will apply to all enabled telegrams. The SIGNAL telegrams will be transmitted at different times (i.e. not all at the same time one after another) in that case.

TRANSMISSION RATE	Transmission rate for SIGNAL telegrams
0b0000	One SIGNAL telegram every 8 data telegrams
0b0001	One SIGNAL telegram every 16 data telegrams
0b0010	One SIGNAL telegram every 24 data telegrams
0b0011 (Default)	One SIGNAL telegram every 32 data telegrams
	...
0b1111	One SIGNAL telegram every 128 data telegrams

Table 17 – TRANSMISSION RATE bit field encoding

10.5.10 LED_MODE

The LED_MODE register determines the brightness of the LED. Figure 41 below shows the structure of the LED_MODE register.

LED_MODE (Default: 0x01)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU						LED	

Figure 41 – LED_MODE register

The encoding used by the LED bit field is shown in Table 18 below.

LED	LED Intensity
0b00	LED is disabled
0b01 (Default)	LED is enabled
0b10, 0b11	Reserved (Do not use)

Table 18 – LED bit field encoding

10.5.11 FUNCTIONAL_MODE

The FUNCTIONAL_MODE register can be used to switch between the different functional modes of STM 550 as described in chapter 2.2.

Figure 42 below shows the structure of the FUNCTIONAL_MODE register.

FUNCTIONAL_MODE (Default: 0x00, OOB: 0x01)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				MODE			

Figure 42 – FUNCTIONAL_MODE register

The encoding used by the MODE bit field is shown in Table 19 below.

MODE	Functional Mode
0b0000 (Default)	Standard Operation Mode
0b0001	Standby (Sleep) Mode
0b0010	Learn Mode
0b0011	Function Test Mode
0b0100	Illumination Test Mode
0b0101	Acceleration Test Mode
0b0111	Factory Reset
Others	Reserved (Do not use)

Table 19 – MODE bit field encoding

Note that the default configuration (after factory reset) is standard operation mode while the out of box configuration (for new devices) is standby (sleep) mode.

10.5.12 STANDARD_TX_INTERVAL

STM 550 uses a standard reporting interval which can be automatically adjusted based on sensor readings as described in chapter 2.4. The standard reporting interval is set by the register STANDARD_TX_INTERVAL shown in Figure 43 below.

STANDARD_TX_INTERVAL (Default: 0x003C)				
Bit 15	Bit 14	...	Bit 1	Bit 0
STANDARD INTERVAL				

Figure 43 – STANDARD_TX_INTERVAL register

The encoding used by the STANDARD INTERVAL bit field is shown in Table 20 below.

STANDARD INTERVAL	Standard Reporting Interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 20 – STANDARD INTERVAL bit field encoding

10.5.13 THRESHOLD_CFG1

STM 550 can reduce the reporting interval based on the illumination of the solar cell, the light illumination of the light level sensor, the temperature or the humidity as described in chapter 2.4.

The use of these reduced reporting intervals is enabled by the THRESHOLD_CFG1 register shown in Figure 44 below.

THRESHOLD_CFG1 (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
HUMIDITY SENSOR		TEMP SENSOR		LIGHT SENSOR		SOLAR CELL	

Figure 44 – THRESHOLD_CFG1 register

The encoding used by the SOLAR CELL bit field is shown in Table 21 below.

SOLAR CELL	Reporting interval reduction based on solar cell illumination
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if illumination below threshold
0b10	Enabled, Reporting interval reduction if illumination above threshold
0b11	Reserved (Do not use)

Table 21 – SOLAR CELL bit field encoding

The encoding used by the LIGHT SENSOR bit field is shown in Table 22 below.

LIGHT SENSOR	Reporting interval reduction based on light sensor illumination
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if illumination below threshold
0b10	Enabled, Reporting interval reduction if illumination above threshold
0b11	Reserved (Do not use)

Table 22 – LIGHT SENSOR bit field encoding

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The encoding used by the TEMP SENSOR bit field is shown in Table 23 below.

TEMP SENSOR	Reporting interval reduction based on temperature
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if temperature below threshold
0b10	Enabled, Reporting interval reduction if temperature above threshold
0b11	Reserved (Do not use)

Table 23 – TEMP SENSOR bit field encoding

The encoding used by the HUMIDITY SENSOR bit field is shown in Table 24 below.

HUMIDITY SENSOR	Reporting interval reduction based on temperature
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if humidity below threshold
0b10	Enabled, Reporting interval reduction if humidity above threshold
0b11	Reserved (Do not use)

Table 24 – HUMIDITY SENSOR bit field encoding

10.5.14 THRESHOLD_CFG2

STM 550 can reduce the reporting interval based on the acceleration sensor status and the magnet contact status as described in chapter 2.4.

The use of these reduced reporting intervals is enabled by the THRESHOLD_CFG2 register shown in Figure 45 below.

THRESHOLD_CFG2 (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU				MC SENSOR		ACC SENSOR	

Figure 45 – THRESHOLD_CFG2 register

The encoding used by the ACC SENSOR bit field is shown in Table 25 below.

ACC SENSOR	Reporting interval reduction based on acceleration
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Reserved (Do not use)
0b10	Enabled, Reporting interval reduction if acceleration above threshold
0b11	Reserved (Do not use)

Table 25 – ACC SENSOR bit field encoding

The encoding used by the MC SENSOR bit field is shown in Table 26 below.

MC SENSOR	Reporting interval reduction based on magnet contact status
0b00 (Default)	Disabled (No reporting interval reduction)
0b01	Enabled, Reporting interval reduction if contact is open
0b10	Enabled, Reporting interval reduction if contact is closed
0b11	Reserved (Do not use)

Table 26 – MC SENSOR bit field encoding

10.5.15 LIGHT_SENSOR_CFG

STM 550 allows the user to select if the reported light level is the one measured by the ambient light sensor or the one measured by the solar cell. Refer to chapter 4.1 for a description of the ambient light sensor and to chapter 4.2 for a description of the solar cell functionality.

The selection between these two option is made using the LIGHT_SENSOR_CFG register shown in Figure 46 below.

LIGHT_SENSOR_CFG (Default: 0x00)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU							INPUT SELECTION

Figure 46 – LIGHT_SENSOR_CFG register

The encoding used by the INPUT SELECTION bit field is shown in Table 27 below.

INPUT SELECTION	Input value used for illumination reporting
0b0 (Default)	Ambient light sensor
0b1	Solar cell

Table 27 – INPUT SELECTION bit field encoding

10.5.16 ACC_SENSOR_CFG

The operation parameters of the acceleration sensor in STM 550 can be configured using the ACC_SENSOR_CFG registers shown in Figure 47 below. Refer to chapter 4.5 for a description of the acceleration sensor function.

ACC_SENSOR_CFG (Default: 0x14)							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RFU			WAKE	SAMPLING RATE		FULL SCALE	

Figure 47 – ACC_SENSOR_CFG register

The encoding used by the FULL SCALE bit field is shown in Table 25 below.

FULL SCALE	Full scale value of the acceleration sensor
0b00 (Default)	+ -2 g
0b01	+ -4 g
0b10	+ - 8g
0b11	+ - 16g

Table 28 – FULL SCALE bit field encoding

The encoding used by the SAMPLING RATE bit field is shown in Table 29 below.

SAMPLING RATE	Sampling rate of the acceleration sensor
0b00	1.6 Hz
0b01 (Default)	12.5 Hz
0b10	25 Hz
0b11	50 Hz

Table 29 – SAMPLING RATE bit field encoding

The wake-on-acceleration function can be enabled and disabled using the WAKE bit field as shown in Table 30 below.

WAKE	Wake-on-acceleration
0b0	Disabled
0b1 (Default)	Enabled

Table 30 – WAKE bit field encoding

10.5.17 SOLAR_THRESHOLD

If reduction of the reporting interval based on the solar cell light level has been enabled then the light level threshold is defined by SOLAR_THRESHOLD register as shown in Figure 48 below.

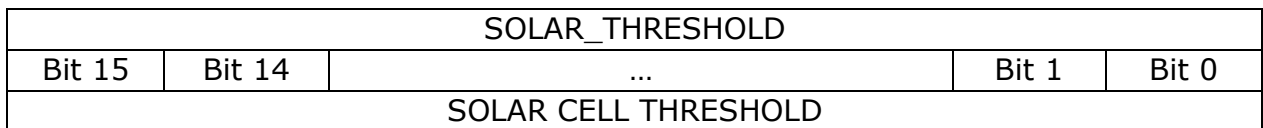


Figure 48 – SOLAR_THRESHOLD register

The encoding used by the SOLAR CELL THRESHOLD bit field is shown in Table 31 below.

SOLAR CELL THRESHOLD	Threshold
0x0000	0 lux (minimum setting)
...	...
0x00C8 (Default)	200 lux seconds (default setting)
...	...
0xFFFF	65535 lux (maximum setting)

Table 31 – SOLAR CELL THRESHOLD bit field encoding

The default setting for the solar cell threshold is 200 lux which corresponds to good availability of ambient light for harvesting.

10.5.18 SOLAR_TX_INTERVAL

If solar cell illumination-controlled reporting has been enabled and the solar cell illumination is above the defined threshold then the resulting reporting interval will be determined by the register SOLAR_TX_INTERVAL shown in Figure 49 below.

SOLAR_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
SOLAR CELL INTERVAL				

Figure 49 – SOLAR_TX_INTERVAL register

The encoding used by the SOLAR CELL INTERVAL bit field is shown in Table 32 below.

SOLAR CELL INTERVAL	Solar cell illumination-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 32 – SOLAR CELL INTERVAL bit field encoding

The default reporting interval while solar cell illumination is above the solar cell illumination threshold is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

10.5.19 LIGHT_THRESHOLD

If reduction of the reporting interval based on the light level measured by the light sensor has been enabled then the light level threshold is defined by LIGHT_THRESHOLD register as shown in Figure 50 below.

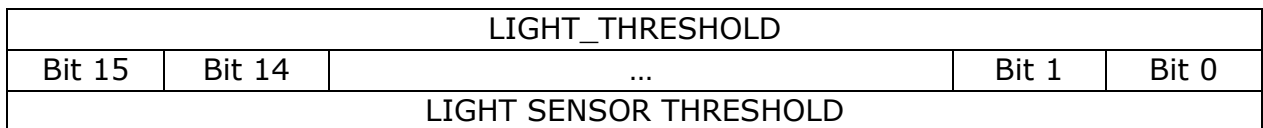


Figure 50 – LIGHT_SENSOR_THRESHOLD register

The encoding used by the LIGHT SENSOR THRESHOLD bit field is shown in Table 33 below.

LIGHT SENSOR THRESHOLD	Threshold
0x0000	0 lux (minimum setting)
...	...
0x00C8 (Default)	200 Lux seconds (default setting)
...	...
0xFFFF	65535 lux (maximum setting)

Table 33 – LIGHT_SENSOR_THRESHOLD bit field encoding

The default setting for the light sensor threshold is 200 lux.

10.5.20 LIGHT_TX_INTERVAL

If solar cell illumination-controlled reporting has been enabled and the solar cell illumination is above the defined threshold then the resulting reporting interval will be determined by the register LIGHT_TX_INTERVAL shown in Figure 51 below.

LIGHT_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
LIGHT SENSOR INTERVAL				

Figure 51 – LIGHT_TX_INTERVAL register

The encoding used by the LIGHT SENSOR INTERVAL bit field is shown in Table 34 below.

LIGHT SENSOR INTERVAL	Light sensor illumination-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 34 – LIGHT SENSOR INTERVAL bit field encoding

The default reporting interval while the light level measured by the light sensor is above the light sensor illumination threshold is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

10.5.21 ACCELERATION_THRESHOLD

If reduction of the reporting interval based on acceleration has been enabled then the acceleration threshold is defined by ACCELERATION_THRESHOLD register as shown in Figure 52 below.

Note that this threshold is also used for the wake-on-acceleration function as described in chapter 4.5.

ACCELERATION_THRESHOLD				
Bit 15	Bit 14	...	Bit 1	Bit 0
ACCELERATION_THRESHOLD				

Figure 52 – ACCELERATION_THRESHOLD register

The encoding used by the ACCELERATION_THRESHOLD bit field is shown in Table 35 below.

ACCELERATION_THRESHOLD	Threshold
0b000000	Reserved (Do not use)
0b000001 (Default)	1/64 * Full scale
0b000010	2/64 * Full scale
...	
0b111110	62/64 * Full scale
0b111111	63/64 * Full scale

Table 35 – ACCELERATION_THRESHOLD bit field encoding

10.5.22 ACCELERATION_TX_INTERVAL

If acceleration-controlled reporting has been enabled and the acceleration exceeds the defined acceleration threshold then the resulting reporting interval will be determined by the register ACCELERATION_TX_INTERVAL shown in Figure 53 below.

ACCELERATION_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
ACCELERATION INTERVAL				

Figure 53 – ACCELERATION_TX_INTERVAL register

The encoding used by the ACCELERATION INTERVAL bit field is shown in Table 36 below.

ACCELERATION INTERVAL	Acceleration-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 36 – ACCELERATION INTERVAL bit field encoding

The default reporting interval when the acceleration meets the defined threshold criteria is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

10.5.23 TEMPERATURE_THRESHOLD

If reduction of the reporting interval based on the temperature has been enabled then the temperature threshold is defined by TEMPERATURE_THRESHOLD register as shown in Figure 54 below.

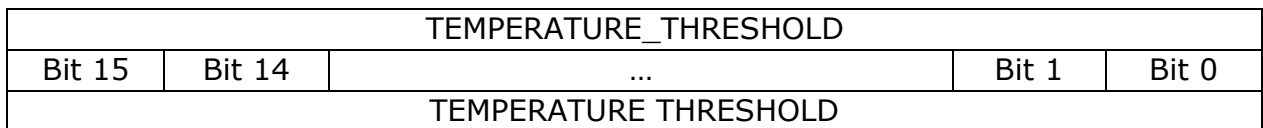


Figure 54 – TEMPERATURE_THRESHOLD register

The encoding used by the TEMPERATURE_THRESHOLD bit field is shown in Table 37 below.

TEMPERATURE_THRESHOLD	Threshold
0x0000	0.0°C
0x0001	0.1°C
...	
0x028A	65.0°C
Reserved	
0xFF38	-20.0°C
...	
0xFFFF	-0.1°C

Table 37 – TEMPERATURE_THRESHOLD bit field encoding

10.5.24 TEMPERATURE_TX_INTERVAL

If temperature-controlled reporting has been enabled and the temperature meets the defined threshold criteria then the resulting reporting interval will be determined by the register TEMPERATURE_TX_INTERVAL shown in Figure 55 below.

TEMPERATURE_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
TEMPERATURE INTERVAL				

Figure 55 – TEMPERATURE_TX_INTERVAL register

The encoding used by the TEMPERATURE INTERVAL bit field is shown in Table 38 below.

TEMPERATURE INTERVAL	Temperature-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 38 – TEMPERATURE INTERVAL bit field encoding

The default reporting interval when the temperature meets the defined threshold criteria is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

10.5.25 HUMIDITY_THRESHOLD

If reduction of the reporting interval based on the humidity has been enabled then the humidity threshold is defined by HUMIDITY_THRESHOLD register as shown in Figure 56 below.

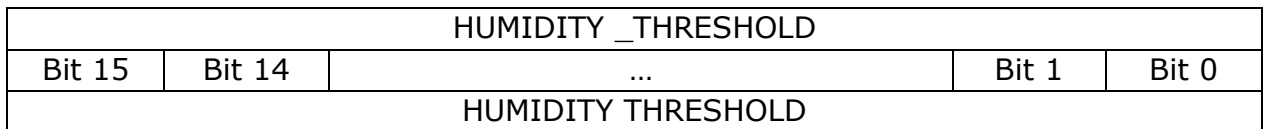


Figure 56 – HUMIDITY_THRESHOLD register

The encoding used by the HUMIDITY_THRESHOLD bit field is shown in Table 39 below.

HUMIDITY_THRESHOLD	Threshold
0x0000	0.0 % r.h.
0x0001	0.5 % r.h.
...	
0x00C7	99.5 %r.h.
0x00C8	100.0 %r.h.
Others	Reserved (Do not use)

Table 39 – HUMIDITY_THRESHOLD bit field encoding

10.5.26 HUMIDITY_TX_INTERVAL

If humidity-controlled reporting has been enabled and the humidity meets the defined threshold criteria then the resulting reporting interval will be determined by the register HUMIDITY_TX_INTERVAL shown in Figure 57 below.

HUMIDITY_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
HUMIDITY INTERVAL				

Figure 57 – HUMIDITY_TX_INTERVAL register

The encoding used by the HUMIDITY INTERVAL bit field is shown in Table 40 below.

HUMIDITY INTERVAL	Humidity-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 40 – HUMIDITY INTERVAL bit field encoding

The default reporting interval when the humidity meets the defined threshold criteria is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

10.5.27 MAGNET_CONTACT_TX_INTERVAL

If magnet contact-controlled reporting has been enabled and the magnet contact state matches the state configured in the THRESHOLD_CFG2 register then the resulting reporting interval will be determined by the register MAGNET_CONTACT_TX_INTERVAL shown in Figure 58 below.

MAGNET_CONTACT_TX_INTERVAL				
Bit 15	Bit 14	...	Bit 1	Bit 0
MAGNET CONTACT INTERVAL				

Figure 58 – MAGNET_CONTACT_TX_INTERVAL register

The encoding used by the MAGNET CONTACT INTERVAL bit field is shown in Table 41 below.

MAGNET CONTACT INTERVAL	Magnet contact-based reporting interval
0x0000, 0x0001, 0x0002	Not supported (Do not use)
0x0003	3 seconds (minimum setting)
...	...
0x003C (Default)	60 seconds (default setting)
...	...
0xFFFF	65535 seconds (maximum setting)

Table 41 – MAGNET CONTACT INTERVAL bit field encoding

The default reporting interval when the magnet contact state meets the defined state is 60 seconds. This can be reduced according to user requirements keeping in mind the energy balance.

10.5.28 ILLUMINATION_TEST_RESULT

If STM 550 has executed an illumination test as described in chapter 2.3.5 then the result (the measured average light level at the solar cell) will be stored in the ILLUMINATION_TEST_RESULT register shown in Figure 59 below.

ILLUMINATION_TEST_RESULT (Default Setting: 0x0000)				
Bit 15	Bit 14	...	Bit 1	Bit 0
ILLUMINATION TEST RESULT				

Figure 59 – ILLUMINATION_TEST_RESULT register

10.6 USER DATA

The USER DATA area allows the user to read and write up to 64 byte of data after entering the correct PIN code. Typical use cases include storing information about the configuration or the installation of the device (by whom, when, what).

STM 550 does not use this area and does not interpret its content in any way.

11 Mechanical interface

11.1 STM 550

STM 550 implements the mechanical interface of the PTM 21x module which is described in more detail in this chapter. All dimensions and tolerances given are in millimetres unless otherwise noted.

11.1.1 Top view

Figure 60 below shows the STM 550 module seen from the top. The cut view along the A-A line is shown in chapter 11.1.3.

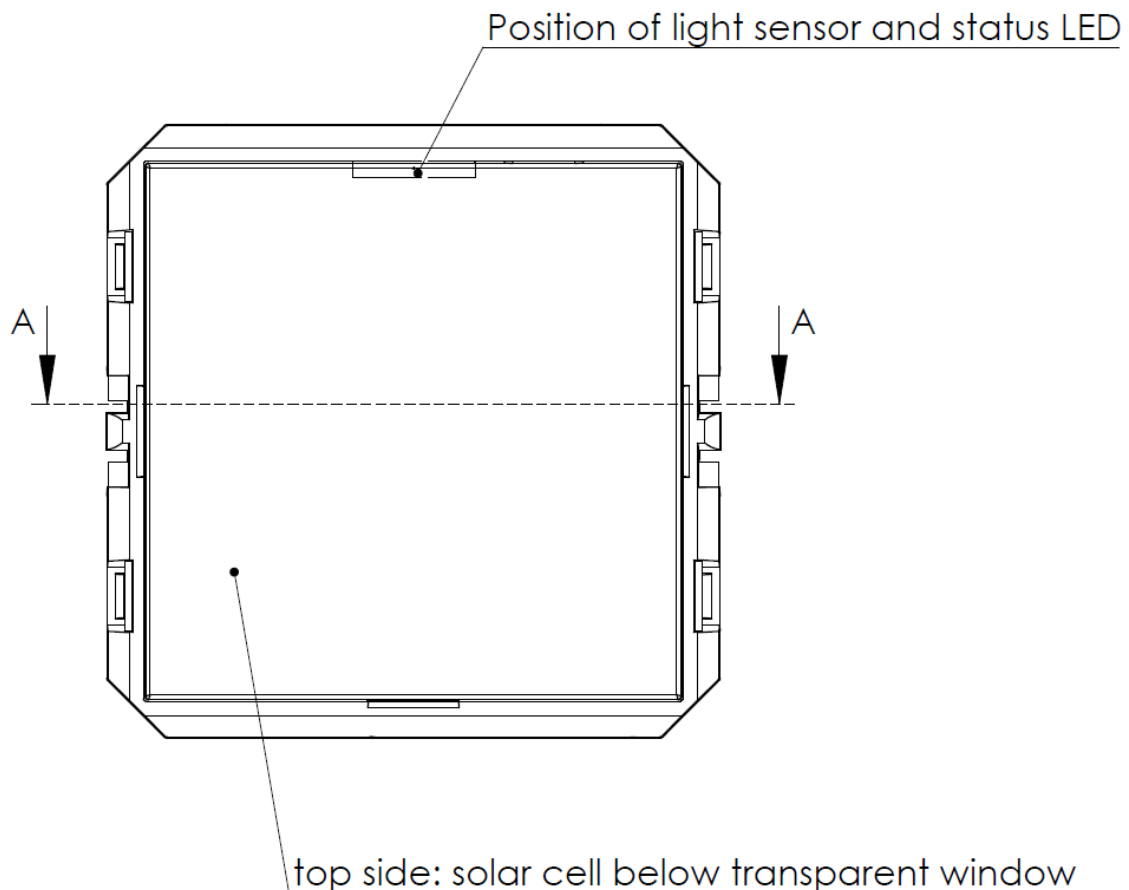


Figure 60 – Top view of STM 550 module

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11.1.2 Bottom view

Figure 61 below shows the STM 550 module seen from the bottom.

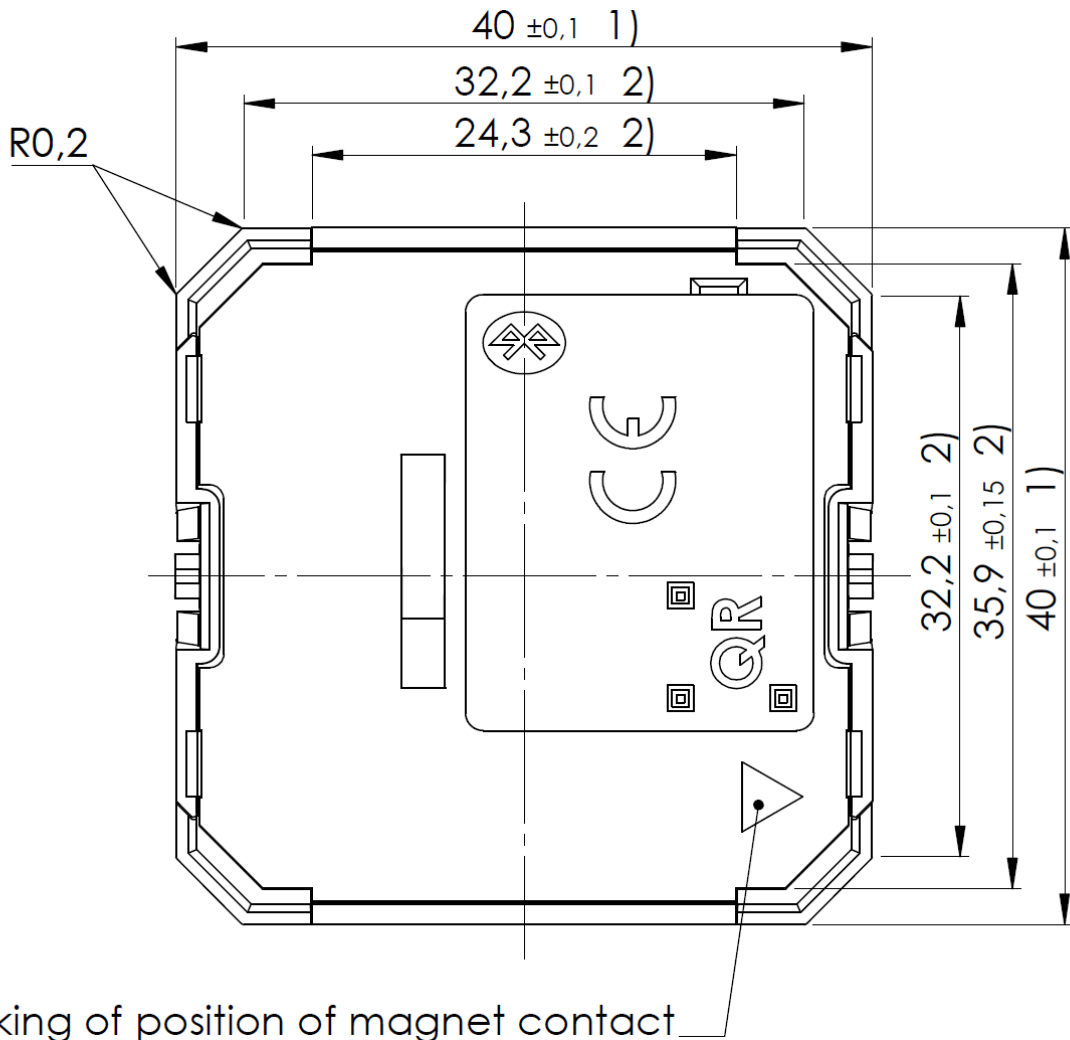


Figure 61 – Bottom view of STM 550 module

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11.1.3 Cut view (A-A)

Figure 62 below shows a cut along the A-A line of Figure 60 and highlights the area of the mounting structure (B region) in more detail.

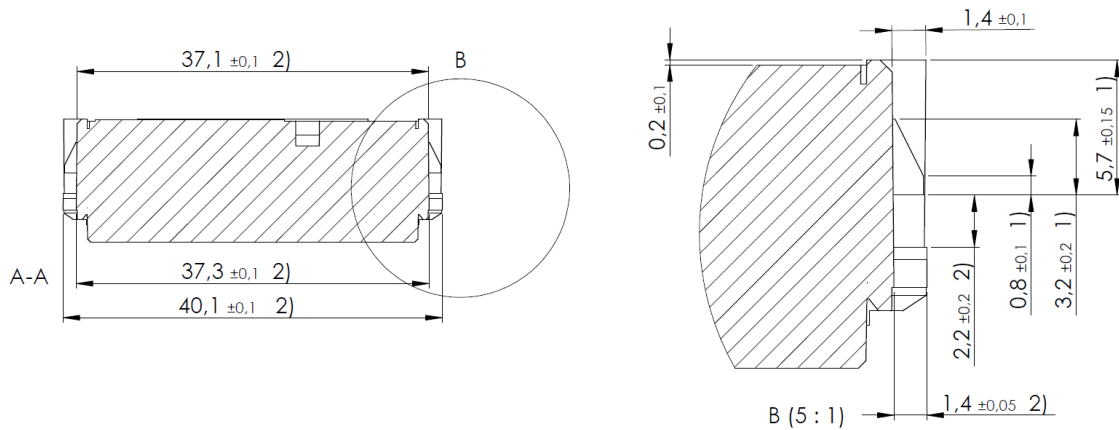


Figure 62 – Cut view (A-A) of STM 550 module

11.1.4 Front view

Figure 63 below shows the STM 550 module seen from the front.

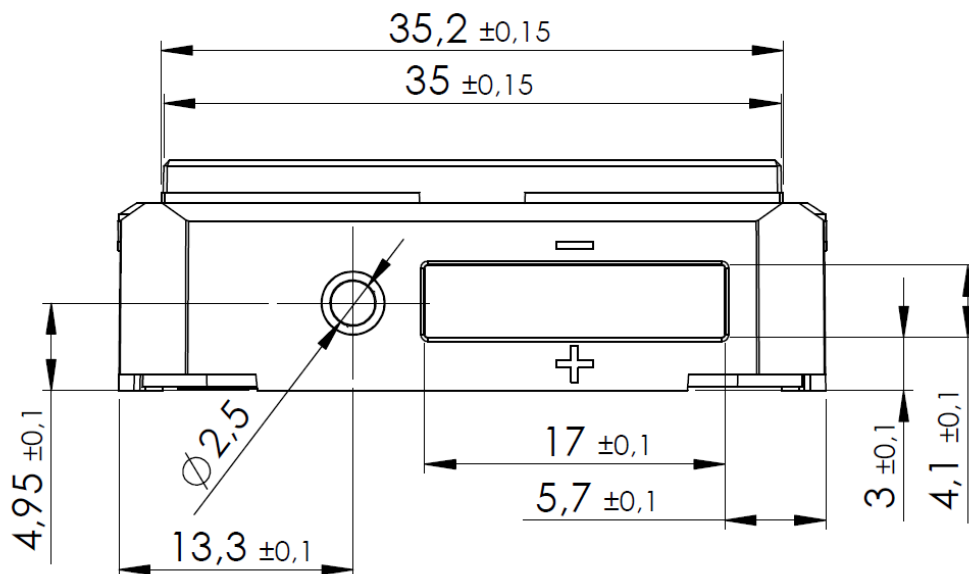


Figure 63 – Front view of STM 550 module

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11.1.5 Side view

Figure 64 below shows the STM 550 module seen from the side.

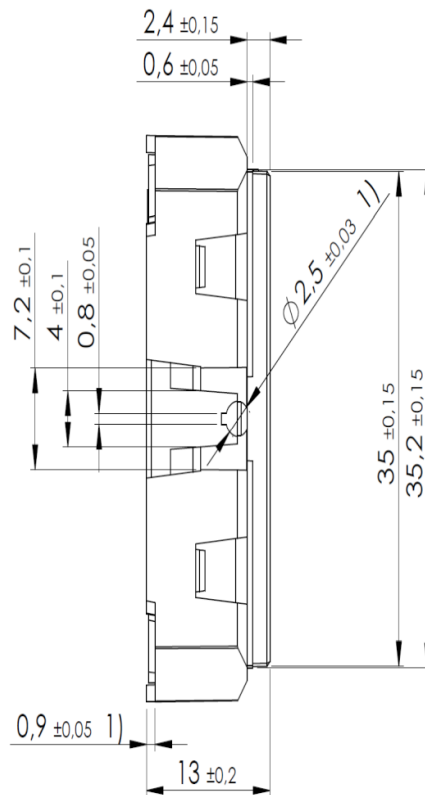


Figure 64 – Side view of STM 550 module

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11.2 EMSI

EMSI integrates the STM 550 module into a housing. Figure 65 below shows the mechanical interface of EMSI.

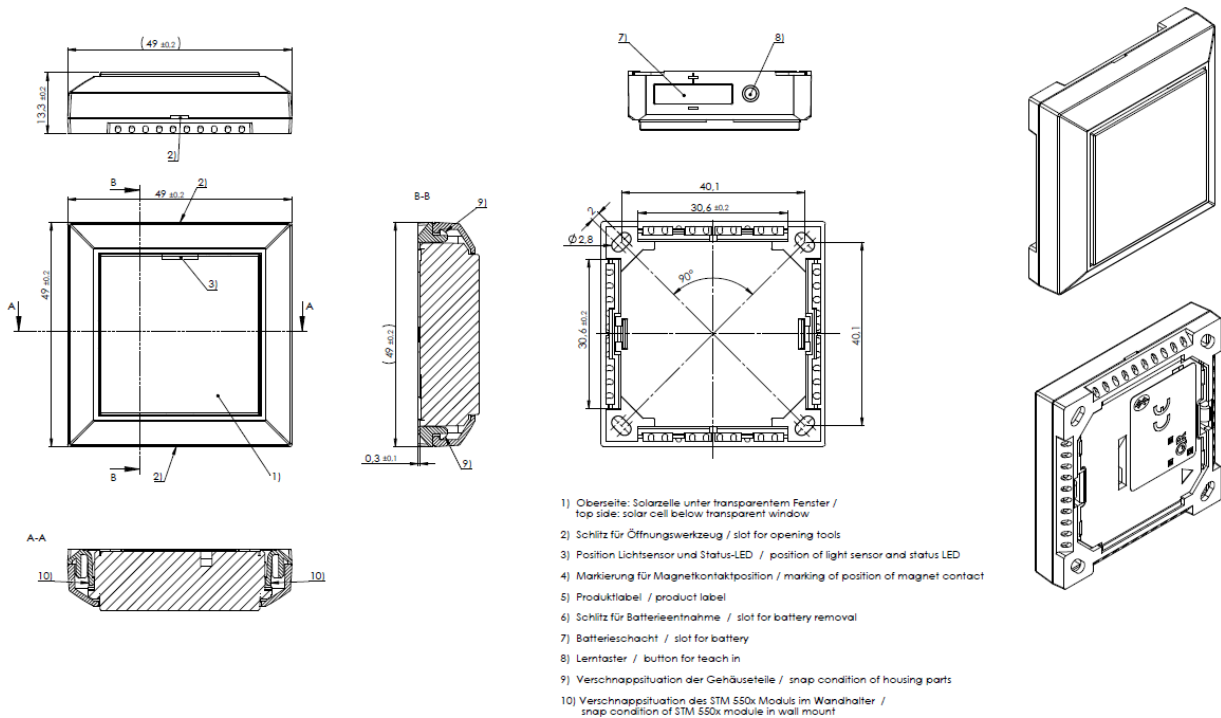


Figure 65 – Mechanical interface of EMSI

EMSI can be attached to a variety of surfaces using the provided adhesive pad. Figure 66 below shows the dimensions of this pad.

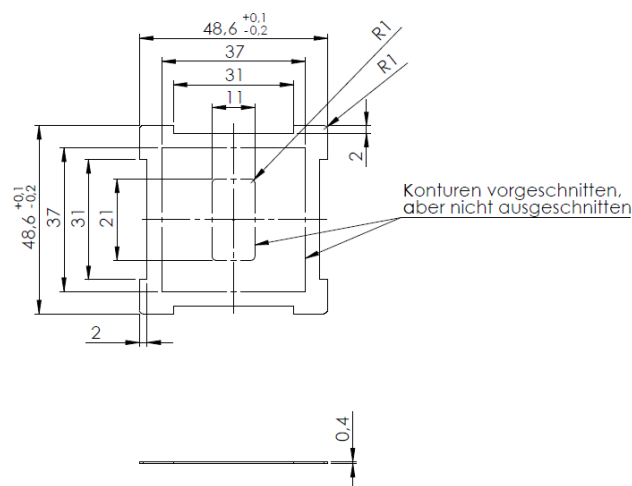


Figure 66 – Adhesive pad

12 Installation recommendations

12.1 Setup instructions

Before installing STM 550 into its intended location, a sufficient initial charge should be provided to STM 550 and its correct operation should be verified.

To do so, follow these steps:

1. Place STM 550 under bright light (daylight or bright light source) for 5 minutes to provide an initial charge
2. Press the LRN button once so that STM 550 will start operation
3. Check that STM 550 transmits radio telegrams at the configured update interval (by default once every 60 seconds). The LED will blink every time a telegram is transmitted (unless this has been disabled via NFC).
4. Use a suitable receiver (for instance a PC with EnOcean USB 300 receiver running DolphinView visualization SW) to capture the STM 550 data telegrams and verify that all required parameters are reported. Consider disabling the measurement and reporting of non-required parameters (especially acceleration) to conserve energy.
5. Check the light level reported by STM 550 at the intended installation location to verify that sufficient light is available for the energy harvesting functionality. Maximize the amount of light available for energy harvesting as much as possible.
6. Make sure that the installation location is chosen according to the guidelines in the subsequent chapters to maximize the measurement accuracy.

After those steps, STM 550 is ready for installation into its intended location.

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12.2 Installation location

Before selecting the installation location for STM 550, please consider the following general guidance:

- STM 550 is designed for indoor use only
- STM 550 should be operated within a temperature range of -5°C ... $+45^{\circ}\text{C}$
Avoid excessive heat-up due to direct exposure to sun light
- STM 550 should be used within a humidity range of 0% ... 90% r.h.
Avoid environments with condensation (for instance the area around entry doors to air-conditioned rooms)
- STM 550 should not be used on fast moving or strongly vibrating parts.
If used as a door sensor, STM 550 should be attached to the stationary door frame

Additional, application-specific guidance (for specific use cases) is provided in subsequent chapters.

12.3 Mounting options (EMSI only)

EMSI combines the STM 550 module with a wall mount and a design frame into a ready to use product. The wall mount can be attached to most surfaces either by screws (using the four screw holes) or via an adhesive pad. Mounting via an adhesive pad is the recommended approach.

EMSI includes a suitable two-zone adhesive pad as shown in below. Use of the outer adhesive zone (marked blue) is sufficient for most applications and enables easy removal of EMSI from the mounting surface. The inner adhesive zone (marked green) can be additionally used if firm attachment to the mounting surface is desired.

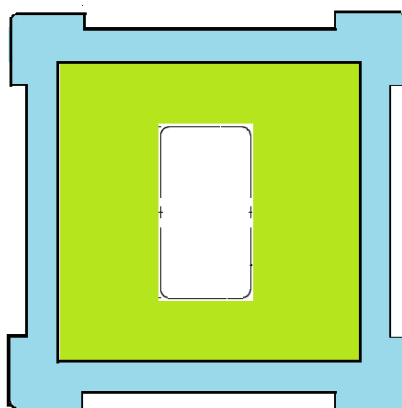


Figure 67 – Adhesive zones

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12.4 Temperature and humidity sensor

The dedicated temperature and humidity sensor integrated into STM 550 accurately measures and reports temperature and humidity present at its surface. To achieve the best possible accuracy, it is important to consider the following points:

- **Installation height**
The sensor should be installed at a height that is representative for the use case. For the case of an office, the sensor should be mounted at desk level.
- **Sun light or heat exposure**
The sensor should be mounted such that it is not directly exposed to sunlight or heat (e.g. close to a radiator)
- **Disturbances**
The sensor should be mounted such that the influence from disturbances such as the air stream from air condition units is minimized. Consider also the possible temperature gradient between wall and room when mounting the sensor directly onto a wall.
- **Air flow**
The sensor should be mounted such that the airflow from the target measurement area towards the air inlets is maximized. This will ensure the lowest possible response time of the sensor. Avoid mounting the sensor in niches or slots with little air flow. The sensor should be mounted such that the airflow from the target measurement area towards the air inlets is maximized. This will ensure the lowest possible response time of the sensor. Avoid mounting the sensor in niches or slots with little air flow. When designing your own housing around an STM 550 module, consider the location of the ventilation slots (there are four of them in total) as shown in Figure 68. Housing design has to maximize the airflow towards these slots focusing especially on the two slots nearest to the sensor which are marked with a green dot.

Figure 68 below shows the location of the temperature and relative humidity (TRH) sensor and of the ventilation slots.

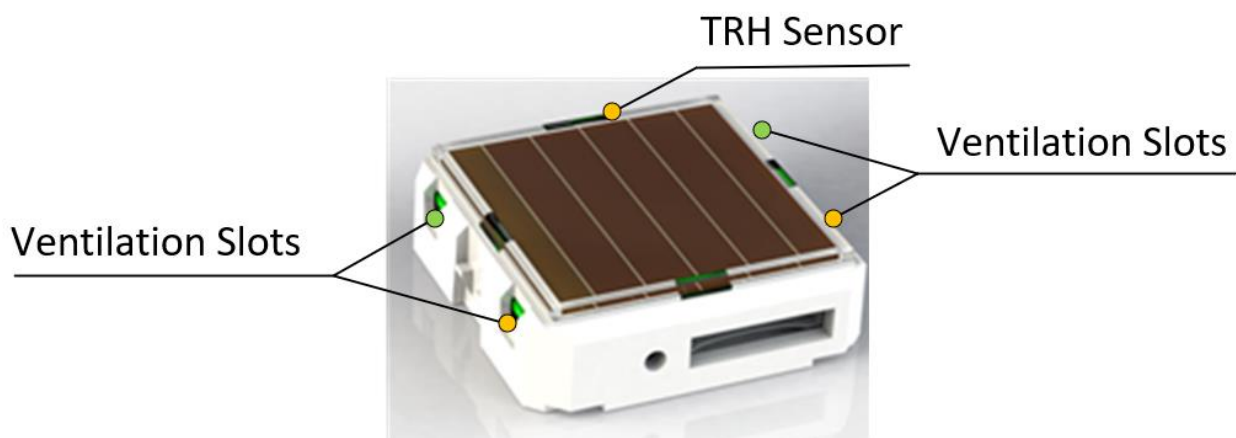


Figure 68 – Location of temperature / humidity sensor and ventilation slots

12.5 Acceleration sensor

Acceleration sensors measure the acceleration vector in all three dimensions $\{x; y; z\}$. This sensor can be used both to determine the device orientation (relative to the earth gravity vector) and the device acceleration (e.g. if a device is moved or shaken). Both cases will be discussed below.

12.5.1 Device orientation use cases

If an object is at rest or continuously moving at the same speed, then the magnitude of the vector will be 1g (i.e. the magnitude of the measured acceleration vector will be equivalent to the magnitude of the earth gravity vector at the location of the device which will be approximately 1g).

Measuring the magnitude in all three dimensions allows determining the orientation of an object relative to the earth gravity as shown in Figure 69 below. This illustration assumes that STM 550 is placed flat onto a surface parallel to the earth surface (e.g. a table).

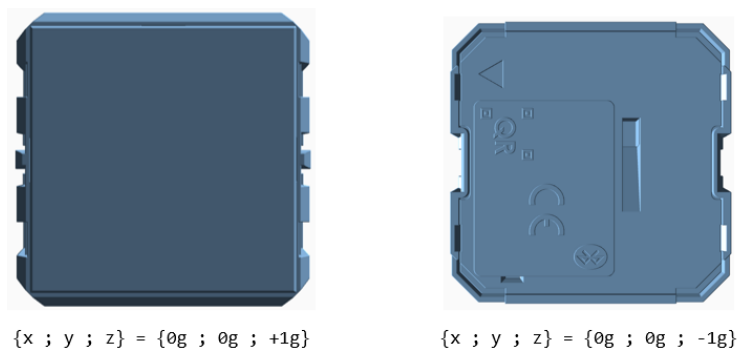


Figure 69 – Acceleration vector based on device orientation

Note that it is not possible to distinguish cases where STM 550 is rotated but its orientation relative to the direction of earth gravity remains the same. This is shown in Figure 70 below for the case of device rotation across the earth gravity vector axis.

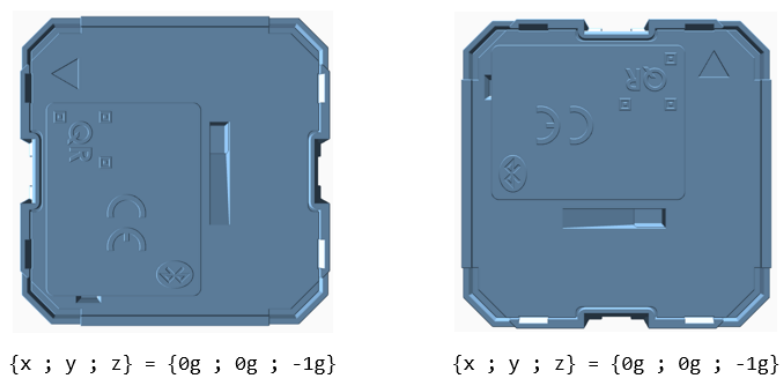


Figure 70 – Device rotation across earth gravity vector axis

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Figure 71 below illustrates this issue in a practical use case:

- The position of the window in the left case (window tilt) could be detected if STM 550 is attached to the window part that is tilted since the orientation of STM 550 relative to the gravity vector would change
- The position of the window in the right case (window open / rotation) could not be detected if STM 550 is attached to the window part that is rotated since the orientation of STM 550 relative to the gravity vector would remain the same. STM 550 would however report that the window was moved due to the resulting acceleration and deceleration.

The surface towards which STM 550 is attached should therefore be chosen to maximize orientation changes relative to the gravity vector.

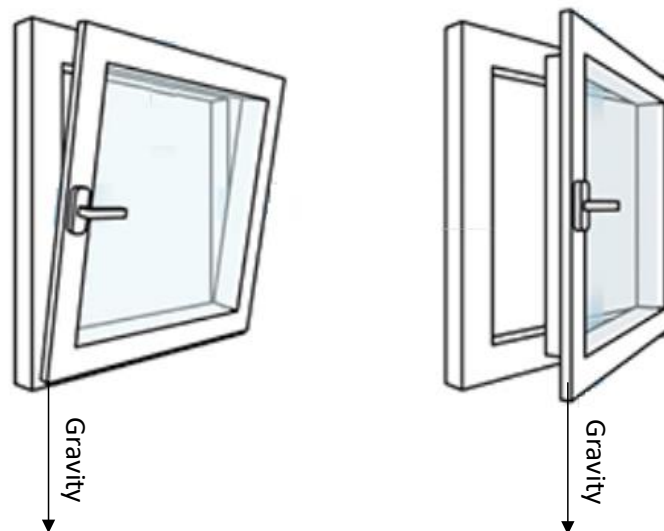


Figure 71 – Tilt versus gravity vector

12.5.1.1 Temperature effects on acceleration vector

For device orientation use cases requiring high resolution (for instance inclination measurements), the effect of temperature changes onto the actual device orientation might need to be considered.

For most materials, an increase of temperature will lead to an expansion while a decrease of temperature will lead to a contraction. This effect applies both to the material onto which STM 550 is mounted and to the material within STM 550 itself (housing and PCB) and might slightly alter the reported orientation.

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12.5.2 Device acceleration use cases

If an object vibrates or is moved after being, then the acceleration vector measured by the acceleration sensor will change. Figure 72 below illustrates this.

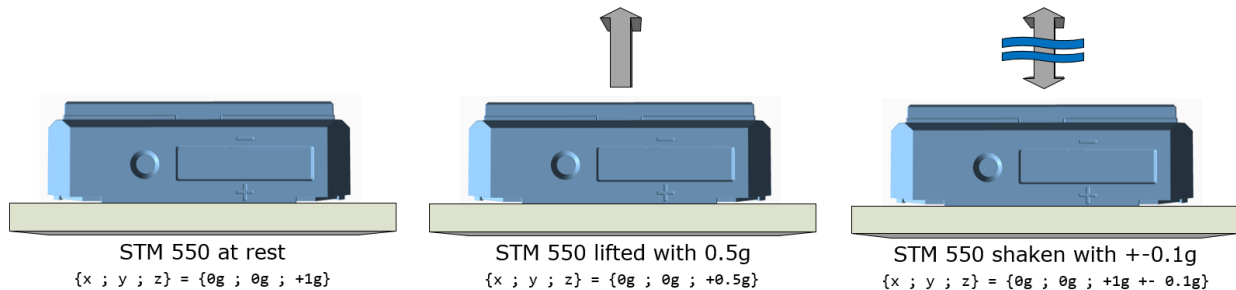


Figure 72 – Acceleration vector changes based on motion or vibration

This principle can be used for two major use cases:

- The approximate location of an object can be tracked based on the strength of the received periodic data telegrams. Movement of the object (e.g. from one room to another) can be detected based on the reported acceleration vector change.
- The utilization of an object (a machine that is running, a chair that is occupied, ...) can be tracked based on the characteristic vibrations associated with this utilization.

In both cases, STM 550 should be attached to the object for which location or utilization shall be monitored. The following chapter gives general guidelines how to do so.

12.5.3 Installation suggestions

The following points should be considered to maximize the reliability of acceleration measurement:

- STM 550 should be firmly attached to the asset without any damping to ensure that any vibration of the asset will be properly propagated to STM 550
- STM 550 should be attached to the asset at the location where the vibration is maximized. For instance, when tracking the utilization of office chairs, the highest acceleration is typically observed at the back rest.
- The acceleration threshold for wake-on-acceleration should be selected such that utilization / motion is reliably detected without false triggers due to spurious vibration (e.g. people walking by)
- Should the default sensitivity be insufficient even at the lowest threshold then the sampling rate should be increased

Use function test mode or acceleration test mode as described in Chapter 2.3 to verify correct installation.

12.6 Illumination measurement

STM 550 offers the option to measure the ambient light level either via the ambient light sensor or via the solar cell. This can be configured using the LIGHT_SENSOR_CFG register of the NFC interface as described in chapter 10.5.15. By default, the ambient light sensor is used.

12.6.1 Ambient light sensor

The ambient light sensor measures and reports the light level with a spectral response close to the human eye's perception of ambient light. The following points should be considered when using the ambient light sensor:

- **Aperture**
The sensor measures the light level within a small radius around its centre axis. If the lighting conditions within that area are not representative for the overall conditions, then the result might be different from expectation.
- **Surface**
The most common application for a ceiling-mounted illumination sensor is to measure the light level at a working desk surface underneath. In this application, the measured light level depends on the reflectivity of the surface. Simply put, a dark desk surface will give a totally different result compared to a white desk surface even when the same luminous flow is directed towards it.
- **Obstruction**
Any obstruction between the sensor and the intended measurement area (desk surface, window) will significantly impact the measurement result. Maintaining a clear line of sight between measurement area and illuminations sensor is therefore essential.
- **Interference**
To ensure accurate measurement results, it is essential to minimize interference from other light sources not contributing to the illumination at the target measurement area. For instance, when measuring the light level at a desk surface, interference might occur due to direct light from the window or from or upwards emission of indirect light sources (floor lamps etc)

12.6.2 Solar cell

The solar cell has a much larger area and aperture compared to the ambient light sensor. Therefore, the light level measured by the solar cell is typically more representative of the average illumination within a wider area.

Note that the solar cell does not apply a spectral response curve close to the human eye's perception of ambient light to the received illumination. The illumination reported by the solar cell will therefore typically be larger than that reported by the ambient light sensor depending on the spectral properties of the ambient light. Calibration at the receiver is suggested to obtain best results for the given lighting situation.

12.7 Magnet contact sensing

If STM 550 is used to detect the presence of a magnet using its magnet contact sensor (e.g. for door or window monitoring), then the magnet has to be in close proximity to the STM 550 magnet contact sensor for the case where a “Magnet Present” (or “Closed”) condition shall be detected. Refer to Chapter 2.2 for the location of the sensor.

Attach the magnet to the intended surface (e.g. door or window) such that the centre of the large side of the magnet is oriented towards the location of the magnet contact sensor in STM 550 and that the distance between magnet and STM 550 housing is less than 1 cm for the “Magnet Present” condition. Verify that the state (e.g. door open or closed) is reported as expected.

12.8 Energy harvesting

STM 550 is powered by ambient light using its integrated solar cell. For best performance it is therefore essential to maximize the amount of light available for harvesting.

Harvestable light will typically be either natural light (daylight coming in through windows etc) or artificial light (direct or reflected light from indoor luminaires). If natural light is available (e.g. from a window) then the solar cell of STM 550 should be oriented as much as possible towards that.

STM 550 is designed to operate self-supplied with its standard parameters based on 200 lux of illumination at its solar cell for at least 6 hours per day. STM 550 can operate for 4 days without available energy after being exposed to 200 lux for 2 days.

Lower levels of available light can be addressed by configuring a lower reporting rate via NFC as discussed in chapter 3.2. If the available light is insufficient, then STM 550 offers the option for a CR1632 backup battery as described in chapter 5.3.

The exact amount of available light can be determined by executing an illumination test as described in chapter 2.3.5.

12.9 NFC configuration

STM 550 can be flexibly configured for a wide range of application scenarios using the NFC configuration interface as described in chapters 9 and 10.

Before making any configuration changes, be sure to familiarize yourself with the device functionality and determine the energy constraints based on the available ambient light as discussed in chapter 3.2. Be especially careful not to configure higher update rates (low reporting intervals) before ensuring that sufficient light is available.

Should you be unsure about the current NFC configuration, then execute a factory reset as described in chapter 2.3.5 to reset all configuration registers to their default setting.

After completing the NFC configuration and ensuring that all functionality works as required, it is recommended to lock the NFC configuration interface by changing the NFC PIN code from its default value to a different (secret) value. Make sure the new PIN code is properly noted down.

13 Regulatory notes

13.1 European Union

13.1.1 Declaration of conformity

Hereby, EnOcean GmbH, declares that this radio equipment is in compliance with the essential requirements and other relevant provisions of Directive 2014/53/EU. A copy of the Declaration of Conformity can be obtained from the product webpage at www.enocean.com

13.1.2 Waste treatment

WEEE Directive Statement of the European Union

The marking below indicates that this product should not be disposed with other household wastes throughout the EU. To prevent possible harm to the environment or human health from uncontrolled waste disposal, recycle it responsibly to promote the sustainable reuse of material resources.

Germany: WEEE-Reg-No.: DE 93770561

BATTERY Directive

The symbol below indicates that batteries must not be disposed of in the domestic waste as they contain substances which can be damaging to the environment and health. Please dispose of batteries in designated collection points.

Germany: UBA Reg-No.: 21008516



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13.2 FCC (United States)

13.2.1 FCC Grant Of Equipment Authorization

TCB

**GRANT OF EQUIPMENT
AUTHORIZATION**

TCB

Certification
Issued Under the Authority of the
Federal Communications Commission
By:

Timco Engineering, Inc.
849 NW State Road 45
Newberry, FL 32669

Date of Grant: 02/04/2021
Application Dated: 02/04/2021

EnOcean GmbH
Kolpingring 18a
Oberhaching, 82041
Germany

Attention: Armin Anders , Director Product Marketing

NOT TRANSFERABLE

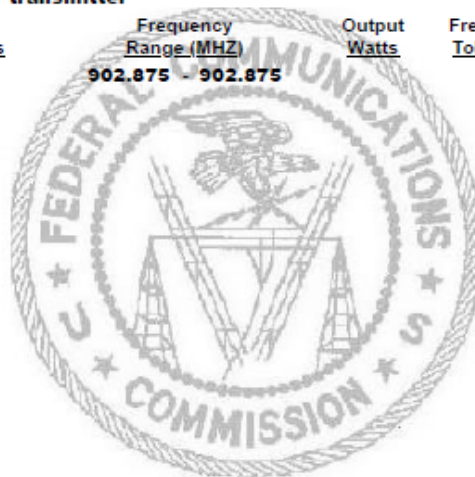
EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

FCC IDENTIFIER: SZV-STM550U
Name of Grantee: EnOcean GmbH
Equipment Class: Part 15 Security/Remote Control
Transmitter
Notes: Temperature and Humidity Sensor with
transmitter

Grant Notes

FCC Rule Parts
15.231

Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
902.875 - 902.875			



13.2.2 FCC OEM requirements

In order to use EnOcean's FCC ID number, OEM integrating STM 550U into own products must ensure that the following conditions are met:

- The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product. Attaching a label to a removable portion of the final product, such as a battery cover, is not permitted.
- The label must include the following text:
Contains FCC ID: SZV-STM550U
The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (i.) this device may not cause harmful interference and (ii.) this device must accept any interference received, including interference that may cause undesired operation.
- The FCC identifier or the unique identifier, as appropriate, must be displayed on the device.
- The user manual for the end product must also contain the text given above.

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13.3 ISED (Industry Canada)

13.3.1 ISED Technical Acceptance Certificate

TIMCO ENGINEERING, INC.

849 NW State Road 45
Newberry, Florida 32669
www.timcoengr.com
(352) 472-5500 CB@timcoengr.com

Job No. > 0564-21

TECHNICAL ACCEPTANCE CERTIFICATE

Certification No. > IC: 5713A-STM550U

Issued To > EnOcean GmbH
Kolpingring 18A
Oberhaching 82041
Germany

Tested By > VPI Laboratories, Inc.
Company No.: 2041B
313 W 12800 S., Suite 311
Draper, UT 84020, USA
801-260-4056; jasons@vpitech.com

Type of Equipment > Low Power Device (902–928 MHz)

Type of Service > New Certification (Single)

Hardware Version Id Number (HVIN) > STM 550U

Firmware Version Id Number (FVIN) > N/A

Product Marketing Name: (PMN) > STM 550U

Host Marketing (HMN) > N/A

FREQUENCY RANGE	EMISSION DESIGNATIONS <small>NECESSARY BANDWIDTH & EMISSION CLASSIFICATION</small>	R.F. POWER	ANTENNA INFO	SPECIFICATION, ISSUE & DATE
902.875 MHz	275KF1D	73.0 dBuV@3m	Wire, 0dBi	RSS-210 Issue 10; Dec.2019

Note 1: This equipment also complies with RSS-102, Issue 5 (March 2015) and RSS-Gen, Issue 5 (March 2019)

Certification of equipment means only that the equipment has met the requirements of the above-noted specification. Licence applications, where applicable to use certified equipment, are acted on accordingly by the ISED issuing office and will depend on the existing radio environment, service and location of operation. This certificate is issued on condition that the holder complies and will continue to comply with the requirements and procedures issued by ISED. The equipment for which this certificate is issued shall not be manufactured, imported, distributed, leased, offered for sale or sold unless the equipment complies with the applicable technical specifications and procedures issued by ISED.

La certification de l'équipement signifie uniquement que l'équipement a satisfait aux exigences de la spécification susmentionnée. Les demandes de licence, le cas échéant pour utiliser un équipement certifié, sont traitées en conséquence par le bureau émetteur d'ISED et dépendront de l'environnement radio, du service et du lieu d'exploitation existants. Ce certificat est délivré à condition que le titulaire se conforme et continuera de se conformer aux exigences et procédures émises par ISED. L'équipement pour lequel ce certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins que l'équipement ne soit conforme aux spécifications et procédures techniques applicables émises par ISED.

I hereby attest that the subject equipment was tested and found in compliance with the above-noted specifications.

J'atteste par la présente que le matériel a fait l'objet d'essai et jugé conforme à la spécification ci-dessus.

ISSUED UNDER THE AUTHORITY OF MINISTER OF INDUSTRY
DELIVRÉ AVEC L'AUTORISATION DU MINISTRE DES INDUSTRIES

DATE: February 5, 2021

Bruno Clavier
Bruno Clavier, General Manager

Canadian Certification

13.3.2 ISED (Industry Canada) regulatory statement

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions:

- (1) this device may not cause interference, and
- (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

- (1) l'appareil ne doit pas produire de brouillage, et
- (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement."

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13.4 ARIB (Japan)

13.4.1 ARIB construction type conformity certificate



Notified Body EMC Directive 2014/30/EU
Notified Body Directive 2014/53/EU
RF CAB under the Japan-EC MRA
FCB under the Canada-EC MRA
TCB under the USA-EC MRA

RF CAB ID No. 206

Designated by the German Regulator Bundesnetzagentur to act as a
Recognised Foreign Conformity Assessment Body in accordance with the Japan-EC MRA

CONSTRUCTION TYPE CONFORMITY CERTIFICATE
for
Specified Radio Equipment

Registration No.	JU000605M
Certificate Holder	EnOcean GmbH Kolpingring 18a 82041 Oberhaching Germany
Product Category	Article 2, Paragraph 1, Item 8 (Y)
Product Designation	TCM 500J, TCM 501J, TCM 515J, STM 550J, EMSIJ, EMDCJ
Product Description	Wireless Transceiver
Software Release No.	--
Manufacturer	Katek GmbH Bahnhofstraße 108 83224 Grassau Germany

When the product is placed on the Japanese market, it must carry the Specified Radio Equipment marking as shown on the right



R 206-000605

The scope of evaluation relates to the submitted documents only.

This Certificate confirms that the listed product has demonstrated conformity with the relevant technical regulations defined in the attached Annex. It is only valid in conjunction with the Annex.

Unterleinleiter,
2020-09-02

Karlheinz Kraft
Recognised Foreign Conformity Assessment Body

EMCCons DR. RAŠEK GmbH & Co. KG • Stoernhofer Berg 15, 91364 Unterleinleiter, Germany
Tel.: +49 9194 7263-888 • Fax: +49 9194 7263-889 • E-mail: emc.cert@emcc.de • Web: www.emcc.de

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14 Product history

Table 42 below lists the product history of STM 550.

Revision	Release	Key changes versus previous revision
STM 550 DA-05	Jun 2020	Market release (868.300 MHz)
STM 550J DA-02	Aug 2020	Market release (902.350 MHz)
STM 550 DB-06	Nov 2020	Product update - Increase of transmission power to +10 dBm - Improved supply voltage reporting
STM 550 DB-07 STM 550J DA-03	Mar 2021	Product update - Corrected issues with EEP support and backup battery
STM 550U DA-05	May 2021	Market Release (902.875 MHz)

Table 42 – Product History