SPECIFICATION V1.3

EnOcean
Self-powered IoT

EnOcean Radio Protocol 2

July 31, 2020

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REVISION HISTORY

The following major modifications and improvements have been made to the first version of this document:

No	Major Changes
1.0	Document created
1.1	Extended Type updated
1.2.	Minor: Repeating levels in US noted.
1.3.	Sub-telegram timing corrected

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Important!

This information describes the type of component and shall not be considered as assured characteristics. No responsibility is assumed for possible omissions or inaccuracies. Circuitry and specifications are sub-telegram ject to change without notice. For the latest product specifications, refer to the EnOcean website: http://www.enocean.com.

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References/Applicable Documents

[1] ISO/IEC 14543-3-10, Edition 1.0 2012-03,
[2] FCC 47 Part 15.231
[3] RSS210 Issue 7
[4] ARIB STD-T108 Version 1 (english translation)
[5] Smart Acknowledge Specification
[6] EnOcean Radio Protocol 1 - http://www.enocean.com/fileadmin/redaktion/pdf/tec_docs/EnOceanRadioProtocol.pdf

Terms and Definitions

EnOcean Radio Protocol 2

This term refers to the protocol specified by this document.

ASK

Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave.

Bit

A bit (a contraction of binary digit) is the basic capacity of information in computing and telecommunications; a bit represents either 1 or 0 (one or zero) only.

BTor BT product

BT is a product, where B is the 3 dB bandwidth of the filter and T is the symbol duration.

Byte

In this document a byte is equal to an octet. An octet is a unit of digital information in computing and telecommunications that consists of eight bits.

Carrier Leakage Emission

Carrier leakage emission is the emission of a carrier if no signal is intended to emit. E.g. the synthesizer is running but the driver and power amplifiers are switched off.

EnOcean Radio Protocol 1

This term refers to the protocol given in [1] and [6].

Data_DL

The Data_DL consists of the data that shall be transmitted via the Data Link Layer.

Data_PL

The Data_PL consists of the data that shall be transmitted via the Physical Layer.

Data Rate

This term describes the number of bits transmitted during one second.

Endianness

Defines whether the MSB (Big Endianness) or the LSB (Little Endianness) bit is transmitted first.

Frame

A Frame is a digital data transmission unit that includes frame synchronization, i.e. a sequence of bits or symbols making it possible for the receiver to detect the beginning and end of the packet in the stream of symbols or bits. If a receiver is connected to the system in the middle of a frame transmission, it ignores the data until it detects a new frame synchronization sequence.

Frequency Deviation

Frequency deviation (Δf) is used in FM radio to describe the maximum instantaneous difference between an FM modulated frequency and the nominal carrier frequency.

LSB

Abbreviation for "Least Significant Bit"

Frequency Error

The frequency error is the difference between the nominal frequency and the receiver or transmitter frequency.

FSK

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave.

Gaussian Filter

A Gaussian filter is a filter whose impulse response is a Gaussian function. Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time.

The Gaussian filter is generally specified by its BT product.

Length Field (short Length)

A data length field is a special data field that describes how many data bytes will follow.

MSB

Abbreviation for "Most Significant Bit"

NRZ

In telecommunication, a non-return-to-zero (NRZ) line code is a binary code in which 1s are represented by one significant condition (usually a positive voltage) and 0s are represented by some other significant condition (usually a negative voltage), with no other neutral or rest condition.

OSI Model

The Open Systems Interconnection (OSI) model is a product of the Open Systems Interconnection effort at the International Organization for Standardization. It is a prescription of characterizing and standardizing the functions of a communications system in terms of abstraction layers. Similar communication functions are grouped into logical layers. A layer serves the layer above it and is served by the layer below it.

For example, a layer that provides error-free communications across a network provides the path needed by applications above it, while it calls the next lower layer to send and receive packets that make up the contents of that path. Two instances at one layer are connected by a horizontal connection on that layer.

PA Ramp-On Time

If high RF power shall be emitted, the power amplifier (PA) is slowly switched on and increased in output power to avoid spurious emissions. The time the power is slowly pitched up is called PA Ramp-On time.

This specification subsumes also the leading carrier leakage emission as PA Ramp-On time.

PA Ramp-Off Time

If high RF power shall be emitted, the power amplifier (PA) is slowly switched off and decreased in output power to avoid spurious emissions. The time the power is slowly pitched up is called PA Ramp-On time.

This specification subsumes also the trailing carrier leakage emission as PA Ramp-Off time.

Preamble

A Preamble is an alternating sequence of bits and sent in each frame. It is used for threshold generation and bit synchronization. Dependent on the implementation only threshold generation might be done.

Synchronizations Word

A synchronization word is a sequence of known bits and sent in each frame. It is used for byte synchronization and in some architecture for bit synchronization too.

1 Introduction

This document describes all aspects, values and tolerances of the EnOcean Radio Protocol 2.

The EnOcean Radio Protocol 2 uses Frequency Shift Keying (FSK).

The EnOcean Radio Protocol 2 uses a longer Preamble as 8 bits are not enough to generate a decent threshold.

The length of the Sync Word (formerly known as Start of Frame SOF) has been increased significantly. This reduces false frame detection significantly and as second this will allow many other RF chips to receive the protocol.

The End of Frame (EoF) is dropped in favor of a data length field. This still allows variable lengths at minimal overhead.

2 Layer Architecture

The following table describes the current status of the layer architecture in accordance to the OSI layer model.

Layer	Data Unit	Description	Status
7. Application	Data		Not part of this specification
6. Presentation			Not part of this specification
5. Session			Not part of this specification
4. Transport	Segment		Not part of this specification
3. Network	Packet	Sub-telegram Timing, Media Access CSMA-CA (LBT)	Defined
2. Data Link	Frame	Sub-telegram structure, Hash Algorithms, Header Compression	Defined
1. Physical	Bit	Frequency, Modulation, Preamble, Sync, Coding, Length	Defined

Figure 1

Only the Layers 1 to 3 are covered by this specification.

3 Physical Layer

3.1 Electrical Specification

The electrical specification is open to any frequency.

Currently, only two frequencies are specified. Depending on national regulatory requirements and new markets additional frequencies may be implemented.

General Specifications

The following table provides the key parameters for the EnOcean Radio Protocol 2.

Parameter	Min.	Value	Max.	Unit
Frequency Error	-18		-18	kHz
Modulation[1]		FSK		
Frequency Deviation	±55.0	±62.5	±70.0	kHz
Data Rate		125		kbps
Data Rate Tolerance[2]	-30		+30	ppm
PA Ramp-On Time			40	µs
PA Ramp-Off Time			40	µs
Coding		NRZ		
Code for 1		+62.5		kHz
Code for 0		-62.5		kHz

Figure 2

902.875 MHz

The following table provides the specific parameters for the EnOcean Radio Protocol 2 at 902.875MHz which is aimed for the North American Market.

Parameter	Min.	Value	Max.	Unit
Nominal Frequency		902.875		MHz

Figure 3

[1] It is allowed to use GFSK with various filter parameters (BT) depending on national regulation requirements. See appendixes for details.

[2] This provides 1 µs time offset between RX and TX after 256 bytes. Transmitters may feature higher tolerances given that the time offset between RX and TX does not exceed 1 µs after the maximum number of bytes the transmitter does transmit.

928.35 MHz

The following table provides the specific parameters for the EnOcean Radio Protocol 2 at 928.35MHz which is aimed for the Japanese Market.

Parameter	Min.	Value	Max.	Unit
Nominal Frequency		928.35		MHz

Figure 4

Other Frequencies

The aim of this specification is to be frequency independent.

Additional frequencies may be introduced as new markets or requirements arise.

3.2 Frame Specification

The data to be transmitted is transmitted in frames. Each frame is preceded by a preamble for bit synchronization and the generation of the data slicing thresholds. After this a synchronization word is transmitted to enable the receiver to synchronize to the data bytes. The first byte transmitted after the synchronization word the length of the Data_PL. Its value is the number of the bytes transmitted in the Data_PL.

A complete frame is shown in the following diagram.

Preamble	Synchronization-Word	Length	Data_PL

Figure 5

The following table provides the parameters for the frame structure.

Parameter	Value
Endianness	The MSB is transmitted first (Big-Endian).
Preamble	16 bit 0b1010101010101010 (0xAAAA)
Synchronization Word	16 bit 0b1010100100111100 (0xA93C)
Length	1st Byte, containing the number of data bytes.
Data_PL	Bytes containing the transmitted data.
Minimum Number of Data Bytes	1
Maximum Number of Data Bytes[3]	255

Figure 6

The following diagram provides the complete frame structure and shows the physical layer to data link layer conversion.

[3] Implementation platform EO3000I and EO1000I will only support 59 Data_PL bytes!

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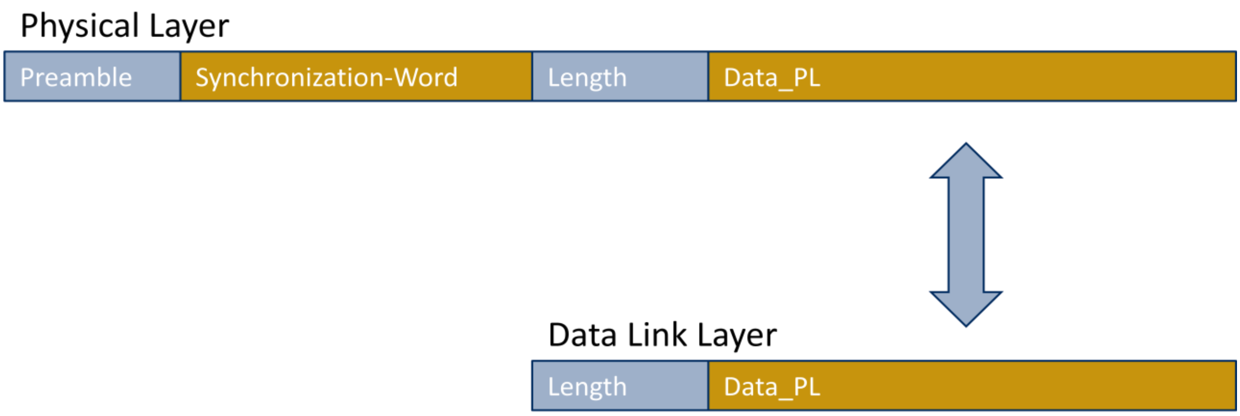

Figure 7

The Length followed by the Data_PL is transferred to the Data Link Layer located above this Physical Layer. Vice versa the Length followed by the Data_PL, have to be transferred from the upper lying Data Link Layer.

4 Data Link Layer

4.1 Introduction

At the data link layer, the transmitted data are one or more sub-telegrams. The structure of these is described above.

4.2 Sub-telegram timing

The sub-telegram timing aims to avoid collisions from different transmitters. Each sub-telegram is transmitted in a different time range. The limits of the sub-telegram timing are determined by the TX and RX maturity times. The maturity time specifies the length of the time range within which the transmission of all sub-telegrams has to be completed and received. The values of the TX and RX maturity times are specified in Table 1 below.

A complete telegram consists of a maximum of 3 sub-telegrams. The transmission of the start of the first sub-telegram and the end of the last sub-telegram by the transmitter shall not exceed the TX maturity time.

Repeaters have the same sub-telegram timing range as the original transmitter.

For the receiver, all sub-telegrams from the same transmitter received from the end of the first sub-telegram until the RX maturity time shall be considered part of the same, including when repeaters are involved. Sub-telegrams received beyond the RX maturity time shall be considered another.

The LBT technique makes it possible to avoid collision by controlling the sub-telegram transmission timing, but it cannot completely guarantee the avoidance of a collision.

4.2.1 Sub-telegram timing parameters: 921 MHz & 928 MHz

Table 1: Maturity time parameters

Description	Parameter
Maximum TX maturity time	**25 ms**
RX maturity time	**100 ms**

To schedule the sub-telegram transmission, the TX maturity time is divided in 25 time slots of 1 ms. The enumeration of the time slots starts with 0 and ends with 24.

These time slots shall be used for sending a maximum of 3 sub-telegrams. The scheduling determines in which range each sub-telegram number is allowed to be sent. Table 2 defines the time range in which each sub-telegram may be transmitted. The specific time range is determined by the numbered time slots.

Table 2: Allocation of time slots to the different sub-telegrams

1st sub-telegram -	2nd sub-telegram -	3rd sub-telegram -
0..1	4…12	14…22

All sub-telegrams shall be transmitted within these time ranges. A second or third sub-telegram transmission may only start if the previous sub-telegram transmission has been completed. There is no specified minimum pause between sub-telegrams. The transmitter and repeater may use any time slot within each time range.

The transmission start of the first sub-telegram of an original transmitter starts the time counting for the transmitter. The completion of the first sub-telegram received (which due to disturbances is not always the first one from the transmitter) starts the counting in the receiver or the repeater.

If the wireless channel is occupied by the transmission of other transmitters, the LBT functionality can delay the transmission until the end of the TX maturity time is reached.

4.2.2 Sub-telegram timing parameters: 902 MHz & 868 MHz

Table 3: Maturity time parameters

Description	Parameter
Maximum TX maturity time	**40 ms**
RX maturity time	**100 ms**

To schedule the sub-telegram transmission, the TX maturity time is divided in 40 time slots of 1 ms. The enumeration of the time slots starts with 0 and ends with 39.

These time slots shall be used for sending a maximum of 3 sub-telegrams. The scheduling determines in which range each sub-telegram number is allowed to be sent. Table 2 defines the time range in which each sub-telegram may be transmitted. The specific time range is determined by the numbered time slots.

Table 4: Allocation of time slots to the different sub-telegrams

Status of	1st sub-telegram	2nd sub-telegram	3rd sub-telegram
Original	**0**	**1...9**	**20...39**
Level 1 repeated	**10...19**	**20...29**	
Level 2 repeated	**0...9**	**20...29**	

All sub-telegrams shall be transmitted within these time ranges. A second or third sub-telegram transmission may only start if the previous sub-telegram transmission has been completed. There is no specified minimum pause between sub-telegrams. The transmitter and repeater may use any time slot within each time range.

The transmission start of the first sub-telegram of an original transmitter starts the time counting for the transmitter. The completion of the first sub-telegram received (which due to disturbances is not always the first one from the transmitter) starts the counting in the receiver or the repeater.

If the wireless channel is occupied by the transmission of other transmitters, the LBT functionality can delay the transmission until the end of the TX maturity time is reached.

4.3 Listen before talk

Listen before talk (LBT) is a technique used in wireless communications whereby a wireless transmitter or repeater first senses its wireless environment before starting a transmission. The aim is to avoid collisions with other senders. It is an optional feature of the transmitting device.

Prior to transmitting a sub-telegram, the transmitting device checks whether there is an ongoing transmission. If this is the case, the transmission is suspended for the delay of a random time range. After this delay, the transmitter check is repeated. If no ongoing transmission is detected, the sub-telegram is transmitted. In case the calculated random delay would lead to a violation of the TX maturity time, the sub-telegram is sent irrespective of any other transmissions.

It is recommended to implement and use LBT before each sub-telegram transmission, but it is not required. Some transmitting devices cannot support this feature such as energy harvesting devices.

4.4 Data contents for Length <=6 bytes

Telegrams <= 6 bytes length do have a fixed structure for special messages, e.g. Acknowledges, Keep alive, Error messages. As these do not have any safety mechanisms the upper layers have to ensure data integrity.

The content of the frame has the following structure:

Length	Originator-ID	Data of Data Link Layer (Data_DL)

Figure 8

The size of the Originator-ID and Data_DL field depends from the length of the according to the following table:

Length	Originator-ID	Data_DL	Interpretation
1	8 bit	0 bit	reserved
2	8 bit	8 bit	reserved
3	16 bit	8 bit	reserved
4	24 bit	8 bit	reserved
5	32 bit	8 bit	Smart Acknowledge Reclaim
6	32 bit	16 bit	reserved

Figure 9

Telegrams with length of 5 bytes are defined for Smart Acknowledge Reclaim according [6]. All other length values are for future use, the interpretation of the data has to be defined in an extra document, e.g. EnOcean Alliance specification or similar.

As there is no possibility to insert the repeater hop counter, it is defined that's <= 6 bytes will be never repeated.

4.5 Data contents for Length > 6 Bytes

The following illustration shows the content of the Data_PL field of the physical layer for telegrams with length > 6 Bytes.

Length	Header	Ext. Header	Ext.-Tele-gramtype	Originator-ID	Destination-ID	Data of Data Link Layer (Data_DL)	Optional Data	CRC

Figure 10

Header

The Header field is 8 bit long and contains information about ID-Sizes, availability of extended header and the telegram type.

The following table provides the parameters for the header structure.

Parameter	Value
Bit 5…7 Address Control	000: Originator-ID 24 bit; no Destination-ID 001: Originator-ID 32 bit; no Destination-ID 010: Originator-ID 32 bit, Destination-ID 32 bit 011: Originator-ID 48 bit, no Destination-ID 100: reserved101: reserved110: reserved 111: reserved
Bit 4 Extended header available	0: No extended header 1: Extended header available
Bit 0…3 Telegram type (R-ORG)	0000: RPS telegram (0xF6) 0001: 1BS telegram (0xD5) 0010: 4BS telegram (0xA5) 0011: Smart Acknowledge Signal telegram (0xD0) 0100: Variable length data telegram (0xD2) 0101: Universal Teach-In EEP based (0xD4) 0110: Manufacturer Specific Communication (0xD1) 0111: Secure telegram (0x30) 1000: Secure telegram with encapsulation (0x31) 1001: Secure Teach-In (0x35) 1010: Generic Profiles selective data (0xB3) 1011: ACK (0xA8) 1100: reserved 1101: reserved 1110: reserved 1111: Extended telegram type available

Figure 11

Extended Header

The Extended Header field is 8 bit long and contains information about optional data size and repeater count. The extended header will be added in a line powered device, if necessary. In an ultra-low power device it is not needed.

The following table provides the parameters for the extended header structure.

Parameter	Value
Bit 4…7 Repeater count	0: Original 1…14: Telegram level repeated 15: Original, do not repeat this
Bit 0…3 Length of Optional data	0000: No optional data field in frame Other: Length of optional data field [Bytes]

Figure 12

Extendedtype

The Extended telegram type field is available, if bits 0…3 in Header are all set. If not, the telegram type is specified in the header field and the extended telegram type field is not required.
0x08 to 0xFF is a way to report the non-compressed original R-ORG.

The following table provides the parameters for the extended header structure.

Parameter	Value
Bit 0…7type	0x00: SYS_EX telegram (0xC5) 0x01: Smart Ack Learn request telegram (0xC6) 0x02: Smart Ack Learn Answer (0xC7) 0x03: Chained data message (0x40) 0x04: Decrypted secure telegram (0x32) 0x05: Generic Profiles Teach-in request (0xB0) 0x06: Generic Profiles Teach-in response (0xB1) 0x07: Generic Profiles Complete data (0xB2) 0x08…0xFF: Original R-ORG (e.g. 0x32 = 0x32SEC_D)

Figure 13

Originator-ID

The Originator-ID field contains the module ID of the originator device. If the telegram is repeated, it still contains the originator ID and not the ID of the repeating device.

Due to the definition of the Address Control bits in the Header field, the length of the Originator-ID is 24, 32 or 48 bit.

Destination-ID

The Destination-ID field is available dependent of the Address Control bits in the Header field. It contains always a 32 bit module ID of the destination device.

Data_DL

The Data_DL field contains the payload of the.

Optional Data

The Optional Data field is available dependent of the Bits 0…3 in the Extended Header field; the size is defined there as well.

For each telegram type the content and the length of Data_DL may be different.

Today’s applications have to be compliant with later versions of the EnOcean Radio Protocol 2 ensuring an upwards compatibility.

New software applications or devices might require the definition of additional data. This data can be transmitted in the Optional Data fields, e.g. a sub-telegram counter.

Thus, backwards compatibility is secured.

CRC

See chapter below.

4.6 Data integrity

General

In order to check that a sub-telegram has arrived intact, a hash of the telegram is calculated before transmission and attached to the sub-telegram (field HASH). The attached hash value is not protected and thus only serves to detect transmission failures – not protection against malicious intent. The verification is done by the device receiving the, i.e., a receiving device or a repeater.

If the verification of the intactness of the received sub-telegram fails, the sub-telegram is ignored.

The 8 bit Cyclic Redundancy Check (CRC) hash function algorithm

The hash function supported by the protocol is based on the Cyclic Redundancy Check algorithm providing a hash value of length one byte.

The algorithm starts with the first byte of the sub-telegram (Header) and calculates the remainder of the division (modulo 2) by the generator polynomial $x^8 + x^2 + x + 1$ of the product x^8 multiplied by the first byte of the sub-telegram.

Note The CRC algorithm uses the same generator polynomial ($x^8 + x^2 + x + 1$) as the ATM Header Error Control (HEC) described in ITU-T Recommendation I.432.1.

The result of this calculation is XORed with the next byte in the sub-telegram and again the remainder of the division is calculated as above.

This procedure is repeated until the last byte of the sub-telegram excluding HASH is reached. The remainder of the final division is used as hash value.

Annex A provides an example of an efficient C code implementation of this hash function algorithm.

The CRC field is 8 bit. Each byte of Data_PL is used to calculate the CRC (Length is not used). The algorithm is described in [2] Chapter 7.3.3.

5 Network Layer

The Network Layer specifies the access to the transmission media, redundancy in transmission like repeating or acknowledge. This chapter describes as well repeating and routing.

This chapter depends to some extent on local requirements and thus is divided into a general section and several sub-telegram sections addressing local requirements.

5.1 General

In general routing, repeating and sub-telegram timing will be taken from the ERP 1. Changes will be in the minimum number of sub-telegrams as prefer transmission power is preferred over redundancy.

Redundancy

If no other method of securing transmission like acknowledge is used redundant transmissions shall be used. The transmission shall be repeated at least once[4] and up to a maximum of two repetitions. There shall be a minimum pause of 12 ms[5] between the first and the second transmission.

Typically, this will be applied at devices that are not able to receive (pure transmitters) but is also allowed for transceivers.

Repeating

Repeating will remain the same as in ERP 1.

5.2 Local definitions & Requirements dependent on national specifications

USA/Canada (902.875 MHz)

No special requirements. Level 1 & 2 repeating is allowed.

Japan (928.35 MHz)

Redundant transmissions shall be finished within 50ms. After the last transmission no transmission are allowed for 50ms. Level 1 repeating is supported.

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[4] Concerning the energy budget of a transmitter link budget is preferred over a second redundant transmission.

[5] To avoid interference that is coming from dimmers and other circuitry using 50Hz or 60Hz power supplies.

Annex A Appendix: Local Requirements (not available in customer documentation)

A.1 Europe (868.3 MHz)

Will be defined within due time.

A.2 USA (902.875 MHz)

In general, EnOcean based radio products fall under the category of RF Products for unlicensed operation. In the United States this device group is regulated under FCC (Federal Communications Commission) CFR47 Part 15 (see [2]):

The §15.231 regulates unlicensed transmitters in the 902.875 MHz band. The content of data sent defines which limits are applied to transmitters for this frequency. Two categories of intentional operation are defined:

a) Restricted to the transmission of control signals (data can be transmitted with control signal) §15.231(a). Periodic transmissions are not allowed, only with exception for security and safety applications for polling or supervision transmissions within limit of two seconds per hour.

The field strength of fundamental wave is limited to average 12500µV/m (81.9dBµV/m) measured at 3 meters distance. Spurious emissions limited to average 1250µV/m (61.9dBµV/m) §15.31(o). The limits at 902.875MHz are 101.9dBµV/m (6.64dBm EIRP[6]) for fundamental wave and 81.9dBµV/m (-13.36dBm EIRP) for unintended spurious emissions when EnOcean Radio Protocol 2 is transmitted.

b) Any other type of operation (e.g.: periodic data transmission without control action) §15.231(e). Additionally, the devices are limited to maximum single transmission length of one second, and the silence period should be at least 30 times the duration of the transmission, but never less than 10 seconds.

The field strength of fundamental wave is limited to average 5000µV/m (73.9dBµV/m) measured at 3 meters distance. Spurious emissions limited to 500µV/m (53.9dBµV/m). The peak limits are 93.9dBµV/m (-1.36dBm EIRP) for fundamental wave and 73.9dBµV/m (-21.36dBm EIRP) for unintended emissions.

Additionally, §15.231(c) defines the bandwidth limitations. For 902.875 MHz transmissions, the bandwidth shall not be wider than 4.5 MHz (0.5% of operation frequency). Bandwidth is measured at points 20 dB down from the modulated carrier.

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[6] Relation between field-strength and EIRP:

EIRP=E0+20 log10 (D) –104.8

E.I.R.P. = e.i.r.p. corresponding with the electric field strength E0 (in dBm)

E0 = electric field strength (in dB(uV/m))

D = reference measurement distance (in meters)

(taken from section 2 of the NTIA document Assessment of Compatibility between Ultrawideband Devices and selected Federal systems, NTIA Special Publication 01-43 – Free Space propagation assumed)

A.3 Canada (902.875 MHz)

For usage in Canada the 315 MHz EnOcean based radio modules must fulfill the requirements described in RSS-210 Annex 1 – Momentarily Operated Devices and Remote Control (see [3]).

The maximum allowed transmission power is same as for FCC regulations (dBµV/m) spurious emission limitation is the same as well. But there are some minor differences in regulations, e.g. the 99% of modulated signal bandwidth shall not exceed 0.5% of operation frequency (4.5MHz).

A.4 Japan (928.35 MHz)

For usage in Japan the 928.35MHz based modules must fulfill the requirements described in ARIB STD-T108 Part 2 - Specified low-power radio stations (see [4]).

EnOcean will use the five bundled channels 62 to 66 (each 100kHz bandwidth – total center frequency 928.35MHz, total bandwidth 500kHz). These are the only channels which do not require a carrier sense mechanism in every transmitter. The maximum transmission duration is 50ms. If a shorter transmission is emitted new emissions may be emitted within these 50ms. After the last emission, there has to be an emission pause of at least 50ms. For this, a transmission time control equipment must be in place.

There is no other duty cycle limit in place. So theoretically, the maximum duty cycle is 50%.

The frequency tolerance shall be within 20ppm.

The maximum allowed antenna power for these channels is 3dBm EIRP (0dBm antenna power plus 3dBi antenna gain – it is allowed to compensate poor antenna gain by higher power or better antennas by reducing power). There is an allowed tolerance of +20%/-80% for the antenna power.

Figure 14 illustrates the channel mask requirements within the frequency band specified in [4]. The occupied bandwidth shall be less than (5x100kHz = 500kHz).

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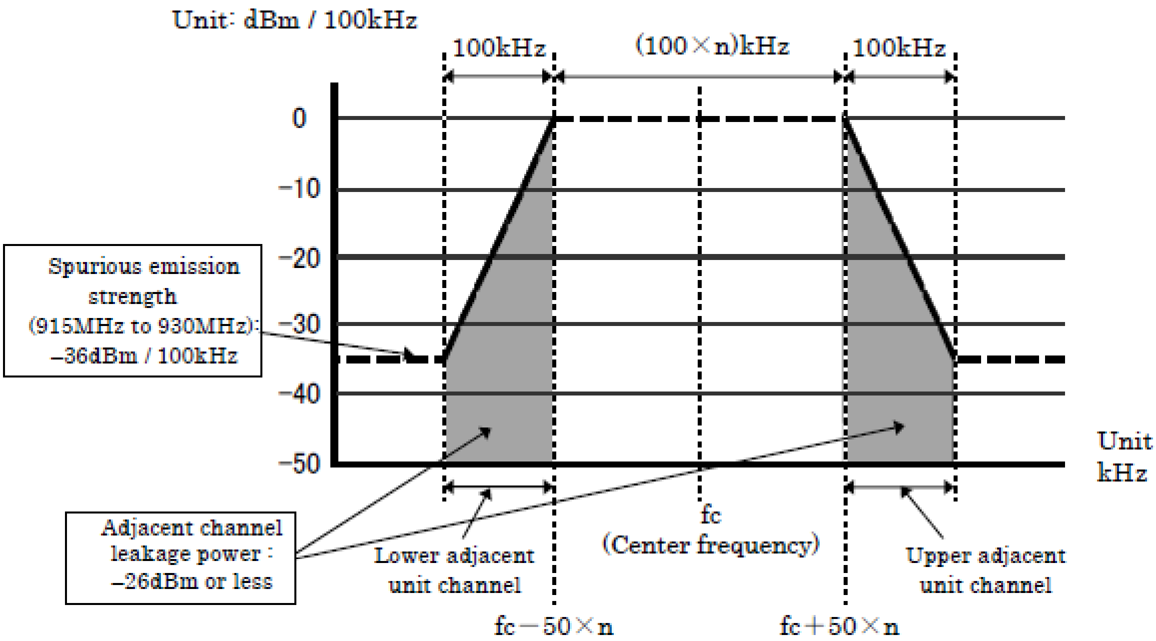

Figure 14 Channel mask of a radio channel whose frequency is from 928.1MHz to 929.7MHz[7]

Furthermore transmitters have to fulfill the following permissible unwanted emission intensity limits at the antenna input.

Frequency Band	Spurious emission strength (average power)	Reference bandwidth
f <= 720MHz	-36dBm	100kHz
720MHz < f <= 900MHz	-55dBm	1MHz
900MHz < f <= 915MHz	-55dBm	100kHz
915MHz < f <= 930MHz[8]	-36dBm	100kHz
930MHz < f <= 1000MHz	-55dBm	100kHz
1000MHz < f <=1250MHz	-45dBm	1MHz
1250MHz < f	-30dBm	1MHz

Figure 15

[7] Refer to [4]

[8] Except for |f-fc| <= (200+100×n) kHz if bandwidth of unit radio channel is 200 kHz,

except for |f-fc| <= (100+50×n) kHz if bandwidth of unit radio channel is 100 kHz.

Except for |f-fc| <= (100+100×n) kHz if frequency band is 915.9MHz <= f <= 916.9MHz and 920.5MHz <= 922.3MHz.

With n being the number of unit radio channels constituting the radio

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Receivers have to fulfill the following permissible limits on secondary radiated emissions, etc.

Frequency Band	Spurious emission strength (average power)	Reference bandwidth
f <= 720MHz	-54dBm	100kHz
720MHz < f <= 900MHz	-55dBm	1MHz
900MHz < f <= 915MHz	-55dBm	100kHz
915MHz < f <= 930MHz	-54dBm	100kHz
930MHz < f <= 1000MHz	-55dBm	100kHz
1000MHz < f	-47dBm	1MHz

Figure 16

The high frequency circuit and modulation modules except for antenna shall be structured not to be opened easily. So this requires a cabinet.

The radio equipment shall transmit and receive automatically identification codes. It shall have identification code which shall be 48 bits length or more.[9]

[9] The ID does not necessarily have to be transmit every time. It is possible to compress the ID.