PTM 216Z

2.4 GHz Zigbee® Generic Switch Pushbutton Transmitter Module

22 February 2021

Observe precautions! Electrostatic sensitive devices!

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REVISION HISTORY

The following major modifications and improvements have been made to this document:

Version	Author	Reviewer	Date	Major Changes
1.0	MKA	MKA	04.09.2018	Initial Release
1.1	MKA	MKA	19.10.2018	Updated version for product release
1.2	MKA	MKA	07.11.2018	Addition of channel lock
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1 General description

1.1 Basic functionality

PTM 216Z enables the realization of energy harvesting wireless switches for systems communicating based on the Generic Switch model of the 2.4 GHz Zigbee® Green Power standard [1].

PTM 216Z is mechanically compatible with the established PTM 21x form factor enabling quick integration into a wide range of designs. Key applications are wall-mounted or portable switches either with up to two rockers or up to four push buttons.

PTM 216Z pushbutton transmitters are self-powered (no batteries) and fully maintenance-free. They can therefore be used in all environments including locations that are difficult to reach or within hermetically sealed housings. The required energy is generated by an electro-dynamic energy transducer actuated by an energy bow located on the left and right of the module. This energy bow which can be pushed from outside the module by an appropriate pushbutton or switch rocker.

When the energy bow is pushed down or released, electrical energy is created and a 2.4GHz radio telegram according to the Zigbee Green Power standard is transmitted. This radio telegram transmits the operating status of all four contact nipples at the moment when the energy bow was pushed down or released. PTM 216Z telegrams are protected with an AES-128 signature based on a device-unique private key.

Figure 1 below shows PTM 216Z.

Figure 1 – PTM 216Z Product Outline

1.2 Technical data

Antenna	Integrated antenna
Max. radio transmit power (measured)	7dBm / 5mW
Communication Protocol	Zigbee Green Power (Generic Switch)
Radio Protocol	2.4 GHz IEEE 802.15.4
Supported Radio Channels	Channel 11 … 26 (Default: Channel 11)
Radio Channel Selection	User-selectable (Commissioning)
Device Identification	Individual 32 Bit Device ID (factory programmed)
Telegram Authentication	AES128 (CBC Mode) with Sequence Code
Power Supply	Integrated Kinetic Energy Harvester
Button Inputs	Up to four buttons or two rockers

1.3 Physical dimensions

Module Dimensions	40.0 x 40.0 x 11.2 mm
Module Weight	20 g

1.4 Environmental conditions

Operating Temperature	-25°C ... 65°C
Storage Temperature	-25°C ... 65°C
Humidity	0% to 95% r.h. (non-condensing)

1.5 Packaging information

Packaging Unit	100 units
Packaging Method	Tray / Box (10 units per tray, 10 trays per box)

1.6 Ordering information

Type	Ordering Code	Frequency
PTM 216Z	S3271-A216	2.4 GHz (IEEE 802.15.4)

2 Functional information

2.1 PTM 216Z device overview

The pushbutton transmitter module PTM 216Z from EnOcean enables the implementation of wireless remote controls without batteries. Power is provided by a built-in electro-dynamic power generator.

The outer appearance of PTM 216Z is shown in Figure 2 below.

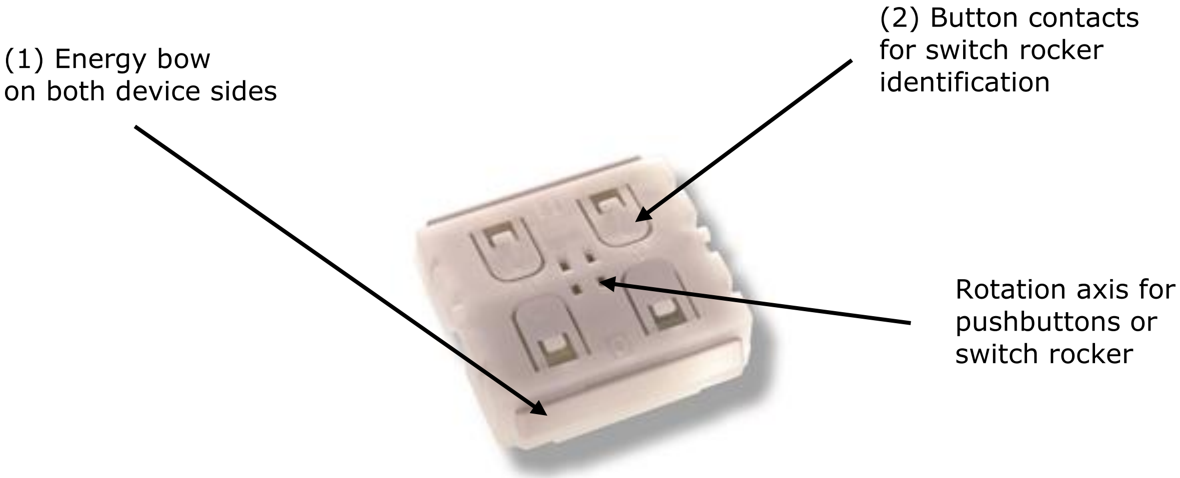


Figure 2 – Electro-dynamic powered pushbutton transmitter module PTM 216Z

2.2 Basic functionality

PTM 216Z devices contain an electro-dynamic energy transducer which is actuated by an energy bow (1). This bow is pushed by an appropriate push button, switch rocker or a similar construction mounted onto the device. An internal spring will release the energy bow as soon as it is not pushed down anymore.

When the energy bow is pushed down, electrical energy is created and a Zigbee Green Power radio telegram is transmitted which identifies the status (pressed or not pressed) of the four button contacts (2). Releasing the energy bow similarly generates energy which is used to transmit a different radio telegram.

It is therefore possible to distinguish between radio telegrams sent when the energy bar was pushed and radio telegrams sent when the energy bar was released.

By identifying these different telegrams types and measuring the time between pushing and releasing of the energy bar, it is possible to distinguish between "Long" and "Short" button contact presses. This enables simple implementation of applications such as dimming control or blinds control including slat action.

2.3 Block diagram

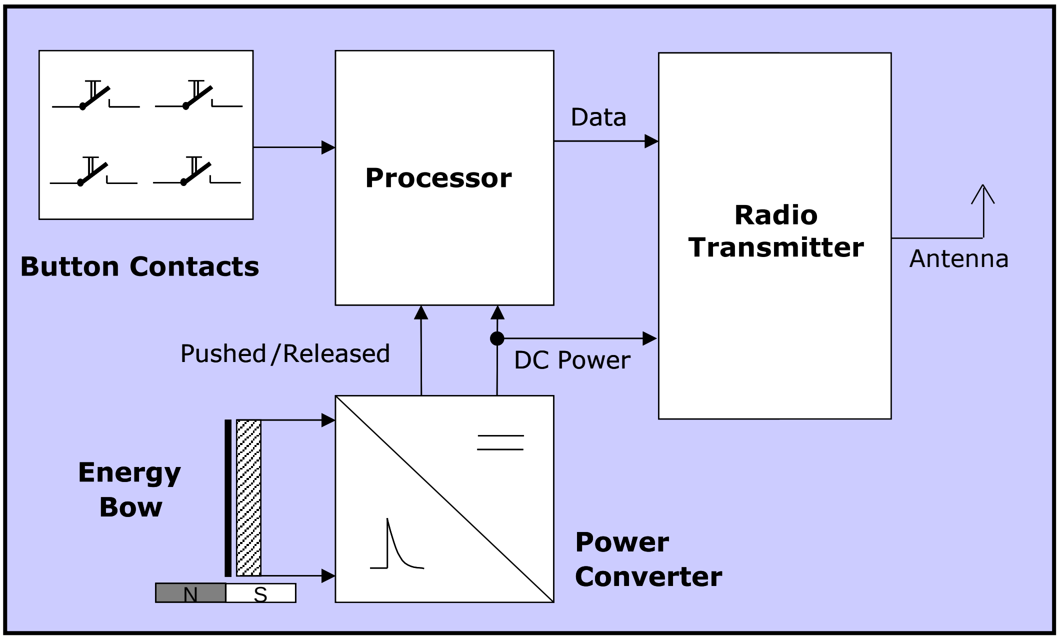


Figure 3 – Block diagram of PTM 216Z

Energy Bow / Power Generator
Converts the motion of the energy bow into electrical energy

Power Converter
Converts the energy of the power generator into a stable DC supply voltage for the device electronics

Processor
Determines the status of the button contacts and the energy bow, encodes this status into a data word, generates the proper radio telegram structure and sends it to the radio transmitter

Radio transmitter
Transmits the data in the form of a series of short Zigbee Green Power radio telegrams using the integrated antenna

2.4 User interface

PTM 216Z devices provide four button contacts. They are grouped into two channels (Channel A and Channel B) each containing two button contacts (State O and State I).

The state of all four button contacts (pressed or not pressed) is transmitted together with a unique device identification (32 Bit Zigbee Green Power Device ID) whenever the energy bow is pushed or released.

Figure 4 below shows the arrangement of the four button contacts and their designation:

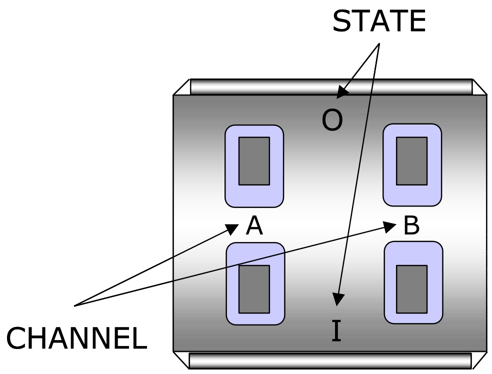


Figure 4 – Button contact designation

3 Radio protocol

3.1 PTM 216Z radio channel parameters

PTM 216Z supports all sixteen IEEE 802.15.4 / Zigbee Green Power radio channels in the 2.4 GHz band (channels 11 … 26 according to IEEE 802.15.4 notation) which can be selected as described above.

Table 1 below shows the correspondence between channel number and channel frequency (in MHz).

Channel ID	Lower Frequency	Centre Frequency	Upper Frequency
11	2404	2405	2406
12	2409	2410	2411
13	2414	2415	2416
14	2419	2420	2421
15	2424	2425	2426
16	2429	2430	2431
17	2434	2435	2436
18	2439	2440	2441
19	2444	2445	2446
20	2449	2450	2451
21	2454	2455	2456
22	2459	2460	2461
23	2464	2465	2466
24	2469	2470	2471
25	2474	2475	2476
26	2479	2480	2481

Table 1 - IEEE 802.15.4 Radio Channels and Frequencies (in MHz)

3.2 Telegram structure

PTM 216Z transmits radio telegrams in the 2.4 GHz band according to the IEEE 802.15.4 frame structure [2] using a Zigbee Green Power compliant payload.

Note that the byte order used by these standards is little endian. This means that for multi-byte structures (such as 2 byte, 4 byte or 8 byte fields) the least significant byte (LSB) is transmitted first.

The frame structure used by PTM 216Z consists of the following four main parts:

- PHY Header
  The PHY header indicates to the receiver the start of a transmission and provides information about the length of the transmission.
  It contains the following fields:
  - Preamble
    Pre-defined sequence (4 byte, value `0x00000000`) used to adjust the receiver to the transmission of the sender
  - Start of frame
    Pre-defined symbol (1 byte, value `0xA7`) identifying the start of the actual data frame
  - Length of frame
    1 byte indicating the combined length of all following fields

- MAC Header
  The MAC header provides detailed information about the frame.
  It contains the following fields:
  - Frame control field
    2 bytes (always `0x0801`) identifying frame type, protocol version, addressing and security mode
  - Sequence number
    1 byte sequential number identifying the order of transmitted frames
  - Address
    PAN ID and address of source (if present) and destination of the telegram
    PTM 216Z does not use source address and source PAN ID

- MAC Payload
  The MAC payload is based on the Zigbee Green Power standard. It contains telegram control, device ID, telegram data and telegram security fields.

- MAC Trailer
  The MAC Trailer contains the Frame Check Sum (FCS) field used to verify the integrity of the telegram data.

Figure 5 below summarizes the IEEE 802.15.4 frame structure.

<table>
<tr><th colspan="3">802.15.4 PHY Header</th><th colspan="3">802.15.4 MAC Header</th><th>802.15.4 Payload</th><th>802.15.4 MAC Trailer</th></tr>
<tr><td>Preamble</td><td>Start of Frame</td><td>Length of Frame</td><td>Frame Control</td><td>Sequence Number</td><td>DstAddress PAN | Addr</td><td>ZigBee Green Power Payload</td><td>Frame Check Sum (FCS)</td></tr>
<tr><td>4 Byte</td><td>1 Byte</td><td>1 Byte</td><td>2 Byte</td><td>1 Byte</td><td>4 Byte</td><td>16 Byte (DATA)
37 Byte (COM)
15 Byte (DECOM)</td><td>2 Byte</td></tr>
<tr><td>0x00:00:00:00</td><td>0xA7</td><td>0x19 (DATA)
0x2E (COM)
0x18 (DECOM)</td><td>0x01 0x08</td><td></td><td>0xFFFF | 0xFFFF</td><td></td><td></td></tr>
</table>

Figure 5 – IEEE 802.15.4 Frame Structure

The content of these fields is described in more detail below.

3.2.1 802.15.4 PHY Header

The IEEE 802.15.4 PHY header consists of the following fields:

- Preamble
- Start of Frame
- Length of Frame fields

The content of the *Preamble* and *Start of Frame* fields is fixed for all telegram types supported by PTM 216Z as follows:

- Preamble = `0x00000000`
- Start of Frame = `0xA7`

The content of the *Length of Frame* field differs depending on the telegram type as follows:

- Data telegram
  Length = 25 bytes (`0x19`)
- Commissioning telegram
  Length= 46 bytes (`0x2E`)
- Decommissioning telegram
  Length = 24 bytes (`0x18`)

3.2.2 802.15.4 MAC Header

The IEEE 802.15.4 MAC Header contains the following fields:

- Frame Control Field (2 byte)
  The *Frame Control Field* is set to `0x0801` in all PTM 216Z telegrams in order to identify them as data telegrams with short addresses based on version IEEE 802.15.4-2003

- Sequence Number (1 byte)
  The *Sequence Number* is an incremental number used to identify the order of telegrams

- Address Field (4 byte in PTM 216Z implementation)
  The *Address Field* is set to `0xFFFFFFFF` to identify PTM 216Z telegrams as broadcast telegrams using short Destination Address (16 Bit) together with the Destination PAN ID (16 Bit). Source address and Source PAN ID are not present in PTM 216Z MAC Header.

3.2.3 802.15.4 MAC Trailer

The MAC Trailer only contains the Frame Check Sum (FCS) field.

Its length is 2 byte and it is calculated as Cyclic Redundancy Check (CRC16) over the entire MAC payload including the *Length of Frame* field of the PHY Header using the following polynomial: $x^{16} + x^{12} + x^{5} + 1$

3.3 802.15.4 payload (ZGP telegram data)

The 802.15.4 payload contains the Zigbee Green Power (ZGP) telegram data for the following telegram types:

- ZGP data telegram
- ZGP commissioning telegram
- ZGP decommissioning telegram

Each telegram type is described in more detail in the subsequent chapters.

3.3.1 ZGP data telegram

ZGP data telegrams are used by PTM 216Z to transmit button push events (Command ID 0x69 followed by 1 byte button status) and button release events (Command ID 0x6A followed by 1 byte button status). Figure 6 below shows the ZGP payload structure for such data telegrams.

ZGP Payload: Data Telegram (16 Byte)						
Frame Control	**Extended Frame Control**	**Source Address**	**Security Frame Counter**	**Command ID**	**Button Status**	**Security Signature (MIC)**
1 Byte 0x8C	**1 Byte** 0x30	**4 Byte** Device Address	**4 Byte** Current Value	**1 Byte** 0x69 (Push) 0x6A (Release)	**1 Byte** Button Status	**4 Byte** MIC

Figure 6 – ZGP payload structure for data telegrams

The button(s) that were pushed are encoded in one byte as shown in Figure 7 below.

Unused	Unused	Unused	Energy Bar	B1	B0	A1	A0
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

Figure 7 – Button status encoding

If for instance if buttons A0 and B0 were pressed, then this will be transmitted as 0x69 (Push) followed by 0x05 (A0 and B0).

Due to the mechanical design of PTM 216Z, all buttons that were pressed will also be released. Therefore, a release telegram from PTM 216Z will always be 0x6A followed by 0x00 irrespective of the button(s) that had been pushed.

3.3.2 ZGP commissioning telegram

ZGP commissioning telegrams are used to commission PTM 216Z into ZGP networks. ZGP commissioning telegrams are identified by the Command ID 0xE0. The following 31 byte of data identify the properties of PTM 216Z:

- Device type: 0x07 (Generic Switch)
- Options: 0x85
- Extended Options: 0xF2
- Security key 16 byte device-unique security key
- Security key hash 4 byte hash of the key for validation
- Outgoing security counter 4 byte value of security counter
- Options 0x10 (Switch information present)
- Switch Info 0x02 = 2 byte of information follow
- Generic Switch Configuration 0x05 = 5 buttons
- Current Contact Button that was pressed (see Figure 7)

Figure 8 below shows the payload structure for ZGP commissioning telegrams used by PTM 216Z.

ZGP Payload: Commissioning Telegram (37 Byte)												
Frame Control	Source Address	Command ID	Device Type	ZGP Options	Extended Options	Security Key	Security Key MIC	Frame Counter	Application Info	Optional Data Length	Switch Type	Button Pressed
1 Byte 0x0C	4 Byte Device Address	1 Byte 0xE0	1 Byte 0x07	1 Byte 0x85	1 Byte 0xF2	16 Byte Device Unique Key	4 Byte Key MIC	4 Byte Current Value	1 Byte 0x10	1 Byte 0x02	1 Byte 0x05	1 Byte Button Status

Figure 8 – ZGP payload structure for commissioning telegrams

3.3.3 ZGP Decommissioning telegram

ZGP decommissioning telegrams are used to inform the network of devices to which PTM 216Z had been commissioned that PTM 216Z will leave the network due to a change of radio channel.

Decommissioning telegrams are therefore sent each time PTM 216Z changes radio channel during commissioning as described in Chapter 5.

The structure of decommissioning telegrams used by PTM 216Z is shown in Figure 9 below.

ZGP Payload: Decommissioning Telegram (15 Byte)					
Frame Control	Extended Frame Control	Source Address	Security Frame Counter	Command ID	Security Signature (MIC)
1 Byte 0x8C	**1 Byte** 0x30	**4 Byte** Device Address	**4 Byte** Current Value	**1 Byte** 0xE1	**4 Byte** MIC

Figure 9 – ZGP payload structure for decommissioning telegrams

4 Telegram authentication

PTM 216Z implements telegram authentication for data telegrams and decommissioning telegrams to ensure that only telegrams from senders using a previously exchanged security key will be accepted.

4.1 Authentication implementation

Authentication relies on a 32 bit telegram signature which is calculated as shown in Figure 10 below and exchanged as part of the radio telegram.

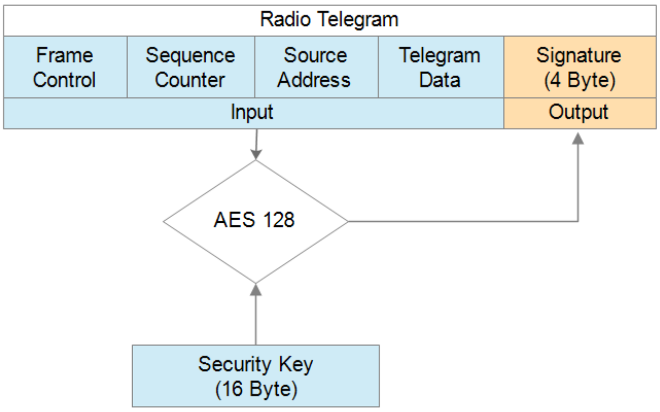


Figure 10 – Telegram authentication flow

Sequence counter, source address and the remaining telegram data together form the input data for the signature algorithm. This algorithm uses AES128 encryption based on the device-unique random security key to generate a 32 bit signature which will be transmitted as part of the radio telegram.

The signature is therefore dependent both on the current value of the sequence counter, the device source address and the telegram payload. Changing any of these three parameters will therefore result in a different signature.

The receiver performs the same signature calculation based on sequence counter, source address and the remaining telegram data of the received telegram using the security key it received from PTM 216Z during commissioning.

The receiver then compares the signature reported as part of the telegram with the signature it has calculated. If these two signatures match then sender (PTM 216Z) and receiver use the same security key and the message content (address, sequence counter, data) has not been modified.

In order to avoid message replay (capture and retransmission of a valid message), it is required that the receiver tracks the value of the sequence counter used by PTM 216Z and only accepts messages with higher sequence counter values (i.e. not accepts equal or lower sequence counter values for subsequent telegrams).

4.2 Algorithm parameters

PTM 216Z implements telegram authentication according to the Zigbee Green Power specification [1]. It uses AES128 in CCM (Counter with CBC-MAC) mode as described in IETF RFC3610 [3].

The 13 Byte CCM Nonce (number used once – unique) initialization value is constructed as concatenation of 4 byte Device ID, 4 byte Device ID again, 4 byte Sequence Counter and 1 status byte of value 0x05.

Note that both Device ID and Sequence Counter use little endian format (least significant byte first). Figure 11 below shows the structure of the AES128 Nonce.

AES128 Nonce (13 Byte)												
Device ID				Device ID				Sequence Counter				STATUS
Byte 0	Byte 1	Byte 2	Byte 3	Byte 0	Byte 1	Byte 2	Byte 3	Byte 0	Byte 1	Byte 2	Byte 3	0x05

Figure 11 – AES128 Nonce structure

The AES128 Nonce and the 128 bit device-unique security key are then used to calculate a 32 bit signature of the authenticated telegram payload for data and decommissioning telegrams.

The authenticated data for data telegrams is shown in Figure 12 below.

Authenticated Data For Data Telegrams (12 Byte)											
Frame Control		Source ID				Sequence Counter				Command	Optional Data
0x8C	0x30	Byte 0	Byte 1	Byte 2	Byte 3	Byte 0	Byte 1	Byte 2	Byte 3	0x69 / 0x6A	Button Status

Figure 12 – Authenticated payload for data telegrams

The authenticated data for decommissioning telegrams is shown in Figure 13 below.

Authenticated Data For Decommissioning Telegrams (11 Byte)										
Frame Control		Source ID				Sequence Counter				Command
0x8C	0x30	Byte 0	Byte 1	Byte 2	Byte 3	Byte 0	Byte 1	Byte 2	Byte 3	0xE1

Figure 13 – Authenticated payload for decommissioning telegrams

The calculated 32 bit signature is then appended to the data telegram payload as shown in Chapter 3.3.

The security key required for the telegram authentication can be obtained from the product DMC code as shown in Chapter 6.3.1. For Zigbee Green Power receivers, it is also provided as part of the commissioning telegram as described in Chapter 3.3.2.

5 Commissioning

Commissioning mode is used to commission (teach-in, learn in) PTM 216Z into a specific (target) receiver or network.

To do so, PTM 216Z provides two key functions:

- Radio channel selection
  This allows to set the radio channel of PTM 216Z such that it matches the radio channel used by the network

- Transmission of a commissioning telegram
  The commissioning telegram is used to learn-in PTM 216Z into the network by communicating device type, device address and security parameters

5.1 Commissioning modes

PTM 216Z supports two commissioning modes:

- Direct commissioning
  If the intended receiver or network operates on one of the primary radio channels (channel 11, 15, 20 or 25) and PTM 216Z is integrated into a double rocker or four button switch then PTM 216Z can be commissioned directly using a simplified button sequence.

- Sequential commissioning
  If the intended receiver or network does not operates on one of the primary radio channels (channel 11, 15, 20 or 25) or the radio channel is unknown or PTM 216Z is integrated into a single rocker design then PTM 216Z can sequentially request to be commissioned on each of the 16 radio channels one after the other until a response from the intended receiver or network is received.

Both commissioning modes are described in more detail below.

5.2 Direct commissioning

Direct commissioning is a simplified procedure by which PTM 216Z may be commissioned onto one of the primary radio channels (channel 11, 15, 20 or 25).

Direct commissioning consists of two steps:

- Commissioning request
  In this step, PTM 216Z sends a commissioning telegram on the selected radio channel to the intended receiver or network

- Radio channel confirmation
  If the commissioning request was accepted by the intended receiver or network then the selected radio channel has to be confirmed so that it will be used for subsequent telegram transmissions.

5.2.1 Commissioning request

The commissioning request is triggered by long-pressing (for 7 seconds or more) one of the four buttons of PTM 216Z. Upon detection of such long button press, PTM 216Z will transmit a commissioning request on the corresponding radio channel.

The correspondence between PTM 216Z button and the radio channel used for the transmission of the commissioning telegram is shown in Table 2 below.

Button	Radio Channel
A0	CH 15
B0	CH 11
AI	CH 20
BI	CH 25
Energy Bar	CH 11

Table 2 – Correspondence between button and radio channel

The commissioning request can be repeated (by repeatedly long-pressing the required button) until a confirmation from the intended receiver or network about acceptance of the commissioning request has been received. This confirmation could be for instance a notification on a user interface (e.g. connected smartphone) or an action by the receiver (e.g. blinking a light).

5.2.2 Radio channel confirmation

Once confirmation about successful commissioning has been received, the radio channel of the PTM 216Z module that was used for transmission of the commissioning telegram has to be confirmed so that it will be used for subsequent transmissions of data telegrams as well.

In order to confirm the radio channel, buttons AI and B0 have to be pressed together as next action after the transmission of the commissioning telegram.

Note that this step requires that both AI and B0 buttons can be operated together. This will be the case when PTM 216Z is integrated into a double rocker or a four button switch design. Otherwise (e.g. for the case of a single rocker switch design) PTM 216Z would have to be removed from the housing design first.

Upon press of AI and B0, PTM 216Z will permanently adjust the radio channel to the one corresponding to the long pressed button as defined in Table 2 and send a data telegram (0x69 + button status) on this channel.

If the new radio channel is different from the previously used radio channel then PTM 216Z will send a decommissioning command (0xE1) on the previously used radio channel upon release of AI and B0. If the radio channel remains unchanged then PTM 216Z will send a data telegram (0x6A + button status) upon release of AI and B0.

5.2.3 Example of direct commissioning

Consider the case where PTM 216Z should be commissioned into a network or receiver operating on radio channel 15.

To do so, follow these steps:

1. Long press (for more than 7 seconds) button A0

2. Verify that the receiver or network received and accepted the commissioning telegram. Otherwise step #1 can be repeated as needed.

3. Confirm the selected radio channel (channel 15 in this case) for subsequent use by pressing AI and B0 together.

5.2.4 Disabling direct commissioning

Direct commissioning can be disabled by pressing A0 and AI together for more than 7 seconds. Note that for rocker switches this is only possible after removing the rocker and manually operating the button contacts and the energy bar.

Direct commissioning can be re-enabled by means of a factory reset as described in Chapter 5.7.

5.3 Sequential commissioning

Sequential commissioning is intended for the case where the intended receiver or network does not operate on one of the primary radio channels or where direct commissioning is not practical due to the mechanical constraints of the switch design (e.g. for single rocker switches).

Sequential commissioning allows selecting any of the 16 radio channels and can be executed even on single rocker switches. It is however more complex than direct commissioning and therefore recommended mainly for cases where direct commissioning cannot be used.

5.3.1 Commissioning request

Commissioning requests are triggered using a special button contact sequence. This is illustrated in Figure 14 below.

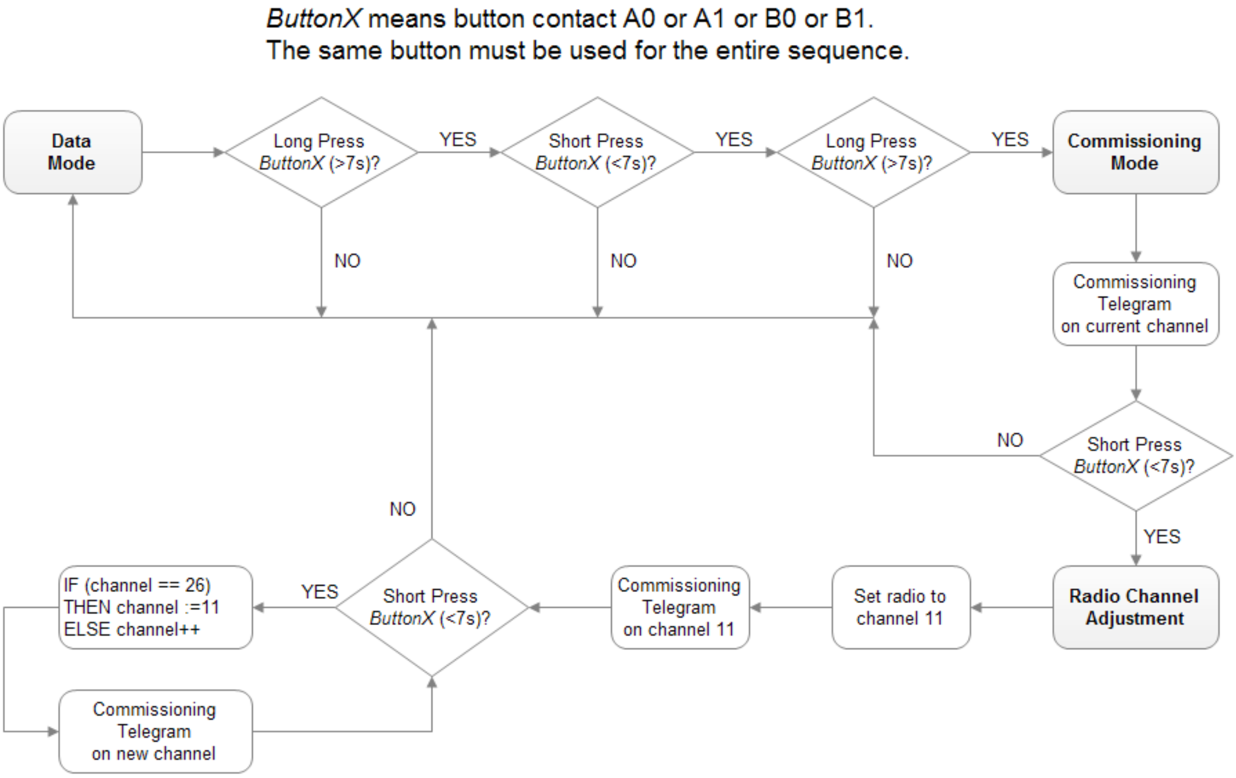


Figure 14 – Button sequence for commissioning mode

To send a commissioning request, start by selecting one button contact of PTM 216Z. Any contact of PTM 216Z (A0, AI, B0, BI) can be used (therefore sequential commissioning will work even for single rocker designs). This contact is referred to as *ButtonX* in Figure 14 above.

Next, execute the following long-short-long sequence:

1. Long press the selected button contact together with the energy bar (e.g. by pressing one side of the selected rocker for more than 7 seconds)

2. Short press the selected button contact together with the energy bar (e.g. by pressing the same side of the selected rocker for less than 2 seconds)

3. Long press the selected button contact together with the energy bar (e.g. by pressing one side of the selected rocker for more than 7 seconds)

Upon detection of this sequence, PTM 216Z will transmit a commissioning telegram on the currently selected radio channel.

The radio channel can be changed by pressing the selected button contact shortly (< 7s). PTM 216Z will then sequentially (one cycle per button press) cycle through the supported radio channels starting with channel 11 and transmit a commissioning telegram every time a new channel is selected.

Sometimes the user might be unsure if PTM 216Z if part of the entry sequence into commissioning mode has already been executed. For such cases, PTM 216Z can always be set into a defined state (normal mode) by shortly (< 7s) pressing two different buttons one after another. After that, PTM 216Z will operate in normal mode and the full sequence for commissioning (long-sort-long) has to be executed again.

5.3.2 Example of sequential commissioning

Consider the case where PTM 216Z should be commissioned into a network or receiver operating on radio channel 17.

To do so, follow these steps:

1. Select a button of the switch and execute the long – short – long sequence. This will cause PTM 216Z to transmit a commissioning telegram on its currently used radio channel

2. Press the same button shortly 7 times to select channel 17.
   PTM 216Z will follow the channel sequence 11 -> 12 -> 13 -> 14 ->15 -> 16 -> 17

3. Confirm selection of radio channel 17 by pressing a button different from the one used during the previous two steps.

5.3.3 Disabling sequential commissioning

Sequential commissioning can be disabled by pressing B0 and BI together for more than 7 seconds. Note that for rocker switches this is only possible after removing the rocker and manually operating the button contacts and the energy bar.

Direct commissioning can be re-enabled by means of a factory reset as described in Chapter 5.7.

5.4 Sequential versus direct commissioning

Sequential commissioning takes priority over direct commissioning if both variants are enabled.

This means that the long press at the end of the long – short – long sequence will cause transmission of a commissioning telegram on the currently used radio channel which might be different from the radio channel corresponding to this button in direct commissioning mode.

Consider the case where PTM 216Z operates on channel 15 and the user executed a long – short long sequence on button AI. In this case, upon the first long button press of the sequence a commissioning telegram will be transmitted on channel 11 which corresponds to this button in direct commissioning mode (see Table 2).

Upon the second long button press (which marks completion of the long – short – long sequence) however, PTM 216Z will transmit a commissioning telegram on the current radio channel which is channel 15.

5.5 Disabling commissioning

Sequential and direct commissioning can both be disabled at the same time by pressing buttons A0, AI and BI at the same time for at least 7 seconds (long press). After that, it is not possible anymore to transmit commissioning telegrams or change the radio channel.

Sequential and direct commissioning can be re-enabled by means of a factory reset as described in Chapter 5.7.

5.6 Disabling channel change

Change of the radio channel by means of direct or sequential commissioning can be disabled by pressing buttons AI, B0 and BI at the same time for at least 7 seconds (long press).

After that, it is not possible anymore to change the radio channel. Any commissioning action (if enabled) will result in commissioning telegrams being transmitted at the currently selected radio channel.

Radio channel change can be re-enabled by means of a factory reset as described in Chapter 5.7.

5.7 Factory reset

PTM 216Z can be reset to factory state by pressing buttons A0, AI, B0 and BI at the same time for at least 7 seconds (long press). After that, PTM 216Z will send a decommissioning telegram (command 0xE1) on the currently used radio channel.

Subsequently, PTM 216Z will transmit data telegrams on channel 11 and both direct and sequential commissioning will be enabled.

6 Device integration

PTM 216Z is designed for integration into button or rocker-based switches. It implements the established PTM 2xx mechanical form factor and can therefore be used with a wide variety of existing designs.

6.1 Mechanical interface characteristics

Energy bow travel / operating force	1.8 mm / typ. 10 N At room temperature Only one of the two energy bows may be actuated at the same time!
Restoring force at energy bow	typ. 0.7 N Minimum restoring force of 0.5 N is required for correct operation
Number of operations at 25°C	typ. 100.000 actuations tested according to VDE 0632 / EN 60669
Cover material	Hostaform (POM)
Energy bow material	PBT (50% GV)

6.2 Mechanical interface drawings

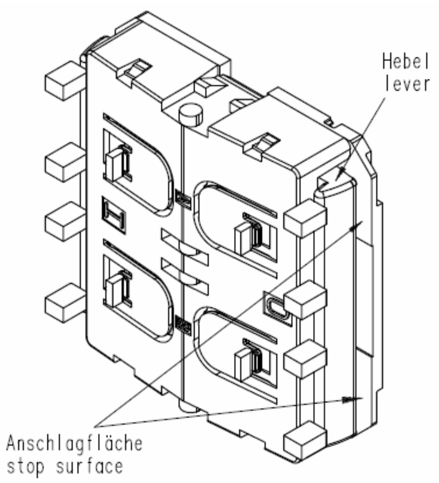
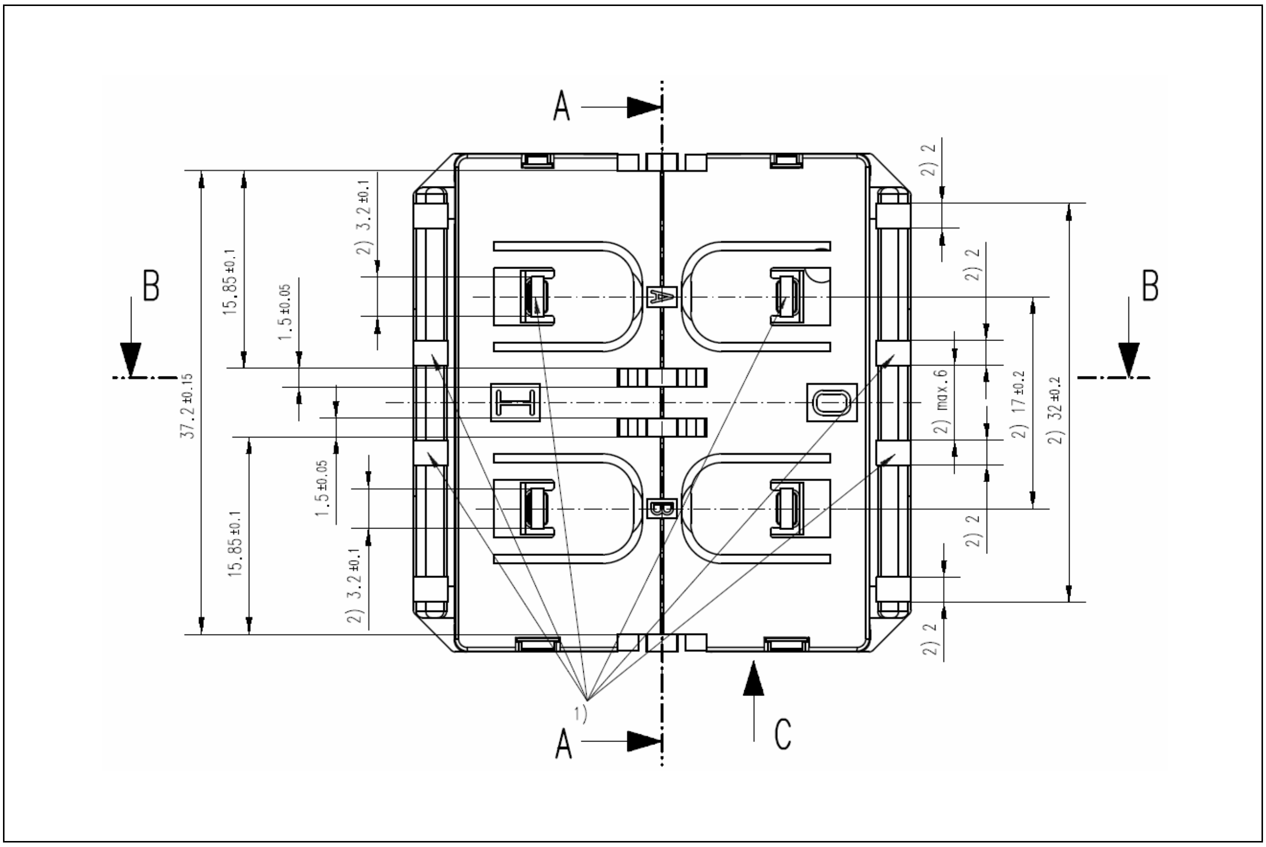


Figure 15 – PTM 216Z, tilted view (including rocker catwalks)



1) these catwalks are not needed when using one single rocker only 2) dimensions of rocker part

Figure 16 – PTM 216Z, top view (note cut A, B and C marking)

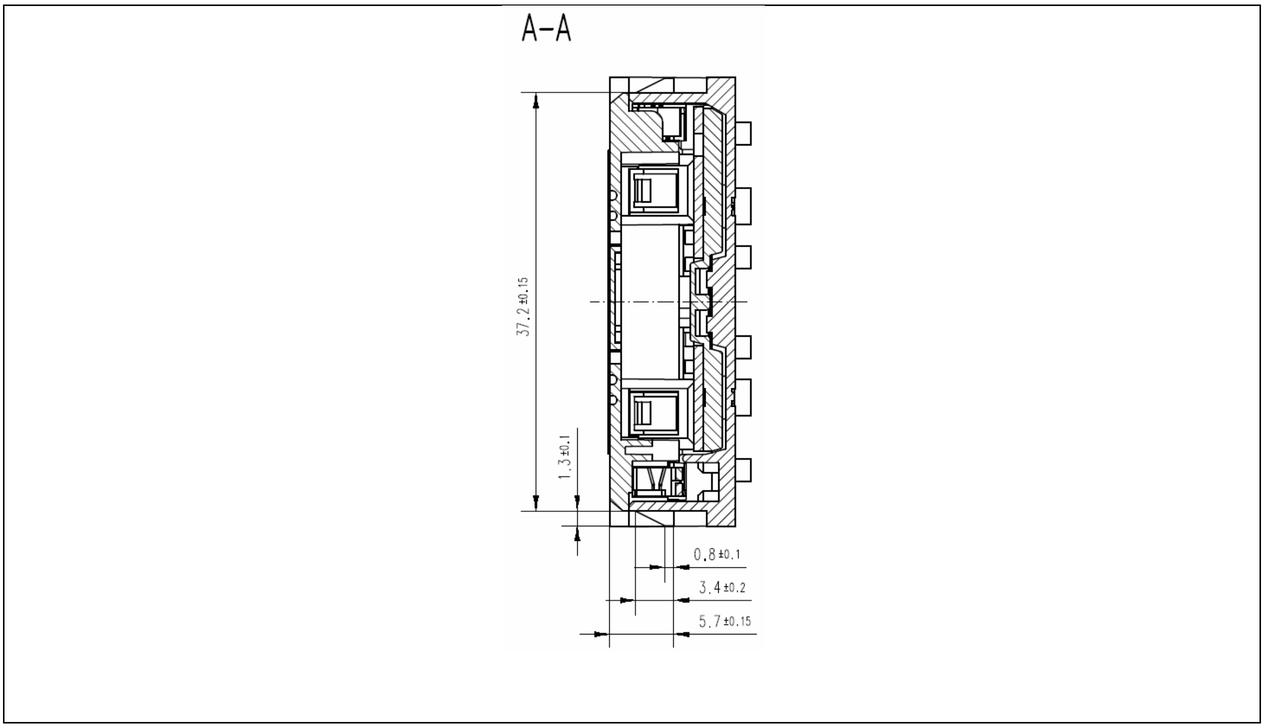
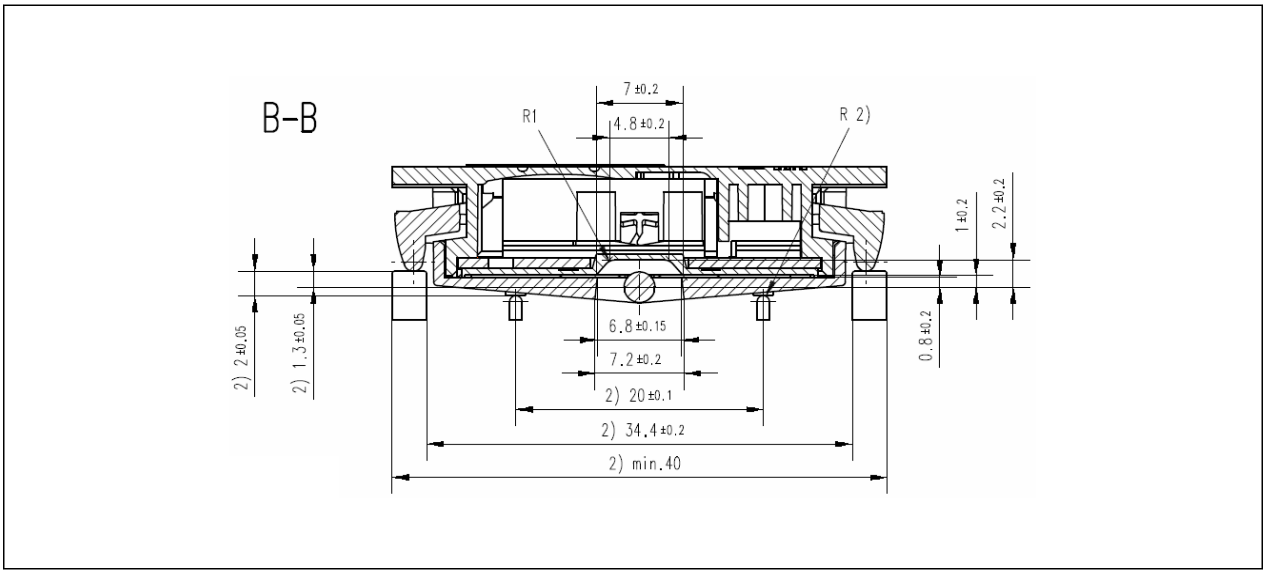
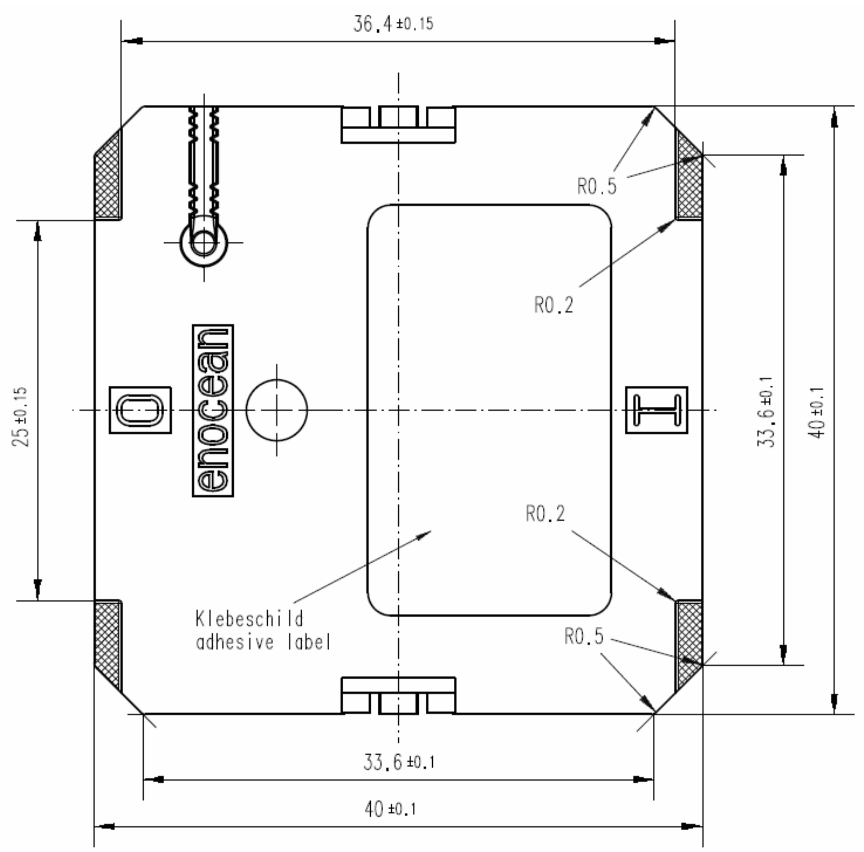


Figure 17 – PTM 216Z, cut A



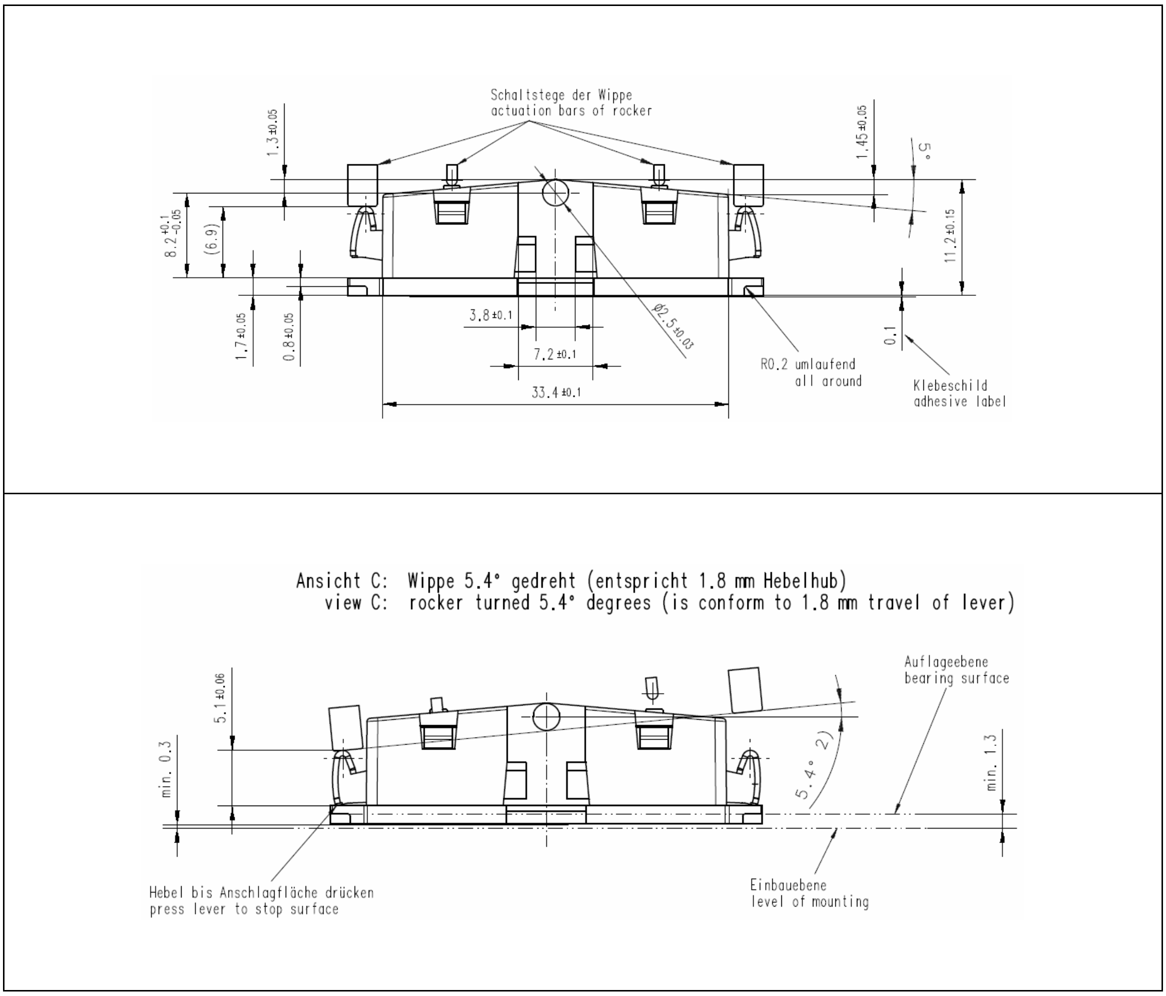
2) dimensions of rocker part

Figure 18 – PTM 216Z, cut B and C



Hatched areas: support planes

Figure 19 – PTM 216Z rear view



2) dimensions of rocker part

Figure 20 – PTM 216Z, side view

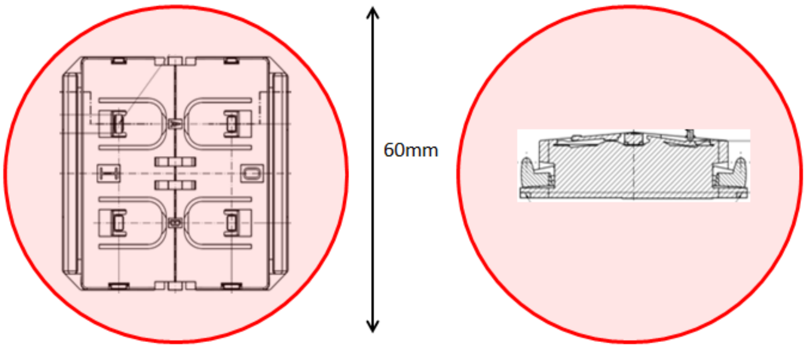
⚠ If the rocker is not mounted on the rotation axis of PTM 216Z several tolerances have to be considered! The measure from support plane to top of the energy bow is 7.70 mm +/- 0.3 mm!

⚠ The movement of the energy bow must not be limited by mounted rockers!

⚠ Catwalks of the switch rocker must not exert continuous forces on the button contacts!

⚠ It is required to use non-conductive material (no metal or plastic with metal or graphite elements) for the rockers, the frame and the base plate to ensure best transmission range.

⚠ PTM 216Z is powered by the electromagnetic generator ECO 200. For proper function there has to be a keep out zone of 60mm for magnets or ferromagnetic materials around the center of PTM 216Z.



6.3 Device label

Each PTM 216Z module contains a device label as shown in Figure 21 below.

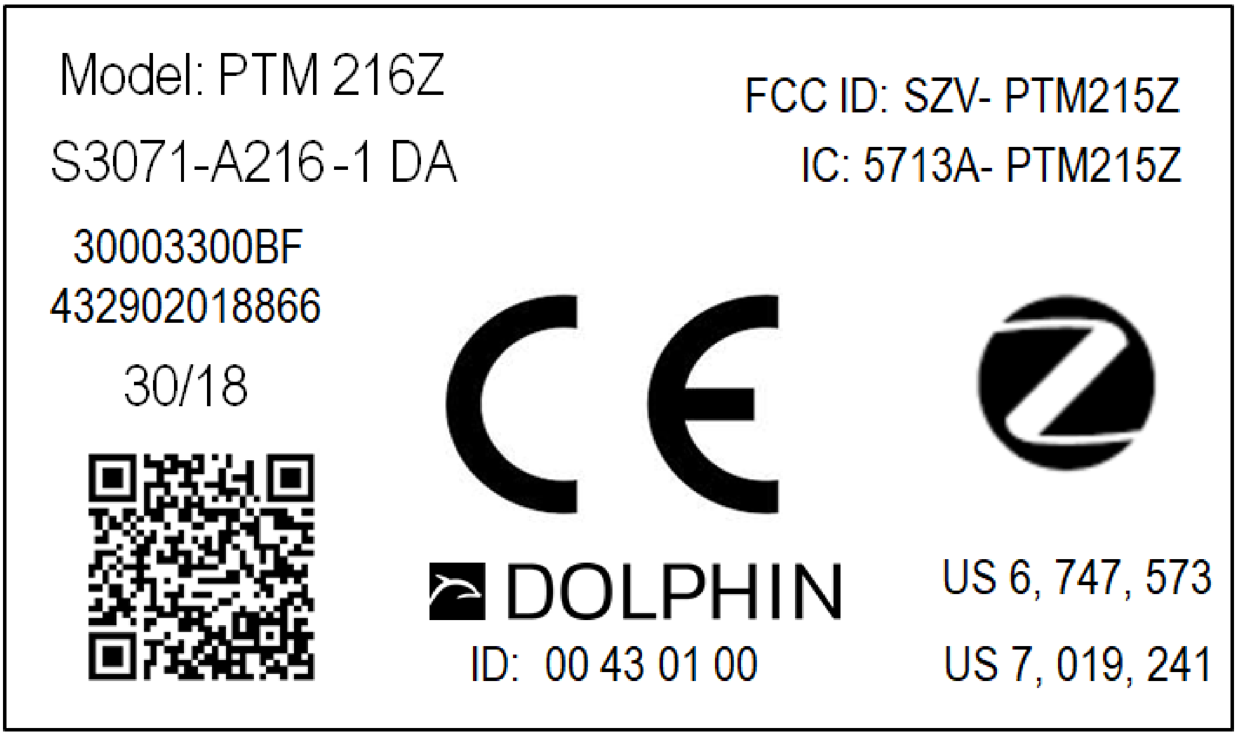


Figure 21 – PTM 216Z device label

This device label identifies the following parameters in writing:

- Model name (PTM 216Z)
- Order number (S3071-A216) and product revision (DA-1)
- Manufacturing date (here week 30, 2018)
- Zigbee Green Power Device ID (here 00430100)

In addition, it contains a QR code providing information about this module in an electronically readable format. The structure of this QR code is described in the subsequent chapter.

6.3.1 QR code format

The QR code used in the new product label encodes the product parameter according to the ANSI/MH10.8.2-2013 industry standard. The QR code shown in Figure 21 above encodes the following string:

```
30S00430100+Z0123456789ABCDEF0123456789ABCDEF+30PS3071-A216+2PDA01+S01234567890123
```

Table 3 below describes the ANSI/MH10.8.2 data identifiers used by the PTM 216Z device label and shows the interpretation of the data therein.

Identifier	**Length of data (excluding identifier)**	**Value**
30S	8 characters	ZGP Source Address (4 byte, hexadecimal format)
Z	32 characters	Security Key (16 byte, hexadecimal format)
30P	10 characters	Ordering Code (S3071-A216)
2P	4 characters	Product Revision (DA-01)
S	14 characters	Serial Number (14 digits, decimal format)

Table 3 – QR code format

7 Application information

7.1 Transmission range

The main factors that influence the system transmission range are:
- Type and location of the antennas of receiver and transmitter
- Type of terrain and degree of obstruction of the link path
- Sources of interference affecting the receiver
- "Dead spots" caused by signal reflections from nearby conductive objects.

Since the expected transmission range strongly depends on this system conditions, range tests should always be performed to determine the reliably achievable range under the given conditions.

The following figures should be treated as a rough guide only:

- Line-of-sight connections
  Typically 15 m range in corridors, up to 50 m in halls

- Plasterboard walls / dry wood
  Typically 15 m range, through max. 2 walls

- Ferro concrete walls / ceilings
  Maximum 1 wall or ceiling, depending on thickness and material

- Fire-safety walls, elevator shafts, staircases and similar areas should be considered as shielded

The angle at which the transmitted signal hits the wall is very important. The effective wall thickness – and with it the signal attenuation – varies according to this angle. Signals should be transmitted as directly as possible through the wall. Wall niches should be avoided.

Other factors restricting transmission range include:
- Switch mounting on metal surfaces (up to 30% loss of transmission range)
- Hollow lightweight walls filled with insulating wool on metal foil
- False ceilings with panels of metal or carbon fibre
- Lead glass or glass with metal coating, steel furniture

The distance between the receiver and other transmitting devices such as computers, audio and video equipment that also emit high-frequency signals should be at least 0.5 m.

8 Regulatory information

PTM 216Z has been certified according to RED (Europe) regulations. Changes or modifications not expressly approved by EnOcean could void the user's authority to operate the equipment.

8.1 RED for the European market

The Radio Equipment Directive (2014/53/EU, typically referred to as RED) replaces R&TTE directive from 1999 as regulatory framework for radio products in the European Union. All products sold to final customers after 12th of June, 2017 have to be compliant to RED. At the time of writing, the text of the RED legislation was available from this link: http://eur-lex.europa.eu/eli/dir/2014/53/oj

Dolphin radio modules are components which are delivered to OEM manufacturers for their use/integration in final or combined products. It is the responsibility of the OEM manufacturer to demonstrate compliance to all applicable EU directives and standards. The EnOcean attestation of conformity can be used as input to the declaration of conformity for the full product.

At the time of writing, guidance on the implementation of EU product rules – the so called "Blue Guide" – was available from this link:
http://ec.europa.eu/DocsRoom/documents/18027/

Specifically within the new RED framework, all OEM manufacturers have for instance to fulfill the following additional requirements:

- Provide product branding (on the product) clearly identifying company name or brand and product name as well as type, charge or serial number for market surveillance
- Include (with the product) documentation containing full postal address of the manufacturer as well as radio frequency band and max. transmitting power
- Include (with the product) user manual, safety information and a declaration of conformity for the final product in local language
- Provide product development and test documentation upon request

Please contact an accredited test house for detailed guidance.

9 Product history

Table 4 below lists the product history of PTM 535BZ.

Revision	Release date	Key changes versus previous revision
DA-01	January 2019	Product release to lead customers
DA-02	June 2019	Product release to broad market

Table 4 – Product History

10 References

[1] Zigbee Green Power Specification

[2] IEEE 802.15.4 Specification

[3] RFC3610 Specification

A Understanding PTM 216Z telegram structure

This appendix describes – purely for reference purposes – how to analyse the PTM 216Z radio telegram structure using the TI CC2531EMK packet sniffer (USB dongle) on a Windows 7 based system.

A.1 Installation instructions for TI CC2531 packet sniffer

The following description assumes the use of the TI CC2531EMK described here:
http://www.ti.com/tool/cc2531emk
CC2531EMK can be used in conjunction with the "TI SmartRF Protocol Packet Sniffer" to capture and visualize IEEE 802.15.4 data telegrams.

To use TI SmartRF Protocol Packet Sniffer, please download the SW package from the TI website. At the time of writing, the SW could be obtained using this link:
http://www.ti.com/tool/packet-sniffer
Please download and install this SW before proceeding with the instructions given in the next chapter.

A.1.1 CC2531EMK setup

After setting up the TI SmartRF Protocol Packet Sniffer please insert the CC2531EMK USB dongle into a USB port of the PC and make sure that the green LED of the dongle is active.

Please make sure that the required device driver for the CC2531EMK has been correctly installed. To do so, please check the Device Manager where you should see an entry named "CC2531 USB Dongle" under the group label "CEBAL Controlled Devices".

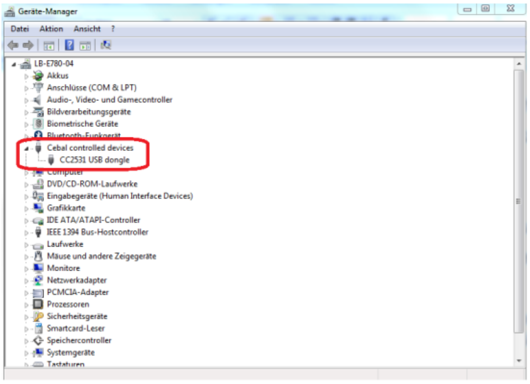


Figure 22 – Correctly installed CC2531EMK

A.2 Configuration

After the installation of the CC2531EMK driver, please start the TI SmartRF Packet Sniffer program. The protocol selection dialog program window which appears after the start of is shown in Figure 23 below.

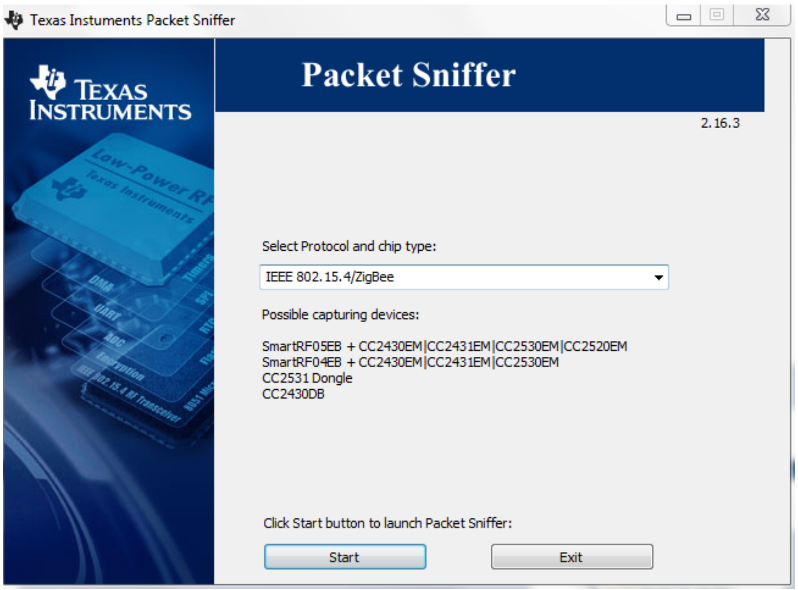


Figure 23 – Protocol selection dialog of TI SmartRF Packet Sniffer

In this dialog, please select "IEEE 802.15.4/Zigbee" as shown above and press the "Start" button. Once the main window comes up, please make sure that "CC2531" is shown in the "Capturing device" tab and in the "RF device:" footer line as shown in Figure 24 below.

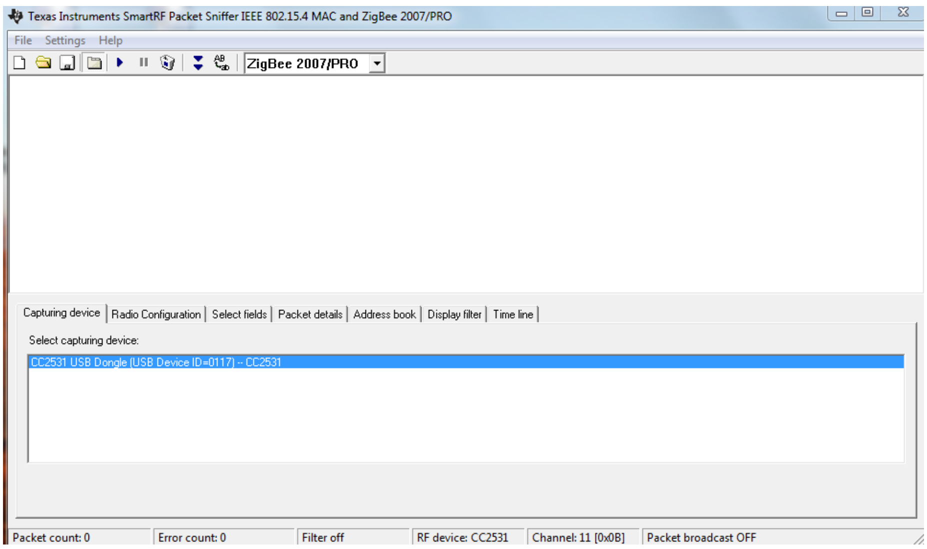


Figure 24 – Main window TI SmartRF Packet Sniffer

Out of the box, PTM 216Z is configured for using IEEE 802.15.4 radio channel 11. Make sure that this radio channel (0x0B) is selected in the "Radio Configuration" tab and shown in the "Channel:" footer line.

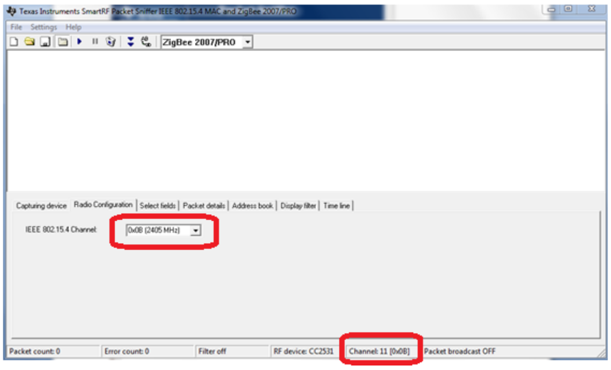


Figure 25 – Radio channel selection

The data fields that will be displayed can be selected in the "Select fields" tab. Make sure that all "MAC Header", "Data" and "Footer" fields are selected and that the "LQI/RSSI" drop-down list is set to "RSSI".

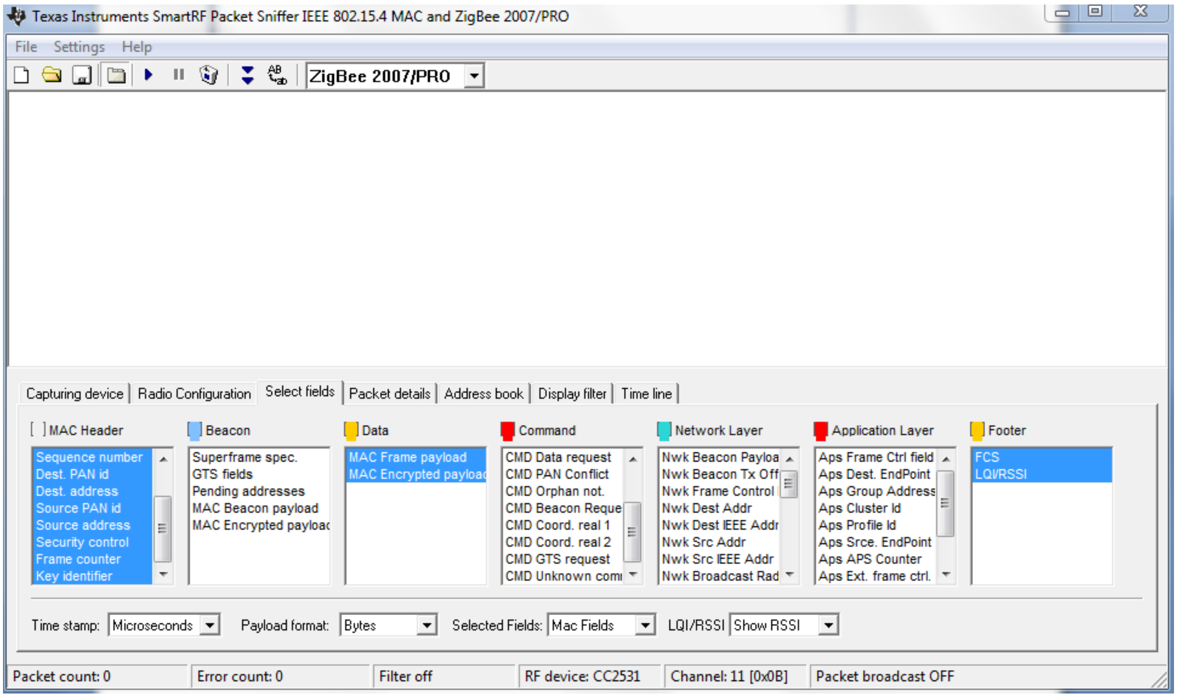


Figure 26 – Payload selection

The TI SmartRF Packet Sniffer is now ready.

A.3 Data capture

Press the triangular button ( ) to start the radio capture and press the auto-scroll button ( ) to automatically select the most recent data telegram. Then press a button of PTM 216Z. You should now see the captured radio telegrams (PTM 215Z sends several redundant radio telegrams per user action).

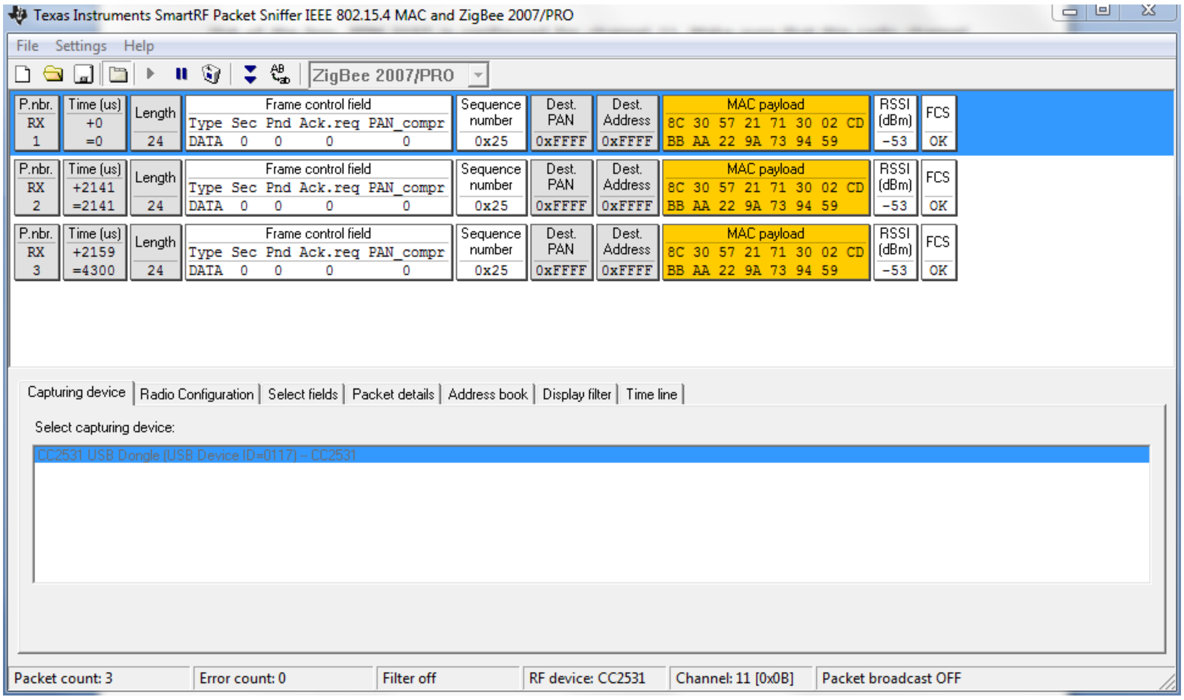


Figure 27 – Captured telegram data

A.4 Interpretation of the telegram data

The following parameters within captured radio telegrams are typically of interest:

1. MAC Payload
   This will contain the ID of the sender, various control and security data fields as well as the actual command data (1 byte)
   The structure of this field is outlined subsequently in more detail.

2. RSSI
   This will show the received signal strength

3. FCS
   This will show the frame integrity (OK / not OK) and should normally show "OK".

A.4.1 MAC Payload

Figure 28 shows an example of a captured MAC payload.

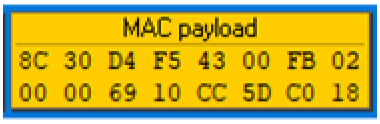


Figure 28 – Captured MAC payload

The hexadecimal representation of this specific payload is:
`8C 30 D4 F5 43 00 FB 02 00 00 69 10 CC 5D C0 18`
The location and interpretation of key parameters is described in the following chapters.

A.4.2 Device ID

The device ID is used to uniquely identify each device in the network. It is 4 byte long and is allocated to byte 2…5 of the MAC payload as highlighted below:

`8C 30 D4 F5 43 00 FB 02 00 00 69 10 CC 5D C0 18`

Note that the byte order is little endian, therefore the ID of this specific device is `0x0043F5D4`.

A.4.3 Sequence Counter

The sequence counter is used to uniquely identify each telegram in order to avoid telegram replay. It is 4 byte long and is allocated to byte 6…9 of the MAC payload as highlighted below:

```
8C 30 D4 F5 43 00 FB 02 00 00 69 10 CC 5D C0 18
```

Note that the byte order is little endian, therefore the current sequence counter value of this specific device is `0x000002FB`.

A.4.4 Command payload

The command payload identifies the action performed on the switch (i.e. which buttons have been pressed). The command is allocated to byte 10 of the MAC payload as highlighted below:

```
8C 30 D4 F5 43 00 FB 02 00 00 69 10 CC 5D C0 18
```

In this case the command is `0x69` (button push) and the optional data is `0x10` meaning that the energy bar has been pressed). Refer to Chapter 3.3.1 for a description of the data telegram payload structure.

A.4.5 Telegram Signature

The PTM 216Z radio telegram is authenticated via a 32 Bit signature. This signature is calculated based on the private key (unique for each device), the data payload and a 32 Bit sequence counter (which is incremented for each data telegram).

This approach prevents unauthorized senders from sending commands. Note that the content of the telegram itself is not encrypted, i.e. the switch command is sent as plain text.
The telegram signature is transmitted using the last 4 byte of the telegram:

```
8C 30 D4 F5 43 00 FB 02 00 00 69 10 CC 5D C0 18
```

Note that the signature changes with each transmission even if the remainder of the MAC payload remains the same.

This is due to the inclusion of the rolling code into the MIC calculation which prevents message replay attacks (capture and reuse of a previous message).