UG523: Bring-Up/Test HW Development User's Guide

This document describes how to use Silicon Labs development tools to bringup and validate HW based on the following Z-Wave 700- and 800 devices:

- ZGM130S and EFR32ZG14 (700 series)
- ZGM230S and EFR32ZG23 (800 series)

The purpose of this document is to describe how to use the RailTest software to perform RF bring-up tests and validate a design based on the Z-Wave 700 (ZGM130S, EFR32ZG14) and 800 devices (ZGM230S, EFR32ZG23).

KEY POINTS

- Provides hardware design considerations for bring-up and validation
- Gives guidelines how to test RF performance of a Z-Wave product
- Provides a basic guide of Railtest to measure Z-Wave devices

Audience and Prerequisites

The audience for this document is Z-Wave hardware developers and test engineers working with the development, bring-up test, and validation test of Z-Wave hardware using Z-Wave 700 and 800 devices. It is assumed that the reader has a basic knowledge of RF metrics and Z-Wave as such.

The prerequisites are:

1. Access to Simplicity Studio
2. A PC with a UART terminal program
3. A Z-Wave development kit or hardware containing a Z-Wave 700 or 800 device with UART access
4. Access to RF measurement equipment, such as an RF Spectrum Analyzer and an RF generator

1. Abbreviations

Abbreviation	Explanation
BOM	Bill Of Materials
CLI	Command Line Interface
CW	Carrier Wave (RF single tone)
DUT	Device Under Test
FSK	Frequency Shift Keying
GFSK	Gaussian shaped Frequency Shift Keying
LBT	Listen Before Talk
OQPSK	Offset Quadrature Phase Shift Keying
PA	Power Amplifier
PCB	Printed Circuit Board
ppm	Parts Per Million, for GHz frequencies app. 1 kHz
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SoC	System On Chip
UART	Universal Asynchrony Receiver and Transmitter (RS232)
UUID	Unique Unit IDentification
WSTK	Wireless Starter Kit
ZWLR	Z-Wave Long Range

2. Bringing Up Z-Wave Hardware in General

When bringing up and validating a Z-Wave 700 or 800 hardware platform, Silicon Labs provides a special software tool called RailTest.

RailTest is part of the Z-Wave software offering, and the following versions are available:

- 700 series:
    1. A version for the ZGM130S SiP module
    2. A version for the EFR32ZG14 SoC
- 800 Series:
    1. A version for ZGM230S SiP module
    2. A version for EFR32ZG23 SoC

RailTest eliminates the need for creating a special “Hardware bring-up” Z-Wave application, because RailTest offers all the functionality needed to exercise the RF parts of the Z-Wave product under development.

Using RailTest, parameters such as:

- RF output power
- RF frequency
- Crystal fine tuning
- Z-Wave sensitivity

can easily be measured on the Z-Wave hardware which is being brought up / validated. Settings for output power, etc., can be fine-tuned and afterwards incorporated in the final Z-Wave application code, thus ensuring that the performance of the Z-Wave product will live up to all customer *and* RF regulatory demands.

2.1 Hardware Design Consideration for Easy Bring-Up and Validation

As a part of the general hardware design procedure for a Z-Wave product, one should take the following items into consideration:

1. How can the RF performance of the product be tested?
2. How to interface the product during the bring-up phase of the project?
3. How to provide means for the RF regulatory authorities to approve the product?
4. How to fine-tune RF parameters to obtain the best possible performance of the product?

If a solution for each of the above-mentioned items is implemented in the product at design-time, the effort of bringing up the product will be significantly reduced.

2.1.1 How to Test the RF Performance of the Z-Wave Product

All Z-Wave products contain an RF antenna, and many products incorporate the RF antenna as an integrated PCB antenna.

If the product has a PCB antenna, it is not easy to measure the output power of a Z-Wave device. Such a measurement usually requires access to an anechoic chamber. However, even though it might be difficult to measure the output, this must be done to pass regulatory RF tests *and* to ensure that the settings of the output power matches the needs for the specific product.

At design time, the decision to add an RF connection point for such a conducted measurement can be taken.

An RF connection point can be a non-populated footprint for an RF connector, which can be switched into the RF path for conducted measurements, or it can be a PCB landing pattern for a soldered attachment of an RF coax pig-tail. If the antenna structure requires an RF matching structure, the placement of the RF matching components can serve as an RF connection point as well. See the examples below:

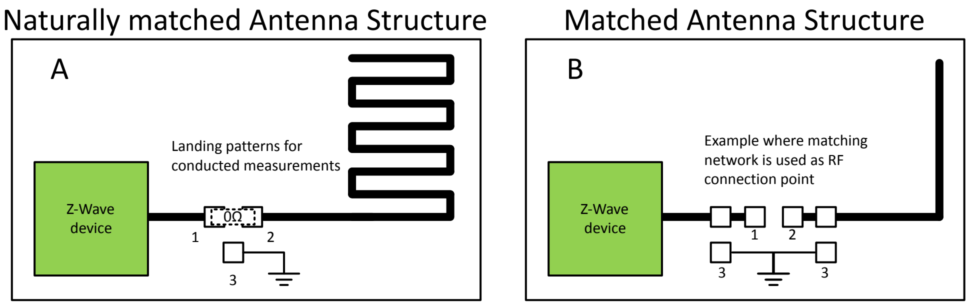

Naturally matched Antenna Structure
A
Landing patterns for conducted measurements
Z-Wave device
0Ω
1
2
3
Matched Antenna Structure
B
Example where matching network is used as RF connection point
Z-Wave device
1
2
3
3

Figure 2.1. Landing Patterns for Conducted RF Measurements

The Figure 2.1 on page 4 shows two examples, a product with a naturally matched antenna, A, and a product requiring a match, B. The three landing patterns shown on Product A can be used to:

1. Measure the output power of the Z-Wave device
2. Measure the RF properties of the antenna structure of the device

For normal usage, the landing patterns marked “1” and “2” on Figure 1 A are shorted by a 0 ohms resistor. Landing pattern “3” is connected to the RF ground plane of the PCB.

For product A: During bring-up of the product or when the RF regulatory authorities are to measure conducted RF power, the 0 ohms resistor is removed, and an RF pig-tail can be soldered to the landing patterns “1” and “3”. The inner-core of the RF pig-tail must be connected to landing pattern “1” and the grounding shield of the RF pig-tail must be connected to landing pattern “3”. The RF pig-tail can now be connected to an RF spectrum analyzer, and the output power transmitted by the Z-Wave device can be measured with a minimal insertion loss and without the need for any radiated RF power measurements.

When the RF properties of the antenna structure are to be measured, this also can be done with the usage of the landing patterns and an RF pig-tail. In this case, the 0 ohms resistor connecting landing pattern “1” and “2” must be removed, and the inner-core of the RF pig-tail must be connected to landing pattern “2” and the grounding shield of the RF pig-tail must be connected to the landing pattern “3”.

Note: When measuring the parameters of the antenna structure using a network analyzer, please be aware of the effect of the cable used to conduct the measurement.

For product A, the cost for this landing-pattern connection method will be the PCB real-estate for the three landing patterns and the BOM cost of a 0 ohms resistor.

If the antenna requires an RF matching structure, such as a T or Pi configuration, please see product B in Figure 1. Here, the landing patterns for the matching components may serve as connections points as well. In this case, the landing pattern “1” can be used to measure the direct output power from the Z-Wave device, whereas landing pattern “2” can be used to measure the RF characteristics of the antenna structure. Again, landing patterns 3 are RF ground connections.

The benefit of this hardware design strategy, where the possibility for an RF connection point is contained in the final product design is:

1. Shorter bring-up time
    - Effortless connection of the RF pig-tail without destroying or cutting in the product
2. More reliable and predictable measurements
    - With a firmly attached RF pig-tail, measurements can be repeated and are not depending on reflections or environmental changes as with radiated measurements
        - Be aware of the cable effect for antenna measurements

3. Better possibilities to adjust the Z-Wave device for best possible performance, which creates a better product.
    - With a well-tuned RF product, most of the RF energy transmitted by the Z-Wave device will be radiated by the antenna-structure, hence the customers will experience the best possible RF range between Z-Wave products.

Note: If a non-populated RF connector is used instead of the landing pattern strategy, an even more robust and easy-to-use RF connection point can be created during the bring-up and validation phase. Then an RF connector is soldered onto the product when needed, and once finished with the prototypes, the RF connector is removed from the BOM.

2.1.2 How to Interface the Z-Wave Product During the Bring-Up Phase of the Project

Since Silicon Labs strongly recommends using the software RailTest during the bring-up and validation phase of a Z-Wave product, interfacing to the Z-Wave device is as important as being able to perform RF measurements on the product.

RailTest is a stand-alone software package, available as a binary, and is *not* a part of any Z-Wave application. To use RailTest, one must be able to flash the Z-Wave device with the software during the development phase.

If the product *does not* contain a host processor, a programming interface to the Z-Wave device will be an integral part of the product, and it will not be a problem to flash RailTest to the Z-Wave device using the main programming interface of the product:

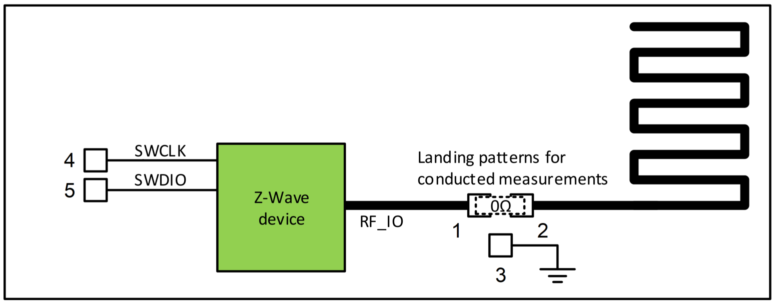


Figure 2.2. Programming Interface Landing Patterns for a Z-Wave Device

The programming pins of Z-Wave 700 devices are located at the ports PF0 and PF1, while the programming pins for Z-Wave 800 devices are located at the ports PA01 and PA02. The interface for these ports, along with supply and ground connections, etc., can be realized as a PCB connector, test points on the PCB, or landings patterns on the PCB. The method is selected depending on the requirements of the BOM cost and on how to assemble and program the Z-Wave product during the manufacturing flow. The main point is that there must be a physical programming interface available in the product.

If the product *does* contain a host processor, there are two possibilities for programming the Z-Wave device:

1. The host processor can download code to the Z-Wave device.
2. The host processor cannot download code to the Z-Wave device.

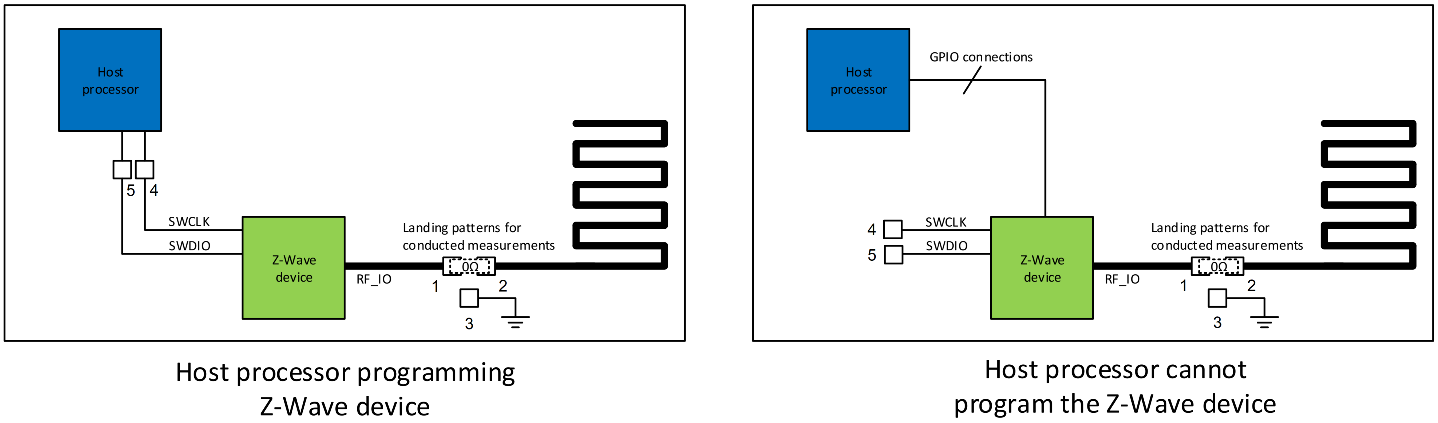

Host processor
5
4
SWCLK
SWDIO
Z-Wave device
RF_IO
Landing patterns for conducted measurements
0Ω
1
2
3
Host processor programming Z-Wave device
Host processor
GPIO connections
4
5
SWCLK
SWDIO
Z-Wave device
RF_IO
Landing patterns for conducted measurements
0Ω
1
2
3
Host processor cannot program the Z-Wave device

Figure 2.3. Host Processor Application

For situation #1, where the host processor can program the Z-Wave device, one must ensure that the host processor is also able to handle and download the RailTest during the bring-up and validation phase. If this is not the case, implementing a direct programming interface to the Z-Wave device, e.g., at a set of landing patterns, is strongly advised.

For situation #2, where the host processor is not able to program the Z-Wave device, programming the Z-Wave device must be handled as if the product did not contain any host-processor at all. In this case, a connector, landing patterns, or test points must be designed in to the product for programming purposes.

Apart from the ability to download RailTest software to the Z-Wave device, one must also be able to use and control the Command Line Interface, CLI, of RailTest, and this requires access to the UART pins of the Z-Wave device.

For products *without* a host processor, the interface to the UART pins of the Z-Wave device can be a connector, a set of landing patterns, or a set of test points on the product. See the example in Figure 2.4 on page 7.

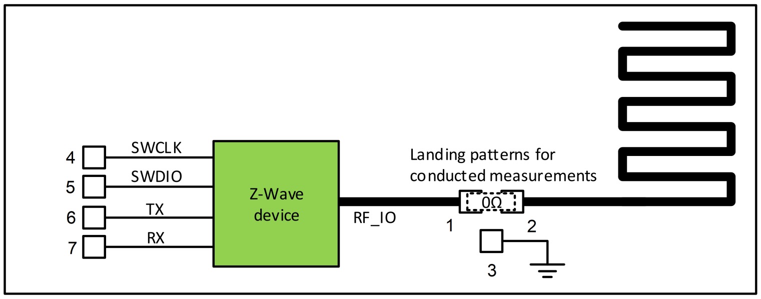
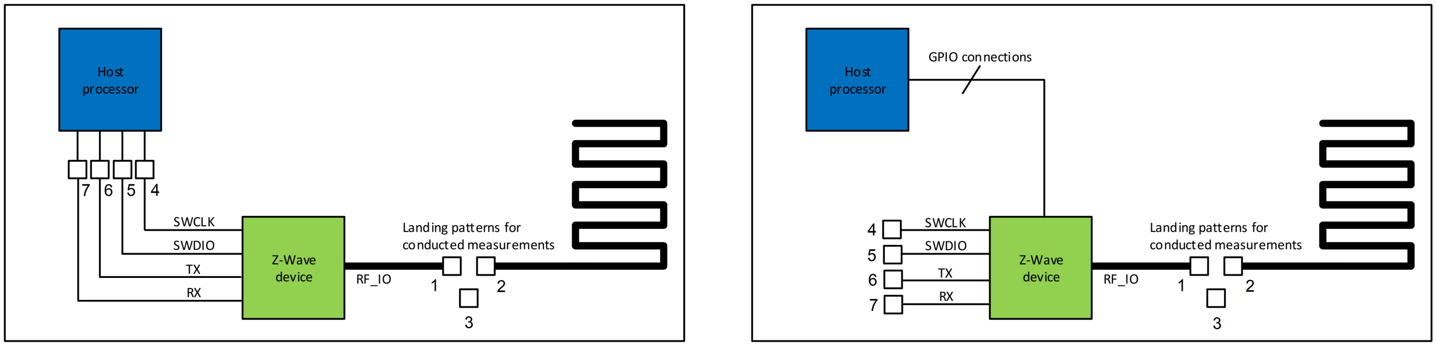


Figure 2.4. UART Connections for Z-Wave Product Without a Host Processor

During the bring-up and validation phase, wires can be temporarily connected to the UART interface and RailTest can be configured and controlled. The UART pins of Z-Wave 700 devices are located at the ports PA00 (UART_TX) and PA01 (UART_RX), while the UART pins for Z-Wave 800 devices are located at the ports PA08 (UART_TX) and PA09 (UART_RX).

For products *with* a host processor, two possibilities exist for controlling the RailTest software through the UART interface of the Z-Wave device:

1. The host processor provides a terminal interface.
2. The Z-Wave device can be controlled directly through its UART interface.



Host processor communicates with
Z-Wave device using UART

Host processor does not communicate with
Z-Wave device using UART

Figure 2.5. UART Connection to Z-Wave Device in Host Processor Products

For situation #1, where the host processor uses the UART lines to control the Z-Wave device, the host processor should be able to directly relay any commands to and from the Z-Wave device. This will enable the developer to control the RailTest software using the connection through the host processor. If this is not possible, a connection in the form of a connector, a set of landing patterns or test points, like those shown in Figure 2.5 on page 7, should be available on the product. During bring-up and validation, temporary connections to the UART connection points can make this be used to control the RailTest software.

For situation #2, where there are no UART connections between the host processor and the Z-Wave device, it is strongly advised to provide connection possibilities to the two UART connections of the Z-Wave device, e.g., the landing patterns 6 and 7 shown in the Figure 2.5 on page 7.

The cost of implementing a programming- and control-interface will depend on the method selected. If a connector is selected, and the connector is going to be permanently mounted in the product for no other reason than ensuring the interface needed for the bring-up phase, the BOM cost will be high. But, if the connector is not mounted in the finished product, or if the interface connections are realized as landing patterns or test points, the cost will only be the added real-estate of the PCB. If the programming interface and control interface are implemented as part of a host processor system, there will be no cost added at all.

The benefit of this hardware design strategy, where the needed interface connections are contained in the final product design is:

1. Shorter bring-up time
   - Effortless reprogramming and control of the product without cuts and straps
2. More reliable and predictable measurements
   - With a firmly attached programming and control interface, changes to settings can be repeated and are not dependent on dangling wires which easily break.

3. Better possibility for third-parties to interact with the product
   - Regulatory authorities can more easily handle the products during the required RF regulatory measurements since the product is not fragile.

As an example of products with added interface structures for use during both bring-up, validation and production, refer to the radio boards from the Z-Wave development kits:

- 700 series: BRD4206A, BRD4207A

- 800 series: BRD4204D, BRD4210A, BRD4205B

2.1.3 How to Provide Means for the RF Regulatory Authorities to Approve a Z-Wave Product

Any product containing a radio transmitting and receiving device must be approved by the appropriate RF regulatory authorities, and this is also valid for products based on the Z-Wave 700 and 800 devices.

The following RF properties are measured during an RF regulatory measurement session:

1. Conducted RF measurements
   - Performed on a CW for each Z-Wave frequency applicable for the product.
2. Radiated RF measurements
   - Performed on a CW for each Z-Wave frequency applicable for the product.
3. Performance measurements, such as blocking performance measurements
   - Performed on a simple Z-Wave system.

To obtain as efficient a measurement session at the RF regulatory authorities as possible, it is strongly advised to be well prepared:

1. Prepare a test product fitted with RF pig-tail/wired RF connection, RailTest downloaded to the product, and UART interface
   - This product will be for the Conducted and Radiated CW measurements
2. Prepare a test product with the Z-Wave application downloaded to the product
   - This product will be for the performance measurements
3. Prepare a controller / companion product for the product, which can enable the product for normal Z-Wave operation
   - This product will be for the performance measurements

The set of pre-configured modules, the controller, and how to use and setup the device for the various tests should be described in a Standard Operating Procedure (SOP), which should be sent with the modules when they are shipped to the RF regulatory authorities.

The controller to use can be a Silicon Labs Z-Wave PC controller or it can be the controller intended for controlling the product. The most important factor is that the controller and how it is to be used in relationship to the RF regulatory measurements is described in such a way that a third party, i.e., the test personnel at the RF regulatory test lab, will be able to setup the needed test sequence.

2.1.4 How to Adjust RF Parameters to Get the Best Possible Performance of the Product

Regarding adjustments and what to adjust to obtain the best possible RF performance of the product, most settings are taken care of by the Z-Wave protocol. There are, however, three settings which cannot be pre-set by the Z-Wave protocol because the settings are dependent of the layout for the product. These settings are as follows:

1. PA setting
   - The output level for the PA
2. Crystal calibration
   - Fine-tuning of the RF and system frequency
3. Listen Before Talk (LBT) RSSI threshold
   - The RF noise level threshold above which Z-Wave transmission is not allowed. Only valid for certain Z-Wave regions.

Regarding the PA setting: For each Z-Wave region, the level of RF power allowed to emit is regulated by the regional RF regulatory authorities. Both RailTest and the Z-Wave protocol allows for setting up the PA to be able to transmit as much RF power as allowed and fulfill the requirements for the RF fundamental as well as the RF harmonics.

Setting up the transmitted RF output power level can be adjusted in RailTest, and once the correct level is found, the setting must be transferred to the settings used in the Z-Wave protocol.

Instructions for using RailTest for setting the PA output power are described in section 3. Using Rail Test of this document.

Regarding the crystal calibration: Calibration/Fine adjustment of the crystal is applicable to products based on the EFR32ZG14 and EFR32ZG23 devices. For products based on ZGM130S and ZGM230S modules, no fine adjustment is needed since these modules are calibrated at production time.

What is the purpose of a system frequency calibration / fine adjustment? The tolerances of all crystals are divided into three components: (1) an initial tolerance, (2) a temperature tolerance, and (3) an aging tolerance. The initial tolerance is what can be removed by a calibration / fine adjustment of the product.

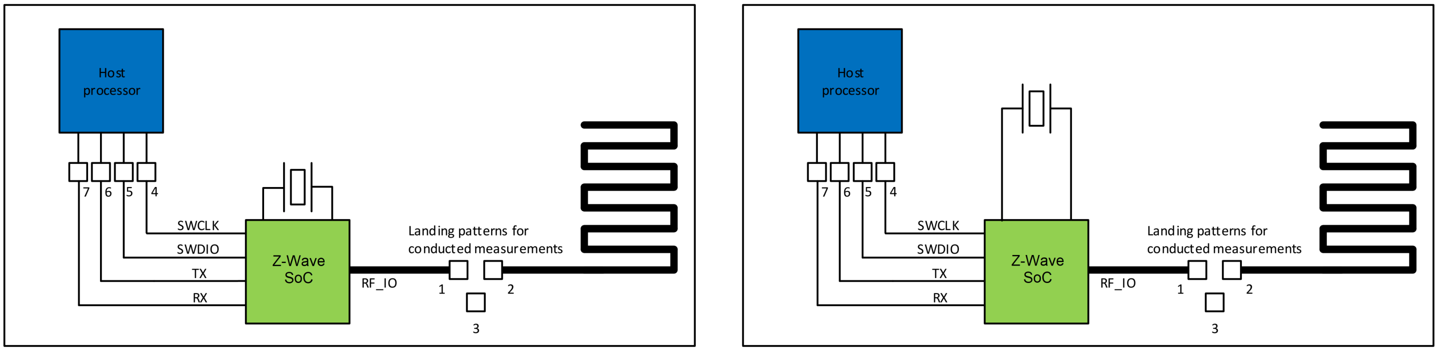
The general need for precise system frequency in a radio system arises from the fact that all receiver systems have filters in the receive path. To eliminate unwanted noise in the receiver path, the bandwidth of these receiver filters must be as narrow as possible. Therefore, a designer must make sure that the frequency variation of the transmitted signal matches the bandwidth of the receiver filters because if the transmitter varies too much, the receiver filters start to attenuate the information carrying signal. So, if both the transmitter and the receiver are aligned on the same RF frequency / system frequency, an optimal receive chain can be realized where only the information from the transmitters signal passes through the receiver filters.

There are two methods which can be used to conduct a crystal fine-tuning / calibration:

1. Each module is individually frequency calibrated during the manufacturing of the product
2. The product is generally frequency adjusted

Approach #1 results in the best possible performance of the product because it will ensure that the individual crystals are adjusted to their nominal frequencies. The drawback is a costly process to perform an inline crystal calibration during the manufacturing of a product. Note that all ZGM130S and ZGM230S devices are individually frequency calibrated during the device manufacturing process at Silicon Labs.

Approach #2 is a general frequency adjustment, which is highly recommended for the product when it is in the prototype phase. The general frequency adjustment counteracts for the parasitic load of the crystal component which varies from product layout to product layout. See the two examples below:



Short distance from system crystal to Z-Wave Gateway device

Long distance from system crystal to Z-Wave Gateway device

Figure 2.6. System Crystal Location on the Product

The product with the short distance between the system crystal and the Z-Wave SoC device has a relative small parasitic load capacitance compared to the product with the longer distance between the crystal and the Z-Wave SoC device.

Note: It is always recommended to keep the distance from the system crystal to the Z-Wave device as short as possible.

An internal load-capacitance can be adjusted through RailTest or through a Z-Wave API in the Z-Wave protocol. Due to lot-to-lot variations between Z-Wave devices, a general adjustment is not possible. Each product item must be individually calibrated during the production of the product.

Refer to Section 3. Using Rail Test to read more about how to perform the crystal adjustment.

Read more about crystal calibration in [3].

Regarding Listen Before Talk RSSI threshold: For certain Z-Wave regions, RF regulatory authorities require that a transmitting device performs a clear channel assessment before the device can transmit any RF energy. In Japan, the LBT limit is -80dBm, and, in Korea, the limit is -65dBm. This means that Z-Wave devices must be able to measure the amount of RF energy in the channel and, if the measured RF noise level is below -80dBm, the Z-Wave device may transmit a Z-Wave frame. The same applies for Z-Wave devices in Korea, only with the limit of RF noise at -65dBm.

To compensate for any RF loss in the RF path of a Z-Wave device, the LBT thresholds -80dBm or -65dBm cannot be used directly as threshold values in the Z-Wave protocol, since this would give a too pessimistic LBT threshold. For example, if the antenna gain of the product is -2dBi and the RF path-loss after the antenna is 2.5dB, due to some matching components, the total loss in the RF path is 4.5dB. With a loss of 4.5dB, the LBT threshold should be set to (-80dBm + 4.5dB) = -75.5dBm for the Japanese LBT threshold or (-65dBm + 4.5dB) = -61.5dBm for the Korean LBT threshold.

Note: Since LBT is part of the RF regulatory tests performed in certain Z-Wave regions, it is important that the LBT thresholds are correctly setup for the Z-Wave product.

Information on using the RailTest for finding the LBT threshold is described in section 3.5.12 How to Find the LBT Threshold of this document.

3. Using Rail Test

As mentioned in Section 2. Bringing Up Z-Wave Hardware in General, RailTest is a software tool distributed as part of the Z-Wave software offering, through which the user can setup various parameters relevant for both RF regulatory testing and for hardware bring-up and validation tests:

1. PA output power setting
2. Crystal fine-adjustment
3. Transmission of CW
4. Transmission of Z-Wave frames
5. Reception of Z-Wave frames
6. Finding the LBT threshold
7. Scripting of RailTest

When using RailTest, a special Z-Wave application is not required for the hardware developer to bring-up a product and validate it.

The usage of RailTest thus decouples the software development phase from the hardware bring-up phase.

3.1 Compiling RailTest

RailTest is part of the Z-Wave software distribution; it is an example project which needs to be compiled to a binary file, ready to be downloaded to the product using a tool such as Simplicity Commander (refer to [1]).

There are two versions of RailTest for 700 series:

1. RailTest for ZGM130S devices
2. RailTest for EFR32ZG14 devices

There are two versions of RailTest for 800 series:

1. RailTest for ZGM230S devices
2. RailTest for EFR32ZG23 devices

The correct RailTest version for the correct Z-Wave device must be used in the product.

How to compile RailTest is described in the Users Guide UG409 [4]. It is most important to select a UART buffer size of 128 bytes and to enable scripting in Flash.

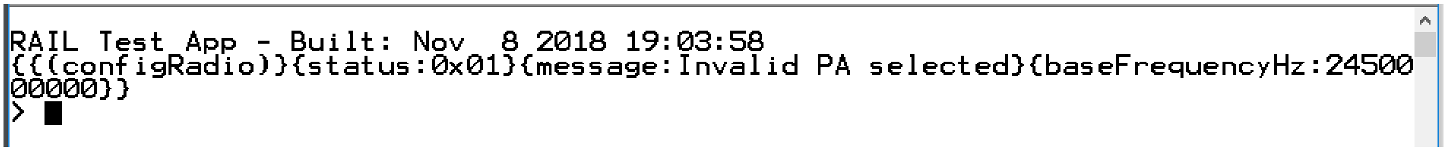
3.2 Interfacing to RailTest

As described in Section 2.1.2 How to Interface the Z-Wave Product During the Bring-Up Phase of the Project, RailTest uses UART lines for communication, which means that a computer with a terminal program is needed to be able to control and use RailTest. The serial settings must be:

1. Baudrate: 115.2kBaud
2. No parity
3. 8 databits
4. 1 stopbit
5. No handshake

3.3 Starting RailTest

Once connected to the product, and after having downloaded RailTest and started the terminal program on the computer, RailTest outputs information on both the display of the BRD4001A WSTK board and on the UART :



```
RAIL Test App - Built: Nov  8 2018 19:03:58
{{(configRadio)}{status:0x01}{message:Invalid PA selected}{baseFrequencyHz:24500
00000}}
> █
```

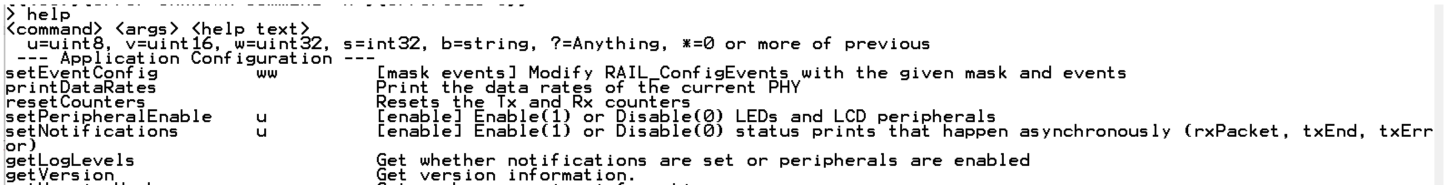
Figure 3.1. RailTest Reset Prompt

The program is now ready for input.

Initially, RailTest enables the device in receive mode at a non-Z-Wave frequency and setting. This setting needs to be changed.

3.4 Getting Help in RailTest

RailTest has a build in Help Menu. The Help Menu is shown using the command ‘help’:



```
> help
<command> <args> <help text>
  u=uint8, v=uint16, w=uint32, s=int32, b=string, ?=Anything, *=0 or more of previous
 --- Application Configuration ---
setEventConfig         ww          [mask events] Modify RAIL_ConfigEvents with the given mask and events
printDataRates                     Print the data rates of the current PHY
resetCounters                      Resets the Tx and Rx counters
setPeripheralEnable    u           [enable] Enable(1) or Disable(0) LEDs and LCD peripherals
setNotifications       u           [enable] Enable(1) or Disable(0) status prints that happen asynchronously (rxPacket, txEnd, txErr
or)
getLogLevels                       Get whether notifications are set or peripherals are enabled
getVersion                         Get version information.
```

Figure 3.2. RailTest Help Menu

The Help Menu will show all the capabilities of RailTest. Many of these are not relevant for Z-Wave applications, and only the relevant ones are described in this document.

3.5 Setting Up the Z-Wave Environment for RailTest

Follow the steps below to change to Z-Wave mode:

- Disable the initial receiver mode.
- Set up Z-Wave mode.
- Set up Z-Wave packets.
- Set up Z-Wave region.
- Set up Z-Wave channel number.

Once this is done, the user must decide if a transmission of Z-Wave frames, a CW transmission, or reception of Z-Wave frames is needed.

The following sections will show how to setup RailTest for various user-scenarios. All RailTest parameters will be written with the `Courier font` and enclosed with `‘’`. Comments are preceded with two semi-colons, such as `;; Comment`.

3.5.1 How to Adjust the PA Output Power Using RailTest

RailTest can be used to set the RF output level of the PA. The ability to adjust the PA output power is required to pass RF regulatory tests, where one of the key measurements is to ensure, that the level of RF power transmitted is at or below the required limits.

The RailTest command used to set up the output power is:

```
'SetPower yy raw'    ;; Set PA output power to setting number yy
```

Please refer to sections 3.5.2 How to Setup for CW Transmission, No SAW Filter/One SAW Filter and 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only) for examples, where this command is used.

The number yy is a decimal number ranging from 0 to 155 for the 700 series and from 0 to 200 for the 800 series, where 0 is the lowest possible power setting and 155/200 is the highest possible power setting.

Note: Please notice, that the RF PA power cannot be adjusted unless the device is in idle mode, that is, the command `‘rx 0’` must have been issued and the device may not be in any kind of transmit mode.

3.5.2 How to Setup for CW Transmission, No SAW Filter/One SAW Filter

This section describes how to use RailTest for setting up a CW transmission and for adjusting the PA output power on products with one or no SAW filters:

```
'rx 0                    ;; Set device in idle state
'SetZwaveMode 1 3'       ;; Setup for Z-Wave operation
'SetTxLength 20'         ;; Setup TX frame length
'SetTxPayload 7 20'      ;; Setup payload type and length
’setzwaveregion x’       ;; Setup Z-Wave region to number x, please see below
'SetPower yy raw’        ;; Set PA output power to setting number yy
‘setchannel z’           ;; Set Z-Wave channel number to z
'settxtone 1'            ;; Enable the CW
```

The number x for Z-Wave regions can be a number ranging from 0 to 13 (refer to the table below: Z-Wave Region Numbers). The Z-Wave frequencies for each region can be found in [2].

Table 3.1. Z-Wave Region Numbers

Region Number	Region Location	Saw Filter Region
0	EU-European Union	E
1	US-United States	U
2	ANZ-Australia/New Zealand	H
3	HK-Hong Kong	H
4	Non-Valid Z-Wave region*	
5	IN-India	E
6	JP-Japan	H
7	RU-Russia	E
8	IL-Israel	U
9	KR-Korea	H
10	CN-China	E
11	Z-Wave Long Range region 1	U
12	Z-Wave Long Range region 2	U
13	Z-Wave Long Range End Device	U
Note: *This Z-Wave region is no longer valid to use.		

According to Table 1, the command `‘setzwaveregion 0’` would enable the device for usage in countries following the European RF legislation.

The output of the PA is regulated using the command `‘setPower yy raw’` and the value yy is a number ranging from 0 to 155 for 700 series and 0 to 200 for 800 series. The higher a number, the more output power; the lower a number, the less output power.

The Z-Wave channel is set up using the command `‘setchannel z’`, and the value z is a number ranging from 0 to 3. Channel and baud-rate are tied together as shown in the table below (Channel Speed):

Table 3.2. Channel Speed[1]

Channel Number	Channel Speed
0	100 kBit/s GFSK
1	40 kBit/s FSK

Channel Number	Channel Speed
2	9.6 kBit/s FSK
3[2]	100 kBit/s OQPSK

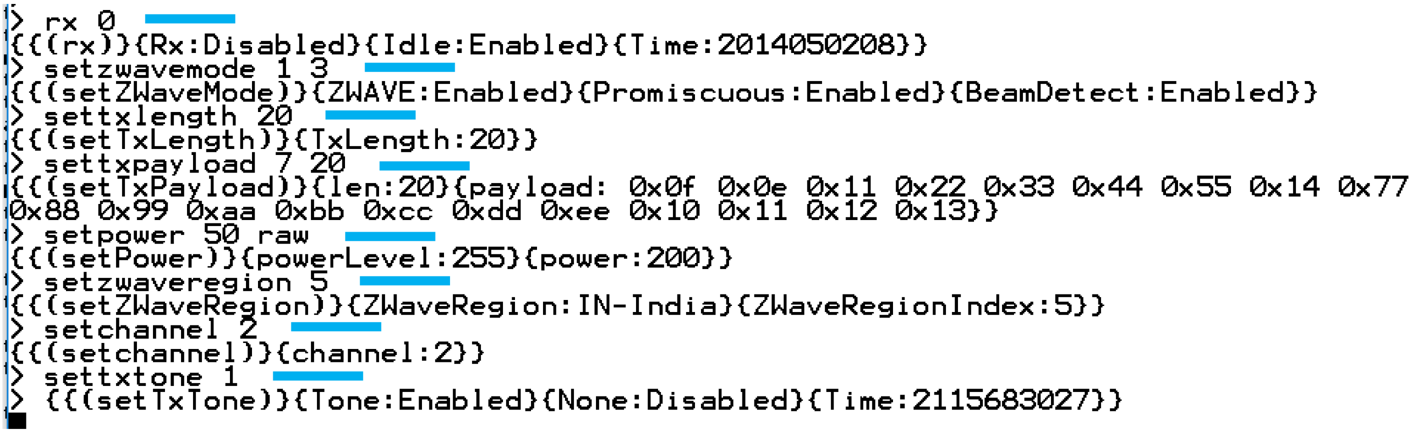
Note:

1. Channel speeds shown are not valid for JP and KR regions. In those regions, all channel speeds are 100 kBit/s GFSK.
2. Channel 3 is only available for regions 11 and 12, the Z-Wave Long Range “controller” regions.

The frequency of the CW is determined by 1) The Z-Wave region selected and 2) The Z-Wave channel selected within the Z-Wave region.

So, if transmission is to be tested on the European frequency 868.42 MHz, which is the 9.6 kBit/s channel, the channel number must be set to 2. And if transmission to be tested is at 912 MHz, which is the Z-Wave Long Range channel, then the region number is 11 and the channel number must be set to 3.

Below is an example where a device is initialized to transmit a CW at the Indian channel 2. The input commands to RailTest are marked with a blue line next to the command:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:2014050208}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 20
{{(setTxLength)}{TxLength:20}}
> settxpayload 7 20
{{(setTxPayload)}{len:20}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x14 0x77
0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x10 0x11 0x12 0x13}}
> setpower 50 raw
{{(setPower)}{powerLevel:255}{power:200}}
> setzwaveregion 5
{{(setZWaveRegion)}{ZWaveRegion:IN-India}{ZWaveRegionIndex:5}}
> setchannel 2
{{(setchannel)}{channel:2}}
> settxtone 1
> {{(setTxTone)}{Tone:Enabled}{None:Disabled}{Time:2115683027}}
```

Figure 3.3. Example of Setting Up a CW for the Indian Channel 2 Using 50 as Raw Power

Note: The product will continue to transmit a CW until the command `‘settxtone 0’` is issued.

3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only)

For products with multiple SAW filters, the correct SAW filter must be selected by setting the appropriate GPIO pins of the Z-Wave 700 device. Below is an example which can be used *if the product is configured like the BRD4200A or BRD4201A Z-Wave 700 development boards*. For these boards, PB14 and PB15 are used to select which SAW filter to use:

Table 3.3. SAW Filter Selection Settings for BRD4200A and BRD4201A Development Boards

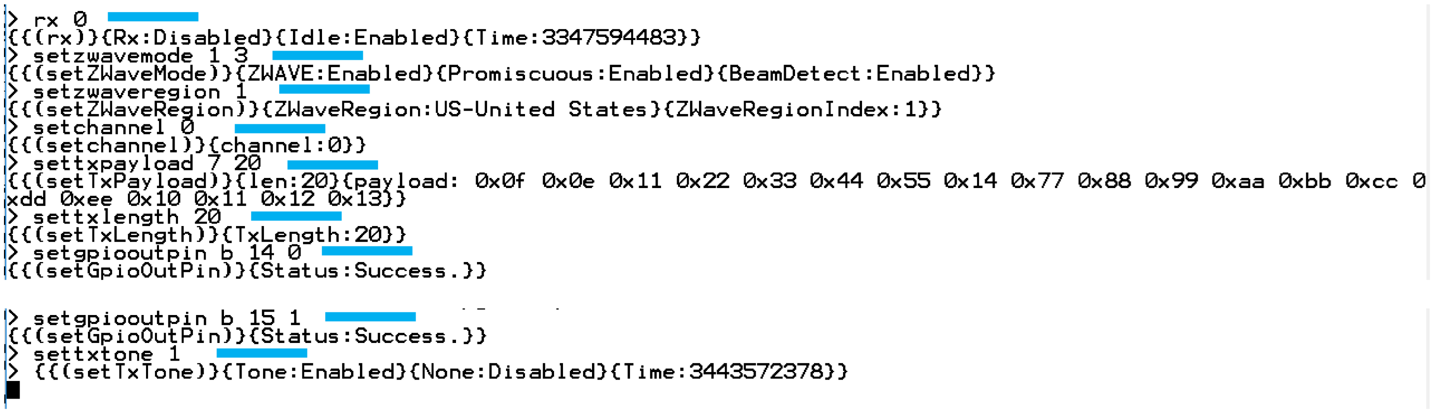
SAW Filter Region	PB14	PB15
H	0	0
E	1	0
U	0	1

```
'rx 0'                     ;; Disable receiver mode
'SetZwaveMode 1 3'         ;; Setup for Z-Wave operation
'SetTxLength 20'           ;; Setup TX frame length
'SetTxPayload 7 20'        ;; Setup payload type and length
’setzwaveregion x’         ;; Setup Z-Wave region to number x
'SetPower yy raw’          ;; Set PA output power to setting number yy
‘setchannel z’             ;; Set Z-Wave channel number to z
'setGPIOoutPin B 14 m'     ;; Set state of PB14 GPIO, m =[0,1]
'setGPIOoutPin B 15 n'     ;; set state of PB15 GPIO, n =[0,1]
'settxtone 1'              ;; Enable the CW
```

For a description of the number for the Z-Wave regions, refer to Table 3.1 Z-Wave Region Numbers on page 13.

For a description of the Z-Wave channels, refer to Table 3.2 Channel Speed[1] on page 13.

Below is an example where the product has a SAW filter bank like the one used on the BRD4200A / BRD4201A boards and the CW must be set to the US channel 0. The input commands are marked with blue line next to the commad:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:3347594483}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> setzwaveregion 1
{{(setZWaveRegion)}{ZWaveRegion:US-United States}{ZWaveRegionIndex:1}}
> setchannel 0
{{(setchannel)}{channel:0}}
> settxpayload 7 20
{{(setTxPayload)}{len:20}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x14 0x77 0x88 0x99 0xaa 0xbb 0xcc 0
xdd 0xee 0x10 0x11 0x12 0x13}}
> settxlength 20
{{(setTxLength)}{TxLength:20}}
> setgpiooutpin b 14 0
{{(setGpioOutPin)}{Status:Success.}}

> setgpiooutpin b 15 1
{{(setGpioOutPin)}{Status:Success.}}
> settxtone 1
> {{(setTxTone)}{Tone:Enabled}{None:Disabled}{Time:3443572378}}
```

Figure 3.4. Example of Setting up a CW for the US Channel 0 and with U-SAW Filter Selected

If the PA power needs to be adjusted, this must be done prior to enabling the CW using the command `‘setpower xx raw’`, where xx is a number ranging from 0 to 155.

Note: The product will continue to transmit a CW until the command `‘settxtone 0’` is issued.

Note: The selection of a SAW filter in a SAW filter bank depends on how the SAW filter bank is implemented in the product.

3.5.4 How to Set Up for Transmitting Z-Wave Frames

RailTest can transmit Z-Wave frames formatted according to the Z-Wave specification. This can be very useful in connection with sensitivity measurements or when the RF regulatory authorities measure the bandwidth of the Z-Wave radio channels.

Setting up for Z-Wave frame transmission is almost identical to setting up for CW transmission, except for the last command, which in this case is not `‘settxtone 1’` but instead `‘tx x’`, where x is a number. If the number is 0, a continuous stream of Z-Wave frames will be transmitted until the command `‘tx 0’` is issued again. If the number is not 0, then the number reflects how many Z-Wave frames should be transmitted.

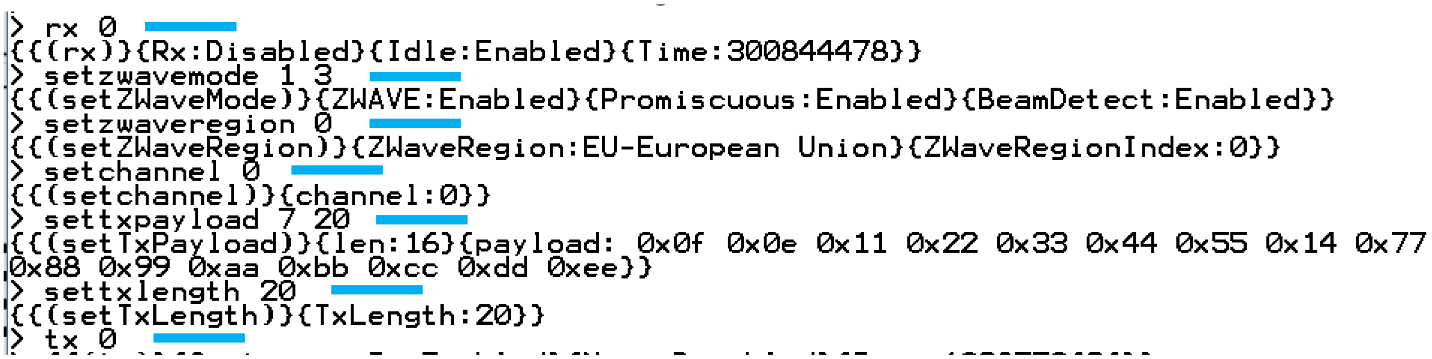
Below is an example where a product with only one or zero SAW filters is enabled for transmitting Z-Wave frames with a length of 20 bytes at the Z-Wave region 0 channel 0, which according to Table 3.1 Z-Wave Region Numbers on page 13 and Table 3.2 Channel Speed[1] on page 13, is the EU region 100 kBit/s channel:

```
‘rx 0’                    ;; disable RX mode
‘setzwavemode 1 3’        ;; Setup Z-Wave mode
‘setzwaveregion 0’        ;; Setup Z-Wave region 0, EU
’setchannel 0’            ;; Setup Z-Wave channel 0, 100 kBit/s channel
’settxpayload 7 20’       ;; Setup payload type and payload length
’settxlength 20’          ;; Setup payload length
’tx 0’                    ;; Start endless transmission of frames
```

For a description of the number for the Z-Wave regions, refer to Table 3.1 Z-Wave Region Numbers on page 13.

For a description of the Z-Wave channels, refer to Table 3.2 Channel Speed[1] on page 13.

Below is an example of how RailTest responds to the commands described above. The input commands to RailTest are marked with a blue line to the right of the command:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:300844478}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> setzwaveregion 0
{{(setZWaveRegion)}{ZWaveRegion:EU-European Union}{ZWaveRegionIndex:0}}
> setchannel 0
{{(setchannel)}{channel:0}}
> settxpayload 7 20
{{(setTxPayload)}{len:16}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x14 0x77
0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee}}
> settxlength 20
{{(setTxLength)}{TxLength:20}}
> tx 0
```

Figure 3.5. Setting Up for Z-Wave Frames Transmission, Region 0 Channel 0

Note: To stop the transmission of Z-Wave frames re-issue the command `‘tx 0’`.

If the Z-Wave 700 product has multiple SAW filters, use the same method as described in section 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only). Use the commands `'setGPIOoutPin B 14 m’` and `'setGPIOoutPin B 15 n'` according to the Table 3.3 SAW Filter Selection Settings for BRD4200A and BRD4201A Development Boards on page 15.

3.5.5 How to Set Up for Reception of Z-Wave Frames for a 700 Series Device

RailTest can receive and decode Z-Wave frames according to the Z-Wave specification. This can be very useful in connection with sensitivity measurements.

When setting up for Z-Wave reception, the setup is a bit more complicated compared to the transmission setup.

Below is an example where a product with only one or zero SAW filters is enabled for receiving Z-Wave frames with a length of 60 bytes at the Z-Wave region 0, which according to Table 3.1 Z-Wave Region Numbers on page 13 is the EU region. Note that setting up a channel is not needed because the Z-Wave 700 device will scan all three Z-Wave channels for valid Z-Wave traffic:

```
'rx 0'                                                           ;; Disable RX
'SetZwaveMode 1 3'                                               ;; Setup for Z-Wave mode
'SetTxLength 60'                                                 ;; Setup Z-Wave frame length
'SetTxPayload 7 60'                                              ;; Setup Z-Wave frame length and type
’setzwaveregion 0’                                               ;; Setup Z-Wave region
'configRXChannelHopping x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11 x12’  ;; Ch setup
'enableRxChannelHopping 1'                                       ;; Enable multi scanning mode
'rx 1'                                                           ;; Enable reception of Z-Wave frames
```

The values for the demodulator settings x_1 to x_{12} must be setup according to the table below:

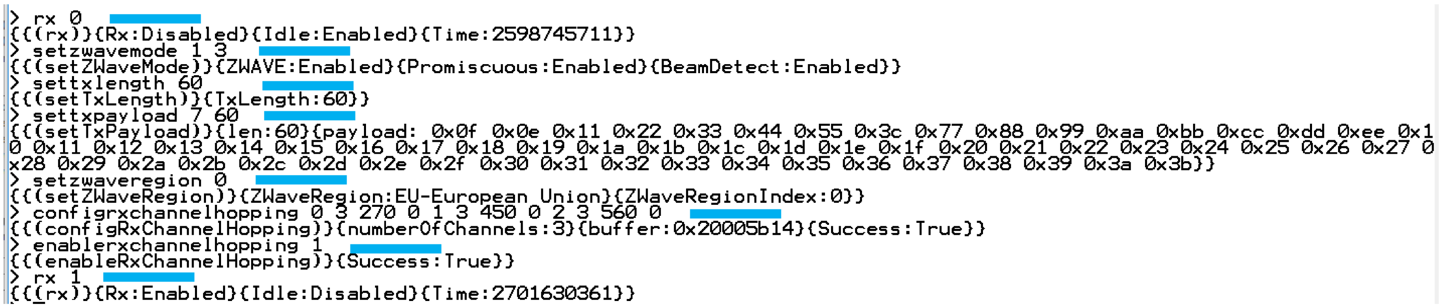
Table 3.4. Multi-Channel Settings

Region	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
0	0	3	270	0	1	3	450	0	2	3	560	0
1	0	3	270	0	1	3	450	0	2	3	560	0
2	0	3	270	0	1	3	450	0	2	3	560	0
3	0	3	270	0	1	3	450	0	2	3	560	0
4[1]	0	3	270	0	1	3	450	0	2	3	560	0
5	0	3	270	0	1	3	450	0	2	3	560	0
6	0	3	270	0	1	3	270	0	2	3	270	0
7	0	3	270	0	1	3	450	0	2	3	560	0
8	0	3	270	0	1	3	450	0	2	3	560	0
9	0	3	270	0	1	3	270	0	2	3	270	0
10	0	3	270	0	1	3	450	0	2	3	560	0

Note:

1. The row in red indicates that region 4 is an invalid Z-Wave region. See Table 3.1 Z-Wave Region Numbers on page 13.

Below is an example of how RailTest responds to the commands described above. The RailTest commands are marked with a blue line:

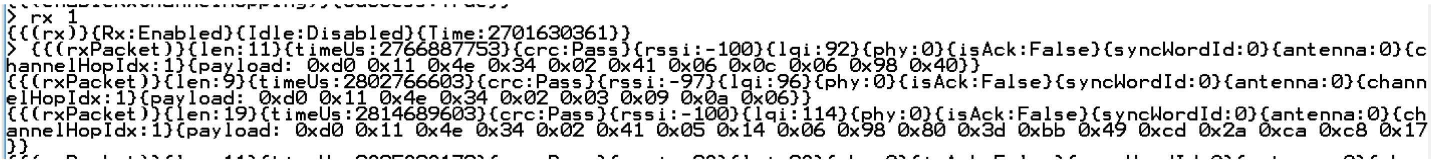


```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:2598745711}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 60
{{(setTxLength)}{TxLength:60}}
> settxpayload 7 60
{{(setTxPayload)}{len:60}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x3c 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x1
0 0x11 0x12 0x13 0x14 0x15 0x16 0x17 0x18 0x19 0x1a 0x1b 0x1c 0x1d 0x1e 0x1f 0x20 0x21 0x22 0x23 0x24 0x25 0x26 0x27 0
x28 0x29 0x2a 0x2b 0x2c 0x2d 0x2e 0x2f 0x30 0x31 0x32 0x33 0x34 0x35 0x36 0x37 0x38 0x39 0x3a 0x3b}}
> setzwaveregion 0
{{(setZWaveRegion)}{ZWaveRegion:EU-European Union}{ZWaveRegionIndex:0}}
> configrxchannelhopping 0 3 270 0 1 3 450 0 2 3 560 0
{{(configRxChannelHopping)}{numberOfChannels:3}{buffer:0x20005b14}{Success:True}}
> enablerxchannelhopping 1
{{(enableRxChannelHopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:2701630361}}
```

Figure 3.6. Setting Up RailTest for Z-Wave Reception in the Z-Wave Region 0, EU Region

The parameters for the channel hopping settings are found in the Table 3.4 Multi-Channel Settings on page 17. It is very important to use the correct settings for the selected Z-Wave region.

Once the receiver is setup and enabled, the product will start to receive any Z-Wave frame correctly formatted according to the Z-Wave specification. An example of received Z-Wave frames due to the setup described are shown in the figure below:



```
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:2701630361}}
> {{(rxPacket)}{len:11}{timeUs:2766887753}{crc:Pass}{rssi:-100}{lqi:92}{phy:0}{isAck:False}{syncWordId:0}{antenna:0}{c
hannelHopIdx:1}{payload: 0xd0 0x11 0x4e 0x34 0x02 0x41 0x06 0x0c 0x06 0x98 0x40}}
{{(rxPacket)}{len:9}{timeUs:2802766603}{crc:Pass}{rssi:-97}{lqi:96}{phy:0}{isAck:False}{syncWordId:0}{antenna:0}{chann
elHopIdx:1}{payload: 0xd0 0x11 0x4e 0x34 0x02 0x03 0x09 0x0a 0x06}}
{{(rxPacket)}{len:19}{timeUs:2814689603}{crc:Pass}{rssi:-100}{lqi:114}{phy:0}{isAck:False}{syncWordId:0}{antenna:0}{ch
annelHopIdx:1}{payload: 0xd0 0x11 0x4e 0x34 0x02 0x41 0x05 0x14 0x06 0x98 0x80 0x3d 0xbb 0x49 0xcd 0x2a 0xca 0xc8 0x17
}}
```

Figure 3.7. Example of Received Z-Wave Frames

The figure above shows how RailTest presents the reception of three different Z-Wave frames. Right after the enabling of the receiver, the command `'rx 1'`, a Z-Wave frame with the length of 11 bytes is received. A time stamp is given, the CRC value of the Z-Wave frame is validated, the incoming RSSI level is stated, and then the payload of the frame is written. Next, a frame of 9 bytes is received, followed by a frame with the length of 19.

So even though a Z-Wave frame length of 60 was set up, all frames are received, validated, and decoded.

If the Z-Wave 700 product has multiple SAW filters, and a SAW filter must be selected, use the same method as described in section 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only) and use the commands `'setGPIOoutPin B 14 m'` and `'setGPIOoutPin B 15 n'` according to the Table 3.3 SAW Filter Selection Settings for BRD4200A and BRD4201A Development Boards on page 15.

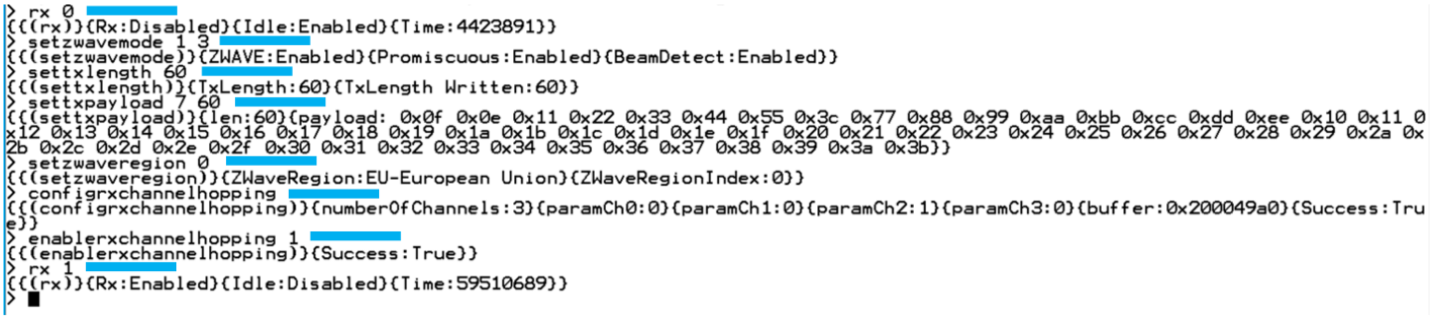
3.5.6 How to Set Up for Reception of Z-Wave Frames for an 800 Series Device

Setting up an 800 series device differs from setting up a 700 series device.

Below is an example where a product is enabled for receiving Z-Wave frames with a length of 60 bytes at the Z-Wave region 0, which according to Table 3.1 Z-Wave Region Numbers on page 13 is the EU region. Note that setting up a channel is not needed because the Z-Wave 800 device will scan all three Z-Wave channels for valid Z-Wave traffic:

```
'rx 0'                        ;; Disable RX
'SetZwaveMode 1 3'            ;; Setup for Z-Wave mode
'SetTxLength 60'              ;; Setup Z-Wave frame length
'SetTxPayload 7 60'           ;; Setup Z-Wave frame length and type
'setzwaveregion 0'            ;; Setup Z-Wave region
'configRxChannelHopping'      ;; Ch setup
'enableRxChannelHopping 1'    ;; Enable multi scanning mode
'rx 1'                        ;; Enable reception of Z-Wave frames
```

Below is an example of how RailTest responds to the commands described above. The RailTest commands are marked with a blue line:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:4423891}}
> setzwavemode 1 3
{{(setzwavemode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 60
{{(settxlength)}{TxLength:60}{TxLength Written:60}}
> settxpayload 7 60
{{(settxpayload)}{len:60}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x3c 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x10 0x11 0
x12 0x13 0x14 0x15 0x16 0x17 0x18 0x19 0x1a 0x1b 0x1c 0x1d 0x1e 0x1f 0x20 0x21 0x22 0x23 0x24 0x25 0x26 0x27 0x28 0x29 0x2a 0x
2b 0x2c 0x2d 0x2e 0x2f 0x30 0x31 0x32 0x33 0x34 0x35 0x36 0x37 0x38 0x39 0x3a 0x3b}}
> setzwaveregion 0
{{(setzwaveregion)}{ZWaveRegion:EU-European Union}{ZWaveRegionIndex:0}}
> configrxchannelhopping
{{(configrxchannelhopping)}{numberOfChannels:3}{paramCh0:0}{paramCh1:0}{paramCh2:1}{paramCh3:0}{buffer:0x200049a0}{Success:Tru
e}}
> enablerxchannelhopping 1
{{(enablerxchannelhopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:59510689}}
> █
```

Figure 3.8. Setting Up RailTest for Z-Wave Reception in the Z-Wave Region 0, EU Region

3.5.7 How to Set Up for Reception of Z-Wave Long Range Frames on a 700 Series Device

Setting up RailTest for reception and decoding of Z-Wave Long Range frames according to the Z-Wave specification. This can be very useful in connection with sensitivity measurements.

When setting up for Z-Wave Long Range reception, the setup is a bit more complicated compared to the transmission setup and to the setup of reception of “normal” Z-Wave. There are two different Z-Wave Long Range modes, controller mode and end-device mode, and both differ from the description shown in section 3.5.5 How to Set Up for Reception of Z-Wave Frames for a 700 Series Device.

The channel hopping options for Z-Wave Long Range are shown in the table below:

Table 3.5. Multi-Channel Settings for ZWLR

Region	11	12	13
X_1	0	0	0
X_2	131	131	2
X_3	290	290	300
X_4	0	0	0
X_5	1	1	1
X_6	131	131	2
X_7	340	340	300
X_8	0	0	0
X_9	2	2	
X_{10}	131	131	
X_{11}	580	580	
X_{12}	0	0	
X_{13}	3	3	
X_{14}	2	2	
X_{15}	300	300	
X_{16}	0	0	

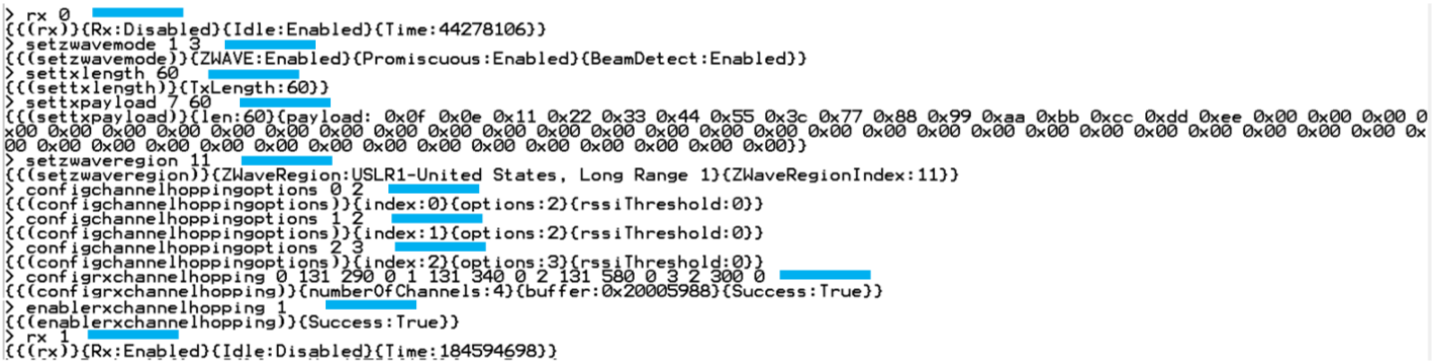
3.5.7.1 Reception of Frames for Z-Wave Long Range Regions 11 and 12

Below is an example where a product with no SAW filters is enabled for receiving Z-Wave Long Range frames with a length of 60 bytes at the Z-Wave region 11, which according to Table 3.1 Z-Wave Region Numbers on page 13 is the US Long Range region 1. Note that setting up a channel is not needed because the Z-Wave 700 device will scan all four Z-Wave channels for valid Z-Wave traffic:

```
'rx 0'                                                                  ;; Disable RX
'SetZwaveMode 1 3'                                                      ;; Setup for Z-Wave mode
'SetTxLength 60'                                                        ;; Setup Z-Wave frame length
'SetTxPayload 7 60'                                                     ;; Setup Z-Wave frame length and type
’setzwaveregion 11’                                                     ;; Setup Z-Wave Long Range region
’configChannelHoppingOptions 0 2’                                       ;; Setup hopping options
’configChannelHoppingOptions 1 2’                                       ;; Setup hopping options
’configChannelHoppingOptions 2 3’                                       ;; Setup hopping options
'configRXChannelHopping x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11 x12 x13 x14 x15 x16’ ;; Ch setup
'enableRxChannelHopping 1'                                              ;; Enable multi scanning mode
'rx 1'                                                                  ;; Enable reception of Z-Wave frames
```

The values for the demodulator settings x_1 to x_{16} must be setup according to Table 3.5 Multi-Channel Settings for ZWLR on page 19.

Below is an example of how RailTest responds to the commands described above. The RailTest commands are marked with a blue line:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:44278106}}
> setzwavemode 1 3
{{(setzwavemode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 60
{{(settxlength)}{TxLength:60}}
> settxpayload 7 60
{{(settxpayload)}{len:60}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x3c 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x00 0x00 0x00 0
x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x
00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00}}
> setzwaveregion 11
{{(setzwaveregion)}{ZWaveRegion:USLR1-United States, Long Range 1}{ZWaveRegionIndex:11}}
> configchannelhoppingoptions 0 2
{{(configchannelhoppingoptions)}{index:0}{options:2}{rssiThreshold:0}}
> configchannelhoppingoptions 1 2
{{(configchannelhoppingoptions)}{index:1}{options:2}{rssiThreshold:0}}
> configchannelhoppingoptions 2 3
{{(configchannelhoppingoptions)}{index:2}{options:3}{rssiThreshold:0}}
> configrxchannelhopping 0 131 290 0 1 131 340 0 2 131 580 0 3 2 300 0
{{(configrxchannelhopping)}{numberOfChannels:4}{buffer:0x20005988}{Success:True}}
> enablerxchannelhopping 1
{{(enablerxchannelhopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:184594698}}
```

Figure 3.9. Setup of Reception of Z-Wave Long Range in Region 11

The parameters for the channel hopping settings are found in Table 3.5 Multi-Channel Settings for ZWLR on page 19. It is very important to use the correct settings for the selected Z-Wave Long Range region.

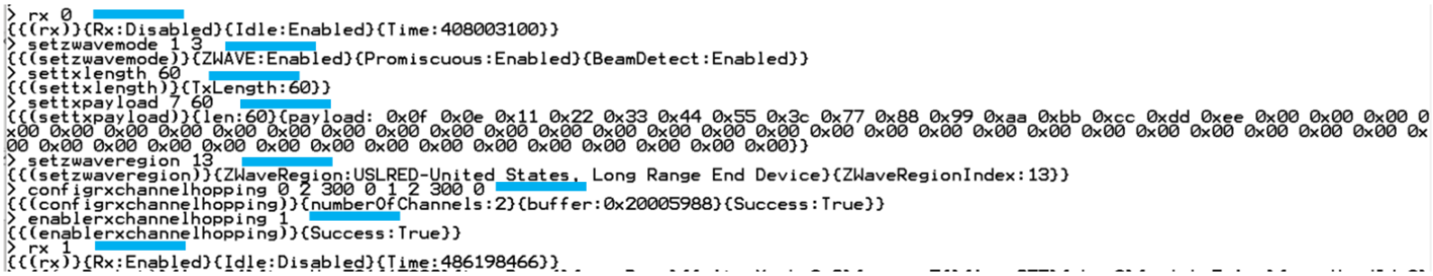
3.5.7.2 Reception of Frames for Z-Wave Long Range Region 13

Below is an example where a product with no SAW filters is enabled for receiving Z-Wave Long Range frames with a length of 60 bytes at the Z-Wave region 13, which according to Table 3.1 Z-Wave Region Numbers on page 13 is the US Long Range region for end-devices. Note that setting up a channel is not needed because the Z-Wave 700 device will scan all four Z-Wave channels for valid Z-Wave traffic:

```
'rx 0'                                                   ;; Disable RX
'SetZwaveMode 1 3'                                       ;; Setup for Z-Wave mode
'SetTxLength 60'                                         ;; Setup Z-Wave frame length
'SetTxPayload 7 60'                                      ;; Setup Z-Wave frame length and type
’setzwaveregion 13’                                      ;; Setup Z-Wave Long Range region
'configRXChannelHopping x1 x2 x3 x4 x5 x6 x7 x8’         ;; Ch setup
'enableRxChannelHopping 1'                               ;; Enable multi scanning mode
'rx 1'                                                   ;; Enable reception of Z-Wave frames
```

The values for the demodulator settings x_1 to x_8 must be setup according to Table 3.5 Multi-Channel Settings for ZWLR on page 19.

Below is an example of how RailTest responds to the commands described above. The RailTest commands are marked with a blue line:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:408003100}}
> setzwavemode 1 3
{{(setzwavemode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 60
{{(settxlength)}{TxLength:60}}
> settxpayload 7 60
{{(settxpayload)}{len:60}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x3c 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x00 0x00 0x00 0
x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x
00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00}}
> setzwaveregion 13
{{(setzwaveregion)}{ZWaveRegion:USLRED-United States, Long Range End Device}{ZWaveRegionIndex:13}}
> configrxchannelhopping 0 2 300 0 1 2 300 0
{{(configrxchannelhopping)}{numberOfChannels:2}{buffer:0x20005988}{Success:True}}
> enablerxchannelhopping 1
{{(enablerxchannelhopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:486198466}}
```

Figure 3.10. Setup of Reception of Z-Wave Long Range in Region 13

The parameters for the channel hopping settings are found in Table 3.5 Multi-Channel Settings for ZWLR on page 19. It is very important to use the correct settings for the selected Z-Wave Long Range region.

3.5.8 How to Set Up for Reception of Z-Wave Long Range Frames on an 800 Series Device

Setting up RailTest for reception and decoding of Z-Wave Long Range frames according to the Z-Wave specification differs between the 700 series and the 800 series.

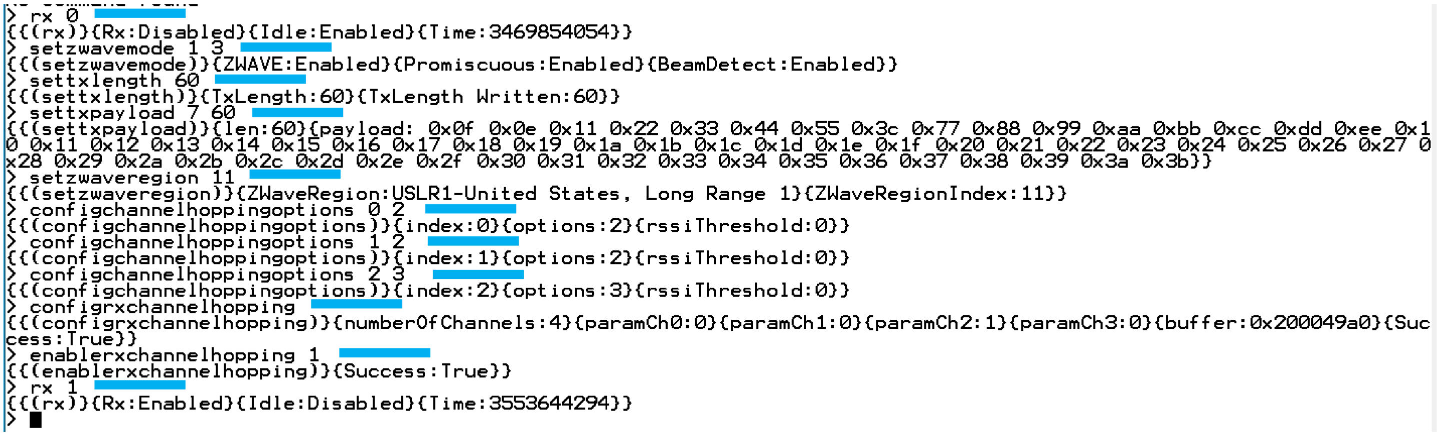
When setting up for Z-Wave Long Range reception, the setup is a bit more complicated compared to the transmission setup and to the setup of reception of “normal” Z-Wave. There are two different Z-Wave Long Range modes, controller mode and end-device mode, and both differ from the description shown in section 3.5.6 How to Set Up for Reception of Z-Wave Frames for an 800 Series Device.

3.5.8.1 Reception of Frames for Z-Wave Long Range Regions 11 and 12

Below is an example where a product is enabled for receiving Z-Wave Long Range frames with a length of 60 bytes at the Z-Wave region 11, which according to Table 3.1 Z-Wave Region Numbers on page 13 is the US Long Range region 1. Note that setting up a channel is not needed because the Z-Wave 800 device will scan all four Z-Wave channels for valid Z-Wave traffic:

```
'rx 0'                                  ;; Disable RX
'SetZwaveMode 1 3'                      ;; Setup for Z-Wave mode
'SetTxLength 60'                        ;; Setup Z-Wave frame length
'SetTxPayload 7 60'                     ;; Setup Z-Wave frame length and type
'setzwaveregion 11'                     ;; Setup Z-Wave Long Range region
'configChannelHoppingOptions 0 2'       ;; Setup hopping options
'configChannelHoppingOptions 1 2'       ;; Setup hopping options
'configChannelHoppingOptions 2 3'       ;; Setup hopping options
'configRXChannelHopping'                ;; Ch setup
'enableRxChannelHopping 1'              ;; Enable multi scanning mode
'rx 1'                                  ;; Enable reception of Z-Wave frames
```

Below is an example of how RailTest responds to the commands described above. The RailTest commands are marked with a blue line:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:3469854054}}
> setzwavemode 1 3
{{(setzwavemode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 60
{{(settxlength)}{TxLength:60}{TxLength Written:60}}
> settxpayload 7 60
{{(settxpayload)}{len:60}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x3c 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x1
0 0x11 0x12 0x13 0x14 0x15 0x16 0x17 0x18 0x19 0x1a 0x1b 0x1c 0x1d 0x1e 0x1f 0x20 0x21 0x22 0x23 0x24 0x25 0x26 0x27 0
x28 0x29 0x2a 0x2b 0x2c 0x2d 0x2e 0x2f 0x30 0x31 0x32 0x33 0x34 0x35 0x36 0x37 0x38 0x39 0x3a 0x3b}}
> setzwaveregion 11
{{(setzwaveregion)}{ZWaveRegion:USLR1-United States, Long Range 1}{ZWaveRegionIndex:11}}
> configchannelhoppingoptions 0 2
{{(configchannelhoppingoptions)}{index:0}{options:2}{rssiThreshold:0}}
> configchannelhoppingoptions 1 2
{{(configchannelhoppingoptions)}{index:1}{options:2}{rssiThreshold:0}}
> configchannelhoppingoptions 2 3
{{(configchannelhoppingoptions)}{index:2}{options:3}{rssiThreshold:0}}
> configrxchannelhopping
{{(configrxchannelhopping)}{numberOfChannels:4}{paramCh0:0}{paramCh1:0}{paramCh2:1}{paramCh3:0}{buffer:0x200049a0}{Suc
cess:True}}
> enablerxchannelhopping 1
{{(enablerxchannelhopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:3553644294}}
> █
```

Figure 3.11. Setup of Reception of Z-Wave Long Range in Region 11

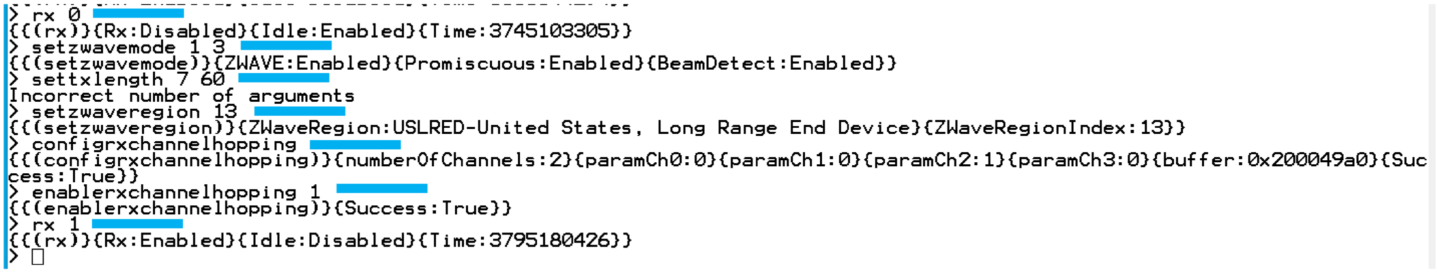
3.5.8.2 Reception of Frames for Z-Wave Long Range Region 13

Below is an example where a product is enabled for receiving Z-Wave Long Range frames with a length of 60 bytes at the Z-Wave region 13, which according to Table 3.1 Z-Wave Region Numbers on page 13 is the US Long Range region for end-devices. Note that setting up a channel is not needed because the Z-Wave 800 device will scan all four Z-Wave channels for valid Z-Wave traffic:

```
'rx 0'                          ;; Disable RX
'SetZwaveMode 1 3'              ;; Setup for Z-Wave mode
'SetTxLength 60'                ;; Setup Z-Wave frame length
'SetTxPayload 7 60'             ;; Setup Z-Wave frame length and type
’setzwaveregion 13’             ;; Setup Z-Wave Long Range region
'configRXChannelHopping’        ;; Ch setup
'enableRxChannelHopping 1'      ;; Enable multi scanning mode
'rx 1'                          ;; Enable reception of Z-Wave frames
```

The values for the demodulator settings x_1 to x_8 must be setup according to Table 3.5 Multi-Channel Settings for ZWLR on page 19.

Below is an example of how RailTest responds to the commands described above. The RailTest commands are marked with a blue line:

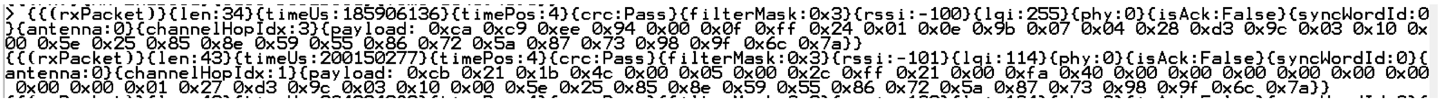


```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:3745103305}}
> setzwavemode 1 3
{{(setzwavemode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> settxlength 7 60
Incorrect number of arguments
> setzwaveregion 13
{{(setzwaveregion)}{ZWaveRegion:USLRED-United States, Long Range End Device}{ZWaveRegionIndex:13}}
> configrxchannelhopping
{{(configrxchannelhopping)}{numberOfChannels:2}{paramCh0:0}{paramCh1:0}{paramCh2:1}{paramCh3:0}{buffer:0x200049a0}{Suc
cess:True}}
> enablerxchannelhopping 1
{{(enablerxchannelhopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:3795180426}}
> □
```

Figure 3.12. Setup of Reception of Z-Wave Long Range in Region 13

3.5.9 Reception of Z-Wave Long Range Frames

Once the receiver is setup and enabled, the product will start to receive any Z-Wave frame correctly formatted according to the Z-Wave and Z-Wave Long Range specification. An example of received Z-Wave frames due to the setup described are shown in the figure below:



```
> {{(rxPacket)}{len:34}{timeUs:185906136}{timePos:4}{crc:Pass}{filterMask:0x3}{rssi:-100}{lqi:255}{phy:0}{isAck:False}{syncWordId:0
}{antenna:0}{channelHopIdx:3}{payload: 0xca 0xc9 0xee 0x94 0x00 0x0f 0xff 0x24 0x01 0x0e 0x9b 0x07 0x04 0x28 0xd3 0x9c 0x03 0x10 0x
00 0x5e 0x25 0x85 0x8e 0x59 0x55 0x86 0x72 0x5a 0x87 0x73 0x98 0x9f 0x6c 0x7a}}
{{(rxPacket)}{len:43}{timeUs:200150277}{timePos:4}{crc:Pass}{filterMask:0x3}{rssi:-101}{lqi:114}{phy:0}{isAck:False}{syncWordId:0}{
antenna:0}{channelHopIdx:1}{payload: 0xcb 0x21 0x1b 0x4c 0x00 0x05 0x00 0x2c 0xff 0x21 0x00 0xfa 0x40 0x00 0x00 0x00 0x00 0x00 0x00
 0x00 0x00 0x01 0x27 0xd3 0x9c 0x03 0x10 0x00 0x5e 0x25 0x85 0x8e 0x59 0x55 0x86 0x72 0x5a 0x87 0x73 0x98 0x9f 0x6c 0x7a}}
```

Figure 3.13. Example of Received Z-Wave Long Range Frames

The figure above shows how RailTest presents the reception of two different Z-Wave frames. Right after the enabling of the receiver, the command `'rx 1’`, a Z-Wave frame with the length of 34 bytes is received. A time stamp is given, the CRC value of the Z-Wave frame is validated, the incoming RSSI level is stated, the channel hop ID is given, and then the payload of the frame is written. Next, a frame of 43 bytes is received, and this frame is received at another hop index than the previous.

So even though a Z-Wave frame length of 60 was set up, all frames at all channels within a region are received, validated, and decoded.

If the Z-Wave 700 product has multiple SAW filters, and a SAW filter must be selected, use the same method as described in section 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only) and use the commands `'setGPIOoutPin B 14 m’` and `'setGPIOoutPin B 15 n'` according to the Table 3.3 SAW Filter Selection Settings for BRD4200A and BRD4201A Development Boards on page 15.

3.5.10 How to Fine-Tune the System Crystal Using RailTest

3.5.10.1 For EFR32ZG14 SoCs

As mentioned in section 2.1.4 How to Adjust RF Parameters to Get the Best Possible Performance of the Product, the RF system frequency must be adjusted and it is strongly recommended for EFR32ZG14 devices to compensate for the parasitic load capacitance added by the products PCB to the system crystal.

The adjustment procedure is a two-step process:

1. Establish the RF frequency offset.
2. Adjust and remeasure the RF frequency offset.

For item #1, generating an RF CW is needed. How to generate a CW using RailTest is described in either section 3.5.2 How to Setup for CW Transmission, No SAW Filter/One SAW Filter or 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only).

Once the product is transmitting a CW, the frequency of the CW must be measured with a precise and newly calibrated spectrum analyzer. The frequency span of the spectrum analyzer should be set to no more than 100 kHz with a low resolution bandwidth in order to be able to measure the small frequency changes introduced by the crystal frequency adjustments.

The frequency measured on the products must be recorded for later comparison purposes.

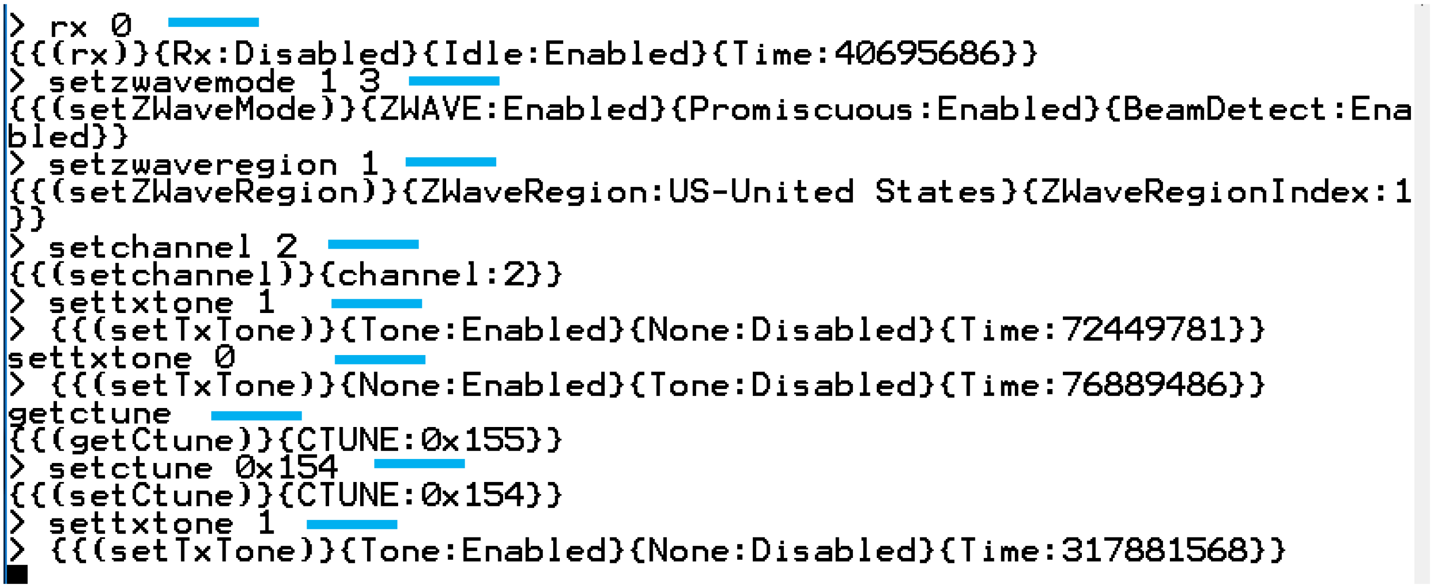
Once the frequency of the board is recorded, the adjustment process can start. Assuming the TxTune being turned on, please use below RailTest commands:

```
‘setTxTone 0’              ;; Disable the TxTone
‘rx 0’                     ;; Set the system in idle
‘getCtune’                 ;; Read the current CTune value
‘setCtune 0xYYY’           ;; Set a new CTune value
‘setTxTone 1’              ;; Re-enable the TxTone again
```

The command `‘getctune’` is used to find the initial setting for the product. This number will be given as a hexadecimal number, hence the notation 0xYYY.

An iterative process now starts. It is strongly advised to only change the value of CTune in small increments, e.g. change the CTune value 2 digits up or down. With the new CTune setting 0xYYY, a new frequency measurement should be performed to verify if the CW frequency is adjusted to the target frequency.

An example of a frequency adjustment cycle is shown below. In the example, the target frequency is 908.42 MHz, since the Z-Wave region is selected to `‘1’` and the channel number is set to 2 (for reference, please see Table 3.1 Z-Wave Region Numbers on page 13 and Table 3.2 Channel Speed[1] on page 13). The product does not have a switchable SAW filter bank. The RailTest commands are marked with a blue line to the right of the command:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:40695686}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Ena
bled}}
> setzwaveregion 1
{{(setZWaveRegion)}{ZWaveRegion:US-United States}{ZWaveRegionIndex:1
}}
> setchannel 2
{{(setchannel)}{channel:2}}
> settxtone 1
> {{(setTxTone)}{Tone:Enabled}{None:Disabled}{Time:72449781}}
settxtone 0
> {{(setTxTone)}{None:Enabled}{Tone:Disabled}{Time:76889486}}
getctune
{{(getCtune)}{CTUNE:0x155}}
> setctune 0x154
{{(setCtune)}{CTUNE:0x154}}
> settxtone 1
> {{(setTxTone)}{Tone:Enabled}{None:Disabled}{Time:317881568}}
```

Figure 3.14. System Frequency Adjustment Procedure

If the CW is adjusted to be within 1ppm, no further adjustments are needed.

Note: Due to the inherent tolerances of crystals, only a “pr. Product” fine-adjustment/calibration will eliminate the frequency offset for each individual product.

3.5.10.2 For ZGM130S SiP modules

Since the ZGM130S devices are frequency calibrated during the manufacturing process, no frequency adjustment is needed to obtain a precise RF frequency. However, RailTest does not automatically use the CTune value found during the calibration. If there is a need to fine-tune a ZGM130S based product during the usage of RailTest, please follow the procedure shown below:

```
‘rx 0’                    ;; Set device in idle
‘getmemw 0xFE081B8’       ;; Read crystal calibration value from ZGM130S
‘setctune 0xZZZ’          ;; write the calibration value to RailTest
```

The value 0xZZZ depends on the value return by the memory read operation `‘getmemw’`. The CTune value 0xZZZ is equal to a binary AND operation of the returned memory content :

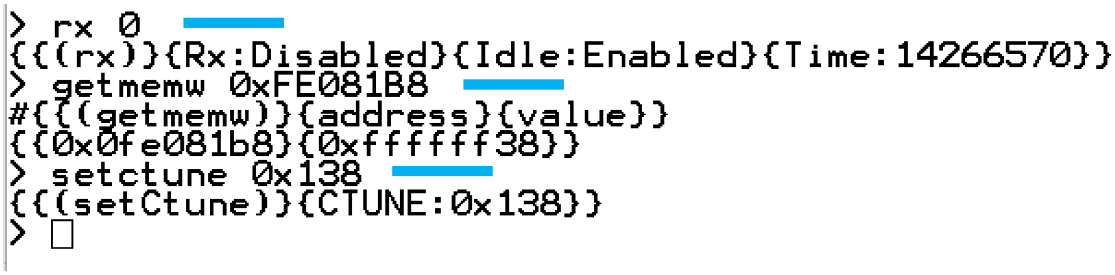
CTune = Returned result of `‘getmemw 0xFE081B8’` & `0x1FF`

Example:

The ‘getmemw’ returns the hexadecimal value `0xffffff38`. The CTune value to write is:

CTune = 0xffffff38 & 0x1ff => Ctune = 0x138

An example of how to read back the calibration value for the system crystal in RailTest is shown below. The RailTest commands are marked with a blue line to the right of the command:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:14266570}}
> getmemw 0xFE081B8
#{{(getmemw)}{address}{value}}
{{0x0fe081b8}{0xffffff38}}
> setctune 0x138
{{(setCtune)}{CTUNE:0x138}}
> □
```

Figure 3.15. Read Back of Crystal Calibration Value for ZGM130S Device

3.5.10.3 For EFR32ZG23 SoCs

As mentioned in section 2.1.4 How to Adjust RF Parameters to Get the Best Possible Performance of the Product, the RF system frequency must be adjusted and it is strongly recommended for Z-Wave EFR32ZG23 devices to compensate for the parasitic load capacitance added by the products PCB to the system crystal.

The adjustment procedure is a two-step process:

1. Establish the RF frequency offset.
2. Adjust and remeasure the RF frequency offset.

For item #1, generating an RF CW is needed. How to generate a CW using RailTest is described in either section 3.5.2 How to Setup for CW Transmission, No SAW Filter/One SAW Filter or 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only).

Once the product is transmitting a CW, the frequency of the CW must be measured with a precise and newly calibrated spectrum analyzer. The frequency span of the spectrum analyzer should be set to no more than 100 kHz with a low resolution bandwidth in order to be able to measure the small frequency changes introduced by the crystal frequency adjustments.

The frequency measured on the products must be recorded for later comparison purposes.

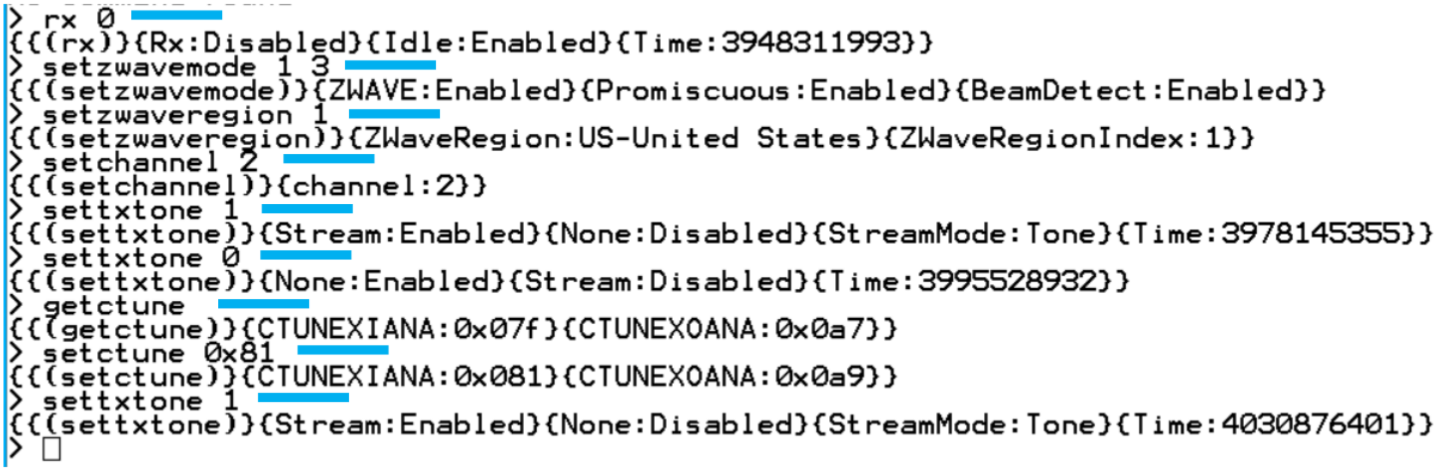
Once the frequency of the board is recorded, the adjustment process can start. Assuming the TxTune being turned on, please use below RailTest commands:

```
'setTxTone 0'              ;; Disable the TxTone
'rx 0'                     ;; Set the system in idle
'getCtune'                 ;; Read the current CTune value
'setCtune 0xYY'            ;; Set a new CTune value
'setTxTone 1'              ;; Re-enable the TxTone again
```

The command `'getctune'` is used to find the initial setting for the product. This number will be given as a hexadecimal number with the notation CTUNEXIANA: 0xYY (Two numbers are returned {CTUNEXIANA:0x0YY}{CTUNEXOANA:0x0ZZ}, but only the CTUNEXIANA is important for the C-tuning).

An iterative process now starts. It is strongly advised to only change the value of CTune in small increments, e.g. change the CTune value 2 digits up or down. With the new CTune setting 0xYY, a new frequency measurement should be performed to verify if the CW frequency is adjusted to the target frequency.

An example of a frequency adjustment cycle is shown below. In the example, the target frequency is 908.42 MHz, since the Z-Wave region is selected to `'1'` and the channel number is set to 2 (for reference, please see Table 3.1 Z-Wave Region Numbers on page 13 and Table 3.2 Channel Speed[1] on page 13). The product does not have a switchable SAW filter bank. The RailTest commands are marked with a blue line to the right of the command:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:3948311993}}
> setzwavemode 1 3
{{(setzwavemode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> setzwaveregion 1
{{(setzwaveregion)}{ZWaveRegion:US-United States}{ZWaveRegionIndex:1}}
> setchannel 2
{{(setchannel)}{channel:2}}
> settxtone 1
{{(settxtone)}{Stream:Enabled}{None:Disabled}{StreamMode:Tone}{Time:3978145355}}
> settxtone 0
{{(settxtone)}{None:Enabled}{Stream:Disabled}{Time:3995528932}}
> getctune
{{(getctune)}{CTUNEXIANA:0x07f}{CTUNEXOANA:0x0a7}}
> setctune 0x81
{{(setctune)}{CTUNEXIANA:0x081}{CTUNEXOANA:0x0a9}}
> settxtone 1
{{(settxtone)}{Stream:Enabled}{None:Disabled}{StreamMode:Tone}{Time:4030876401}}
> □
```

Figure 3.16. System Frequency Adjustment Procedure

In the example above, the CTune value was read back as 0x07F and adjusted to 0x081. If the CW is adjusted to be within 1ppm, no further adjustments are needed.

Note: Due to the inherent tolerances of crystals, only a “pr. Product” fine-adjustment/calibration will eliminate the frequency offset for each individual product.

3.5.10.4 For ZGM230S SiP Modules

Since the ZGM230S devices are frequency calibrated during the manufacturing process, no frequency adjustment is needed to obtain a precise RF frequency.

3.5.11 How to Perform a Sensitivity Measurement Using RailTest

A sensitivity measurement is the most vital measurement which can be performed on a wireless product. It shows the RF qualities of the product, and for wireless enabled products, the RF qualities will define the overall customer experience of the product:

1. The better sensitivity, the better a range between nodes in a Z-Wave network
    - Better coverage with fewer devices
2. Better range means fewer repeater devices in the Z-Wave network
    - Less cost for the customer
    - Lower network latency
3. With better sensitivity, frames do not need to be re-transmitted and hence less power is needed.
    - For sensor products, limiting the number of re-transmissions conserves the battery

There are two ways of conducting sensitivity measurements:

1. Wired
2. Wireless

3.5.11.1 Wired Sensitivity Measurements

For a wired sensitivity measurement, the DUT is connected to a Z-Wave frame transmitter through coax wires, and an adjustable RF attenuator is inserted in between the Z-Wave frame transmitter and the DUT. The Z-Wave frame generator could be a Z-Wave 700 (BRD4206A, BRD4207A) or 800 (BRD4204D, BRD4210A, BRD4205B) development board mounted on a BRD4001A WSTK and flashed with RailTest:

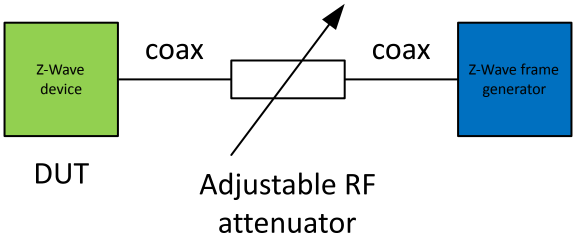


Figure 3.17. Simplified Wired Sensitivity Setup

For each part of the setup shown in the figure above, a control unit is required, e.g. for the Z-Wave device, a computer must be connected to the product in order to configure RailTest. For the adjustable RF attenuator, either a test operator must adjust the RF attenuation or an automatic RF attenuator can be used, and for the Z-Wave Frame generator, control unit is needed as well.

Note: To avoid cross-hearing between the Z-Wave device and the Z-Wave frame generator it is recommended to lower the output power of the Z-Wave transmitters to e.g. -10dBm or even lower. An alternative is to place the Z-Wave device in a radio-shielded box.

Once the setup is created, one could perform the test as described below:

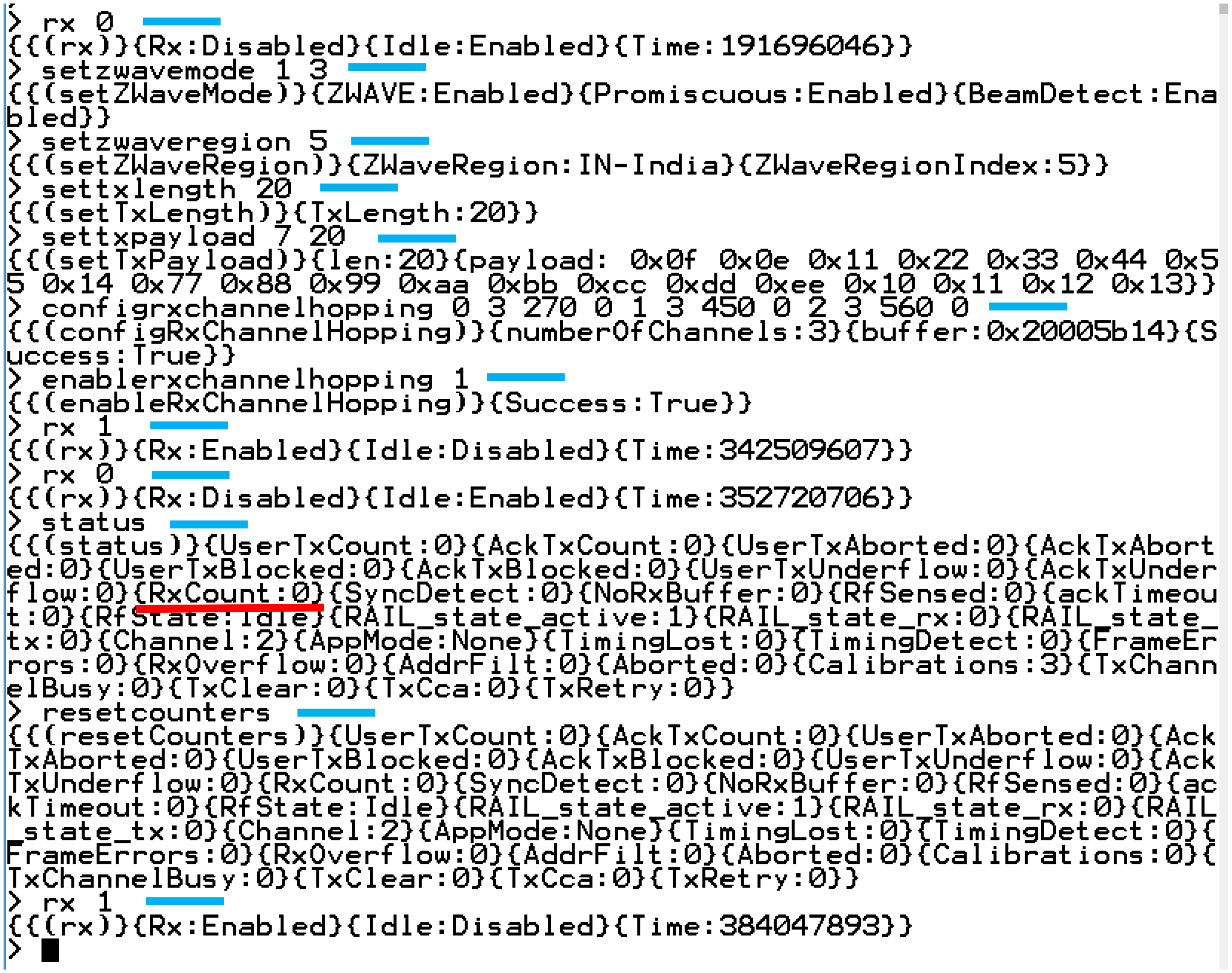
1. Set up both transmitter and receiver to the correct Z-Wave settings, as described in sections 3.5.4 How to Set Up for Transmitting Z-Wave Frames, 3.5.5 How to Set Up for Reception of Z-Wave Frames for a 700 Series Device, or 3.5.6 How to Set Up for Reception of Z-Wave Frames for an 800 Series Device.
2. Set the RF attenuator to setting X, initially e.g. -50dB.
3. Enable the DUT for reception.
4. Transmit 1000 frames.
5. Use RailTest to analyze how many of the 1000 frames were correctly received by the DUT.
6. Reset the receive counters in the DUT.
7. Decrease the RF attenuator value with 1 dB, to e.g. -51dB.
8. Jump to #3 until less than 990 frames are received by the DUT.

Using above described test method will test for a 1% packet error level.

The method to set up a device for Z-Wave frame reception is shown in section 3.5.5 How to Set Up for Reception of Z-Wave Frames for a 700 Series Device / 3.5.6 How to Set Up for Reception of Z-Wave Frames for an 800 Series Device. Apart from this set up, RailTest's 'status' function can be used to evaluate the number of correctly received frames. The commands to use are:

```
'rx 0'                    ;; Disable reception
'status'                  ;; Get frame reception status
'resetCounters'           ;; Reset frame status counters
'rx 1'                    ;; Enable reception for new attenuator setting
```

Below is an example, where the DUT is set up for reception of Z-Wave frames in the Indian region using a Z-Wave device series 700. The product is setup for reception, reception is enabled, status is asked for, the counters are cleared, and the device is re-enabled for another RF attenuator setting. Each RailTest command is marked with a blue line to the right of the command:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:191696046}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Ena
bled}}
> setzwaveregion 5
{{(setZWaveRegion)}{ZWaveRegion:IN-India}{ZWaveRegionIndex:5}}
> settxlength 20
{{(setTxLength)}{TxLength:20}}
> settxpayload 7 20
{{(setTxPayload)}{len:20}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x5
5 0x14 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x10 0x11 0x12 0x13}}
> configrxchannelhopping 0 3 270 0 1 3 450 0 2 3 560 0
{{(configRxChannelHopping)}{numberOfChannels:3}{buffer:0x20005b14}{S
uccess:True}}
> enablerxchannelhopping 1
{{(enableRxChannelHopping)}{Success:True}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:342509607}}
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:352720706}}
> status
{{(status)}{UserTxCount:0}{AckTxCount:0}{UserTxAborted:0}{AckTxAbort
ed:0}{UserTxBlocked:0}{AckTxBlocked:0}{UserTxUnderflow:0}{AckTxUnder
flow:0}{RxCount:0}{SyncDetect:0}{NoRxBuffer:0}{RfSensed:0}{ackTimeou
t:0}{RfState:Idle}{RAIL_state_active:1}{RAIL_state_rx:0}{RAIL_state_
tx:0}{Channel:2}{AppMode:None}{TimingLost:0}{TimingDetect:0}{FrameEr
rors:0}{RxOverflow:0}{AddrFilt:0}{Aborted:0}{Calibrations:3}{TxChann
elBusy:0}{TxClear:0}{TxCca:0}{TxRetry:0}}
> resetcounters
{{(resetCounters)}{UserTxCount:0}{AckTxCount:0}{UserTxAborted:0}{Ack
TxAborted:0}{UserTxBlocked:0}{AckTxBlocked:0}{UserTxUnderflow:0}{Ack
TxUnderflow:0}{RxCount:0}{SyncDetect:0}{NoRxBuffer:0}{RfSensed:0}{ac
kTimeout:0}{RfState:Idle}{RAIL_state_active:1}{RAIL_state_rx:0}{RAIL
_state_tx:0}{Channel:2}{AppMode:None}{TimingLost:0}{TimingDetect:0}{
FrameErrors:0}{RxOverflow:0}{AddrFilt:0}{Aborted:0}{Calibrations:0}{
TxChannelBusy:0}{TxClear:0}{TxCca:0}{TxRetry:0}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:384047893}}
>
```

Figure 3.18. RX Sensitivity Setup Method (Series 700 Device)

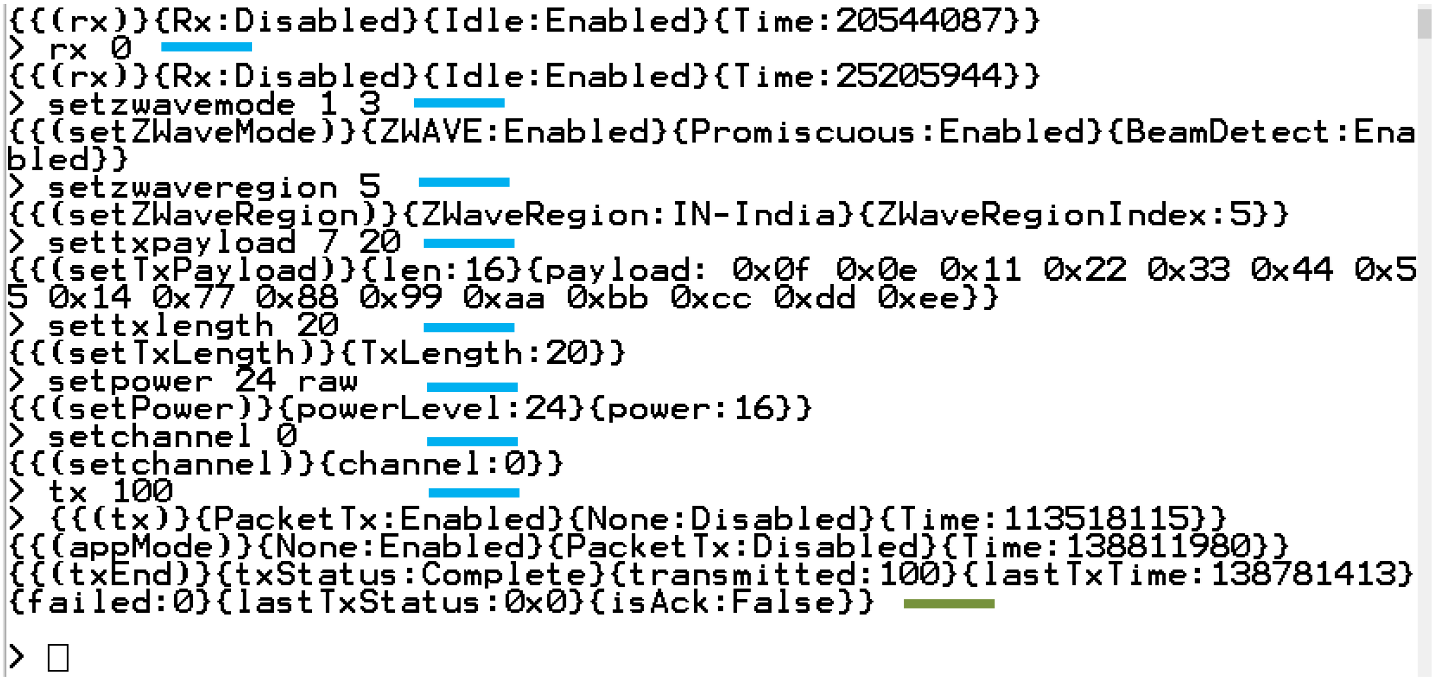
The figure above shows the output of the status command, and there are many parameters being written by RailTest. The important number to notice is the {RxCount} number, underlined with red, in the figure above.

Note: The equivalent setup-sequence for a Z-Wave device series 800 would be identical except for the `'configrxchannelhopping'` command which does not need any parameters, please refer to section 3.5.6 How to Set Up for Reception of Z-Wave Frames for an 800 Series Device.

If the transmitter has been started with the command `‘tx 1000’`, 1000 frames are transmitted. Once the transmission is done, the receiver is disabled with the `‘rx 0’` command, the command `‘status’` is issued on the DUT, and if the reading of the RxCount value is 1000, like {RxCount : 1000}, all of the transmitted frames were received. If the reading is less, Z-Wave frames were lost due to a less optimal RF channel between the Z-Wave frame transmitter and the DUT.

Note: One does not need to set up any channel number in the receiver, since the receiver will scan all the RF channels for the Z-Wave region.

The method for setting up the transmitter for Z-Wave frame transmission is shown in section 3.5.4 How to Set Up for Transmitting Z-Wave Frames. To test all the Z-Wave channels within the Z-Wave region, it is important that each channel number, ranging from 0 to 2, is used in the transmitter setup and the sensitivity test. Below, all RailTest commands are marked with a blue line to the right of the command:



```
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:20544087}}
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:25205944}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Ena
bled}}
> setzwaveregion 5
{{(setZWaveRegion)}{ZWaveRegion:IN-India}{ZWaveRegionIndex:5}}
> settxpayload 7 20
{{(setTxPayload)}{len:16}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x5
5 0x14 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee}}
> settxlength 20
{{(setTxLength)}{TxLength:20}}
> setpower 24 raw
{{(setPower)}{powerLevel:24}{power:16}}
> setchannel 0
{{(setchannel)}{channel:0}}
> tx 100
> {{(tx)}{PacketTx:Enabled}{None:Disabled}{Time:113518115}}
{{(appMode)}{None:Enabled}{PacketTx:Disabled}{Time:138811980}}
{{(txEnd)}{txStatus:Complete}{transmitted:100}{lastTxTime:138781413}
{failed:0}{lastTxStatus:0x0}{isAck:False}}

> □
```

Figure 3.19. TX Sensitivity Setup, 100 Frames Transmitted for Region 5 Channel 0

When the command `'tx xxx'` is issued, immediately the response from the RailTest will be what is shown in the figure above at the `{{(tx)}` *`transmit information`*`}}` information. Once the transmission of the 100 frames is done, the RailTest will show the line marked with the green line, starting with `{{(txEnd)}` *`transmitted information`*`}}` . When this line is observed on the UART output from the Z-Wave frame generator, the receiver is then ready for a status reading using the command `'status'`.

Note: It is most important to know the RF loss in the sensitivity measurement setup. This can be found by replacing the DUT shown in Figure 3.17 Simplified Wired Sensitivity Setup on page 28 with a spectrum analyzer, setting the RF attenuator to 0 dB, and transmitting a CW from the Z-Wave frame transmitter. The RF power measured by the spectrum analyzer can be used to calculate the sensitivity as:

$$\text{Sensitivity} = P_{\text{measured at RF attenuator setting X}} – \text{Attenuator\_setting}_{\text{at 1\% packet error}}$$

Example

A spectrum analyzer is inserted instead of the DUT, the RF attenuator is adjusted to 0 dB attenuation, and the measured power at this RF attenuator setting is -20 dBm.

The following sensitivity measurement shows that there is a 1% packet error level at an attenuator setting of 80 dB.

What is the sensitivity of the system?

$\text{Sensitivity} = -20\text{dBm}_{\text{measured at RF attenuator setting 0dB}} – 80\text{dB}_{\text{attenuator setting at 1\% packet error}}$

Sensitivity = -100dBm

If the 1% packet error level was measured at an RF attenuator setting = -82 dB, the sensitivity of the system is -102 dBm.

To avoid interference from the environment during the sensitivity measurements, it is strongly recommended to perform the measurements in a radio shielded environment, such as an RF shielded room, or by placing the receiver inside an RF shielded box. It is further advised to use a low PA setting for the Z-Wave frame transmitter to avoid any cross radiation directly from the PCB of the Z-Wave frame generator to the PCB of the DUT.

3.5.11.2 Radiated Sensitivity Measurements

A radiated sensitivity measurement is the most representative use-case measurement which can be performed because the DUT is used and tested just like the end-user of the product would experience it.

Reliable and trustworthy radiated measurements can only be conducted if:

1. The radiated measurement setup is performed under strictly controlled manners inside an anechoic chamber and a Total Isotropic Sensitivity test is conducted.
2. The radiated test is performed on a huge open field, high above the ground, and with no nearby constructions to reflect or transmit RF energy.

For normal urban areas in which a test would typically be conducted, the results from a radiated sensitivity measurement cannot be trusted or reproduced because:

1. RF channel will be strongly dependent on the environment:
   - Buildings
   - Reflections from objects
   - Reflections from the ground
   - Weather conditions, if test is performed on an open field
2. RF channel will be strongly dependent on the exact positions of the DUT and the Z-Wave frame generator.

Note: A radiated sensitivity measurement can give an *indication* of the line-of-sight range.

The RailTest setup method for the radiated sensitivity / range measurement is almost identical to the setup described in section 3.5.11.1 Wired Sensitivity Measurements. For the DUT, the method would be identical, but for the Z-Wave frame generator, decreasing the PA setting is not recommended. Instead, the planned PA setting must be used.

The figure below shows a simple radiated setup:

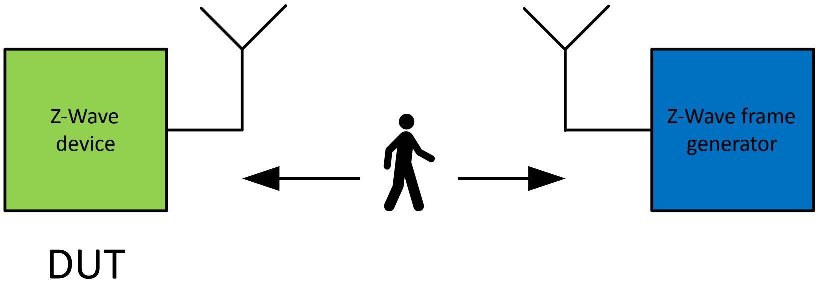


Figure 3.20. Radiated Sensitivity Measurement

Either the DUT or the Z-Wave frame generator is placed in a fixed location, and the distance between the DUT and the Z-Wave frame generator is gradually increased, with one set of frame transmission pr. distance-increment. Once the number of received frames has dropped by 1%, the pathloss due to the distance is equivalent to the sensitivity limit of the product.

The distance can also be increased until no frames are received at all. This would be the maximum line of sight distance that can be obtained with the DUT under the given conditions.

3.5.12 How to Find the LBT Threshold

This section describes how to use a RailTest for 800 series products when finding the LBT threshold for either the Japanese or the Korean Z-Wave region:

```
'rx 0'                                               ;; Set device in idle state
'SetZwaveMode 1 3'                                   ;; Setup for Z-Wave operation
'SetTxLength 20'                                     ;; Setup TX frame length
'SetTxPayload 7 20'                                  ;; Setup payload type and length
’setzwaveregion x’                                   ;; Setup Z-Wave region to number x, see Table 1
’configRXChannelHopping’                             ;; Ch setup
'enableRxChannelHopping 1'                           ;; Enable multi scanning mode
'SetPower yy raw’                                    ;; Set PA output power to setting number yy
‘setLbtParams L1 L2 L3 L4 L5 L6 L7’                  ;; Set LBT params and threshold see ;; Table 6
‘setLbtMode csma’                                    ;; Set detection method
‘configTxOptions 64’                                 ;; Setup transmitter options
'rx 1'                                               ;; Enable reception and apply RF noise
‘getRssi’                                            ;; Read RSSI value for RF noise at threshold
‘rx 0’                                               ;; Set device in idle state
‘setLbtParams L1 L2 L3 L4 L5 L6 L7’                  ;; Set LBT params and threshold
‘rx 1’                                               ;; Enable device in RX mode
‘tx xx’                                              ;; Transmit xx number of frames
```

The parameters for the command `‘setLbtParams’` are shown in the table below (Z-Wave LBT Settings).

Note: Z-Wave device series 700 has an identical setup sequence except for the command `'configRXChannelHopping'` which needs the parameters from Table 3.4 Multi-Channel Settings on page 17

Table 3.6. Z-Wave LBT Settings

Region Number	L_1	L_2	L_3	L_4	L_5	L_6	L_7
6 (Japan)	2	2	15	$\text{RSSI}_{\text{Japan}}$	750	128	200000
9 (Korea)	2	2	15	$\text{RSSI}_{\text{Korea}}$	750	5000	200000

The purpose of this measurement is to find the number for the parameter L_4. This value will vary from Z-Wave region to Z-Wave region and from product design to product design.

Above, the device is initialized to transmit Z-Wave frames with a length of 20 bytes for a certain Z-Wave region. The PA output power is set to a value, yy, and the channel is selected to 0. For this measurement, it does not matter if the channel is set to 0, 1, or 2. The LBT parameters are then initialized, the collision avoidance is selected to type csma, and a TX option is set to 64.

Next the parameter L_4 must be found, and this is done by connecting the Z-Wave product to an RF generator using a wired connection, i.e., a coax cable, setting the output power of the RF generator to the RF regulation limit (for Japan -80 dBm and for Korea -65 dBm), and enabling an RF CW at the frequency of the channel. The Z-Wave device is now exposed to an amount of RF energy identical to the LBT noise level as required by the RF regulatory authorities.

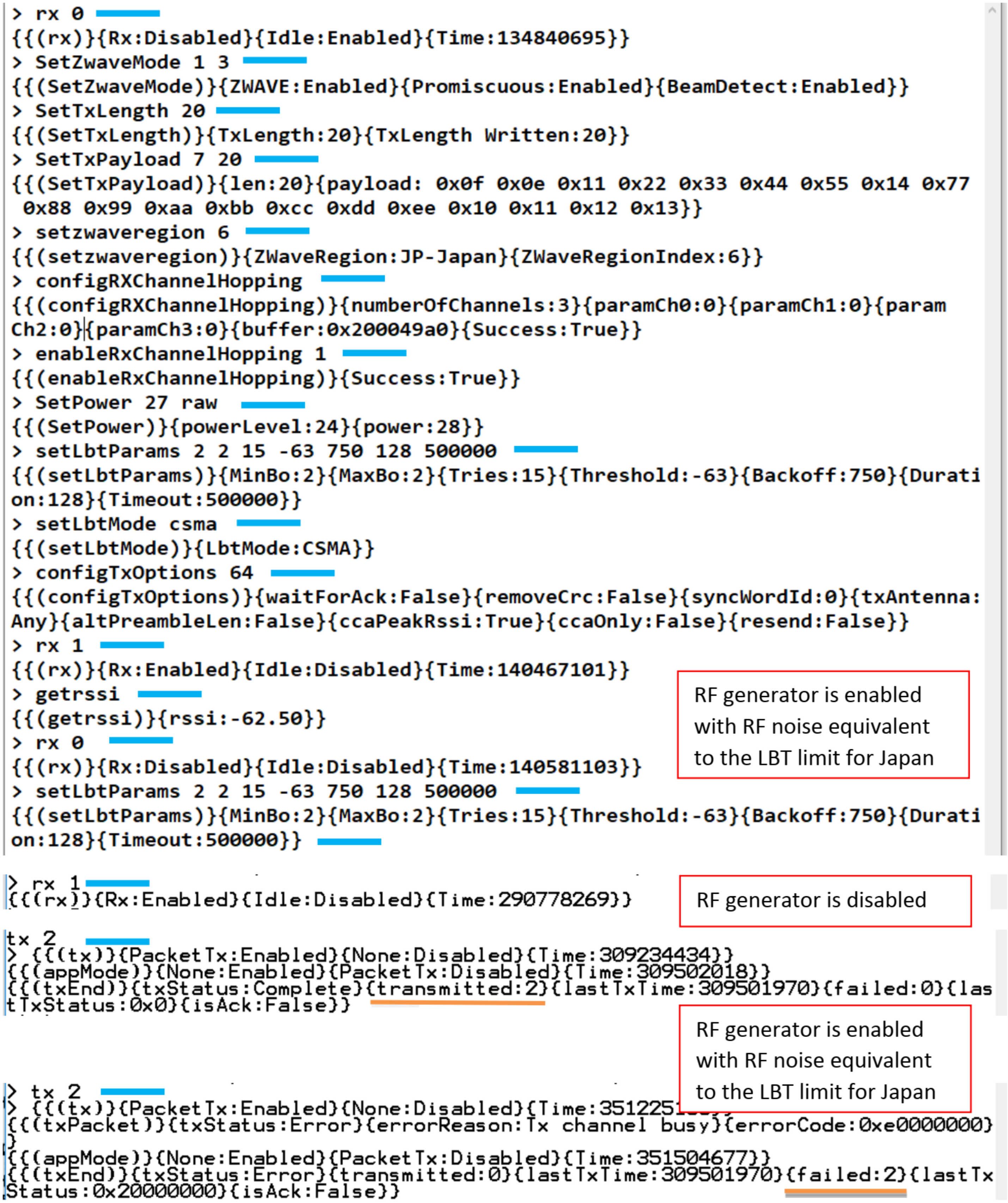
With the CW applied to the Z-Wave product, the Z-Wave product is configured to be in receive mode, and an RSSI reading is performed using the RailTest command `‘getRssi’`. The found RSSI value is identical to the LBT threshold L_4. For a conservative approach, it is advised to set the LBT threshold 1 dB below the found RSSI in order to have some margin in the threshold.

With L_4 found, the LBT parameters are re-initialized with the expected value for L_4 and a test can be performed as described below:

1. Turn off the RF output of the connected RF generator.
2. Transmit XX number of frames using the command `‘tx XX’`.
3. Upon end of transmission, write the statistical values for the number of transmitted frames to the terminal. The number of frames transmitted must match the number of frames used in the command `‘tx XX’`. For example, if the command `‘tx 2’` was used, the status must show that 2 frames were transmitted.
4. Enable the RF generator and set the RF output power to the level which matches the LBT threshold required.
5. Transmit a number of frames.
6. At the end of transmission, the number of frames transmitted should be 0 and the number of failed transmissions should be identical to the number of frames used in the command in item #5.
7. Adjust the output power of the RF generator up and down and check that the LBT threshold is set correct.

Note: For Z-Wave 700 products with a SAW filter or a SAW filter bank, the procedure described is identical except for the fact that for SAW filter bank products one must select the correct SAW as described in section 3.5.3 How to Set Up for CW Transmission with a SAW Filter Bank (700 Series Only).

The figure below shows an example where the LBT threshold is to be found for a device in the Z-Wave region 6, Japan. RailTest commands are underlined in blue and important results are underlined in orange. Information on enabling or disabling the RF generator used to create the noise in the channel are marked with a red box:



```
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:134840695}}
> SetZwaveMode 1 3
{{(SetZwaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enabled}}
> SetTxLength 20
{{(SetTxLength)}{TxLength:20}{TxLength Written:20}}
> SetTxPayload 7 20
{{(SetTxPayload)}{len:20}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55 0x14 0x77
 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x10 0x11 0x12 0x13}}
> setzwaveregion 6
{{(setzwaveregion)}{ZWaveRegion:JP-Japan}{ZWaveRegionIndex:6}}
> configRXChannelHopping
{{(configRXChannelHopping)}{numberOfChannels:3}{paramCh0:0}{paramCh1:0}{param
Ch2:0}{paramCh3:0}{buffer:0x200049a0}{Success:True}}
> enableRxChannelHopping 1
{{(enableRxChannelHopping)}{Success:True}}
> SetPower 27 raw
{{(SetPower)}{powerLevel:24}{power:28}}
> setLbtParams 2 2 15 -63 750 128 500000
{{(setLbtParams)}{MinBo:2}{MaxBo:2}{Tries:15}{Threshold:-63}{Backoff:750}{Durati
on:128}{Timeout:500000}}
> setLbtMode csma
{{(setLbtMode)}{LbtMode:CSMA}}
> configTxOptions 64
{{(configTxOptions)}{waitForAck:False}{removeCrc:False}{syncWordId:0}{txAntenna:
Any}{altPreambleLen:False}{ccaPeakRssi:True}{ccaOnly:False}{resend:False}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:140467101}}
> getrssi
{{(getrssi)}{rssi:-62.50}}
> rx 0
{{(rx)}{Rx:Disabled}{Idle:Disabled}{Time:140581103}}
> setLbtParams 2 2 15 -63 750 128 500000
{{(setLbtParams)}{MinBo:2}{MaxBo:2}{Tries:15}{Threshold:-63}{Backoff:750}{Durati
on:128}{Timeout:500000}}
```

RF generator is enabled with RF noise equivalent to the LBT limit for Japan

```
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:290778269}}
```

RF generator is disabled

```
tx 2
> {{(tx)}{PacketTx:Enabled}{None:Disabled}{Time:309234434}}
{{(appMode)}{None:Enabled}{PacketTx:Disabled}{Time:309502018}}
{{(txEnd)}{txStatus:Complete}{transmitted:2}{lastTxTime:309501970}{failed:0}{las
tTxStatus:0x0}{isAck:False}}
```

RF generator is enabled with RF noise equivalent to the LBT limit for Japan

```
> tx 2
> {{(tx)}{PacketTx:Enabled}{None:Disabled}{Time:351225
{{(txPacket)}{txStatus:Error}{errorReason:Tx channel busy}{errorCode:0xe0000000}
}
{{(appMode)}{None:Enabled}{PacketTx:Disabled}{Time:351504677}}
{{(txEnd)}{txStatus:Error}{transmitted:0}{lastTxTime:309501970}{failed:2}{lastTx
Status:0x20000000}{isAck:False}}
```

Figure 3.21. Example of Setting up a Device for Finding a LBT Threshold

The red boxes in the figure above indicate when to turn on and off the RF generator that creates the noise floor for the RSSI measurement and the following LBT measurement.

In the example, only two frames are transmitted and used to verify if the LBT threshold is correctly set up. It is strongly recommended to use a larger number of frames for this test to increase the statistical validity of the LBT threshold setting.

It may be an iterative process to find the exact LBT value. For good measurements and to add a bit of margin to the LBT threshold, it is advised to add a dB to the threshold value as a margin.

The value found for L_4 must be used in the Z-Wave protocol as described below:

- For EFR32ZG14 and EFR32ZG23 SoCs: LBT threshold value must be used in connection with FUNC_ID_ZW_SET_LISTEN_BEFORE_TALK_THRESHOLD
- For ZGM130S and ZGM230S SiP modules: LBT threshold value must be used in connection with the command EZWAVECOMMANDTYPE_ZW_SET_LBT_THRESHOLD

Note: It is very important to perform the LBT measurements with a calibrated setup, that is, all cable losses must be accounted for when setting the level of the RF generator to the LBT noise level.

3.5.13 Scripting RailTest

For some products, it may be impractical, or even impossible, to submit a product to the RF regulatory authorities if the only means of controlling the product is through a UART terminal interface, as described in Section 3.3 Starting RailTest:

1. The UART terminal interface may be impractical for the test house to handle.
2. The UART terminal interface may completely change the radiation pattern of the product and, thus, give a wrong impression of how the product performs.
3. The test house may not be trusted to correctly setup the device before the RF regulatory tests.

To accommodate for any of above situations, RailTest can be scripted in such a way that the Z-Wave device stores the RailTest instructions in the internal flash memory and then retrieves *and* initializes the Z-Wave device with the stored settings upon reset or re-power.

This means that it will be possible to set up, validate, and ship fully pre-configured products for RF regulatory tests without having the RF regulatory test house do anything else but apply power to the product under test.

This following section describes how to enable the script mode, enter a script, validate a script, and exit script mode.

Note: A permanent UART connection-means to the Z-Wave device in the product is still strongly advised, please refer to Section 3.2 Interfacing to RailTest, since the scripting of the Z-Wave device is done through the UART interface of the Z-Wave device. But once set up, the UART connections used can be removed from the product to ensure that the appearance of the product is as un-interrupted as possible.

3.5.13.1 Workflow for Script Mode

To be able to use RailTest in a scripted mode, one must:

1. Establish power, programming, and UART connections to the product as shown in section 2.1.2 How to Interface the Z-Wave Product During the Bring-Up Phase of the Project.
2. Download RailTest to the product as described in section 3.1 Compiling RailTest.
3. Interface to the UART of the Z-Wave device as described in section 3.2 Interfacing to RailTest.
4. Initialize scripting mode.
5. Enter the script.
6. Exit script mode.
7. Re-power the product.
8. Test the functionality of the script.
9. Power off the product.
10. Remove the UART and the programming connections to the Z-Wave device.

A script can at any time be changed or removed by re-connecting the Z-Wave device of the product to its UART connections and then either delete or change the script.

3.5.13.2 How to Start, Exit, and Erase a Script

RailTest can store commands in the flash memory and retrieve these commands upon a reset of a power-off/on event. This can be very useful in connection with pre-configuration of products which must be submitted to RF regulatory tests.

Below is an example where scripting is enabled and disabled:

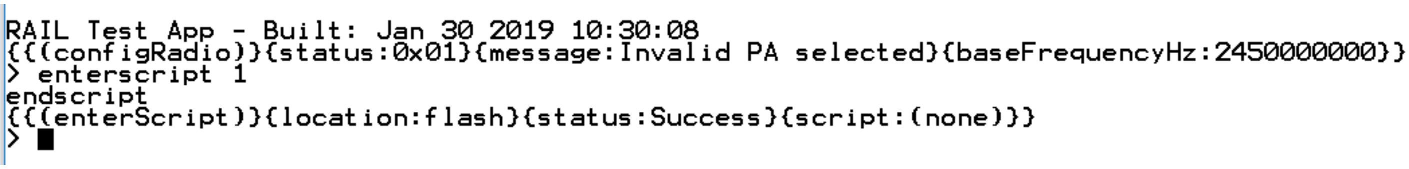
```
'enterscript 1'         ;; Enable script mode, save in flash
'endscript'             ;; End script mode / clear script
```

The first command `‘enterscript 1’` enables scripting mode, and the ‘1’ means that the script is stored in the flash memory of the Z-Wave device.

In the above example, the script is immediately terminated using the command `‘endscript’`. When written as above, both script-mode is terminated *and* an eventual script stored will be erased from the flash memory of the Z-Wave device.

Please notice that the first command written `‘enterscript 1’` must be followed by a `“Return”` character, where as the last command written `‘endscript’` activates once the letter `‘t’` is typed.

The figure below shows an example, where script mode is entered and immediately terminated again.



```
RAIL Test App - Built: Jan 30 2019 10:30:08
{{(configRadio)}{status:0x01}{message:Invalid PA selected}{baseFrequencyHz:2450000000}}
> enterscript 1
endscript
{{(enterScript)}{location:flash}{status:Success}{script:(none)}}
> █
```

Figure 3.22. Enabling and Terminating Script Mode

Note: When the command `‘enterscript 1’` is directly followed by `‘endscript’`, the content of the flash memory is erased and Script mode is disabled.

3.5.13.3 setTxTone Script

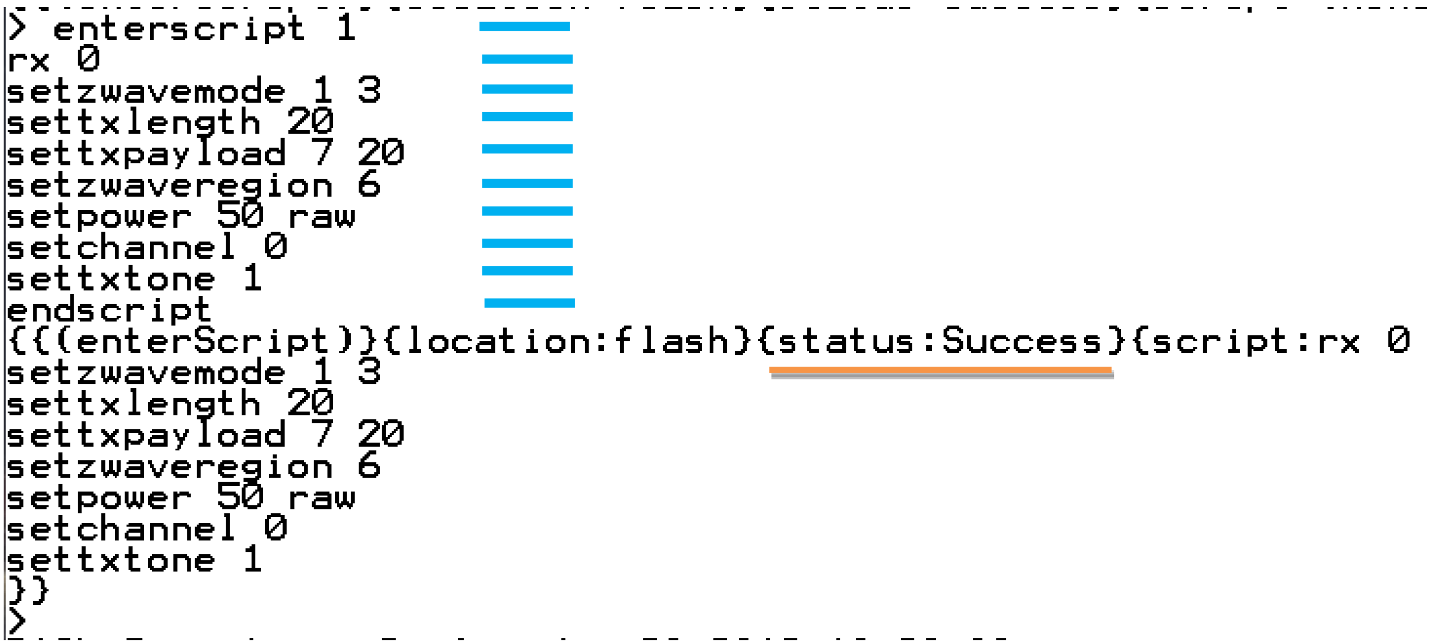
RailTest can handle the same commands in Scripting mode as it can through the interactive CLI previously described in the Sections 3.5 Setting Up the Z-Wave Environment for RailTest through 3.5.15 How to Read UUID of a 800 Series Device. Finding and setting the LBT threshold is an interactive operation and is not well suited for Scripting mode.

Below is an example, where the Z-Wave device is setup to transmit a CW tone:

```
'enterscript 1'         ;; Enable script mode, store in flash
'rx 0'                  ;; Disable RX
'SetZwaveMode 1 3'      ;; Setup for Z-Wave operation
'SetTxLength 20'        ;; Setup payload length
'SetTxPayload 7 20'     ;; Setup payload type and length
'setzwaveregion 6'      ;; Setup Z-Wave region, Japan
'SetPower 50 raw'       ;; Setup output power
'setchannel 0'          ;; Setup Z-Wave channel
'settxtone 1'           ;; Enable CW
'endscript'             ;; Store script in flash and end
```

When comparing the script above with the similar operation performed through the interactive CLI as described in section 3.5 Setting Up the Z-Wave Environment for RailTest, please notice that the only difference between the commands are the `'enterscript 1'` and the `'endscript'`.

The figure below shows an example where the above script is typed into RailTest. RailTest commands are marked with blue.



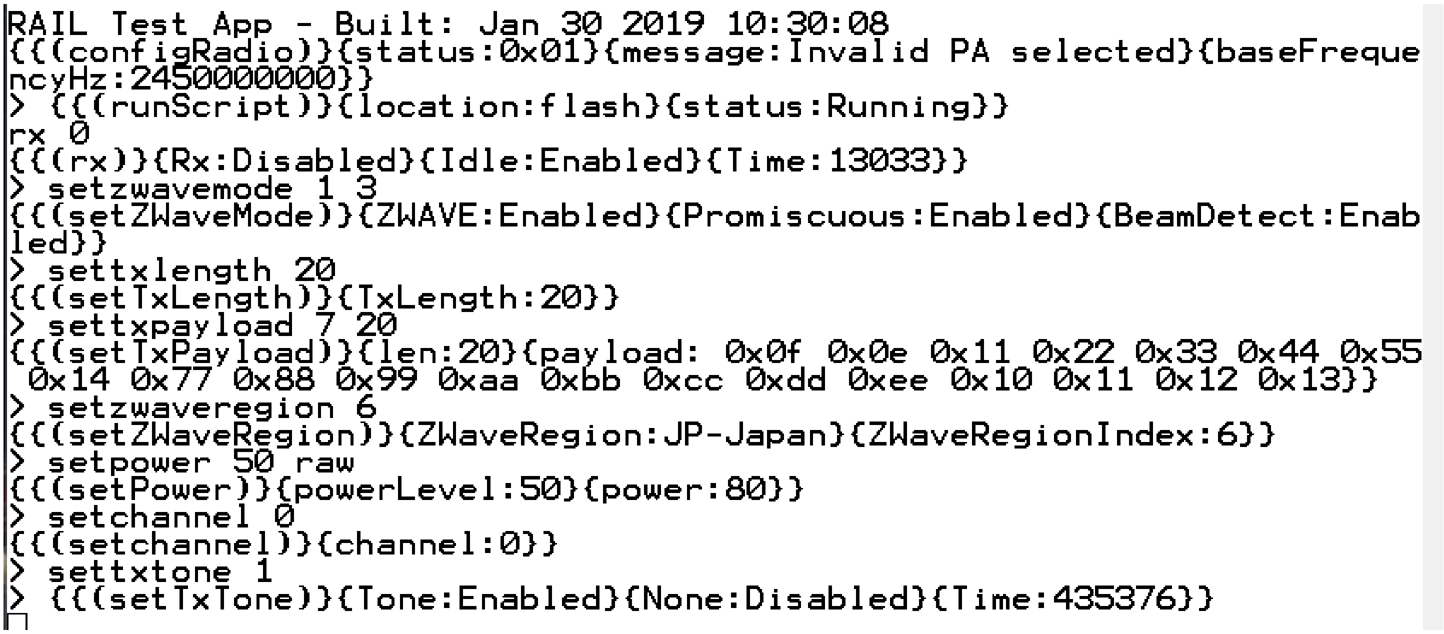
```
> enterscript 1
rx 0
setzwavemode 1 3
settxlength 20
settxpayload 7 20
setzwaveregion 6
setpower 50 raw
setchannel 0
settxtone 1
endscript
{{(enterScript)}{location:flash}{status:Success}{script:rx 0
setzwavemode 1 3
settxlength 20
settxpayload 7 20
setzwaveregion 6
setpower 50 raw
setchannel 0
settxtone 1
}}
>
```

Figure 3.23. Scripting setTXTone

Please notice that when in Script mode, commands are *not* acknowledged by RailTest.

When the letter `"t"` in the command `'endscript'` is typed, the status of the Script operation is shown as well as the content of the script stored. The Script is now stored in the flash memory.

When the Z-Wave device is either reset or power-cycled, the content of the Script will be executed. Please refer to the figure below (Execution of setTxTone script) to see what RailTest outputs when the script from Figure 3.23 Scripting setTXTone on page 37 is executed by means of a reset pulse.



```
RAIL Test App - Built: Jan 30 2019 10:30:08
{{(configRadio)}{status:0x01}{message:Invalid PA selected}{baseFreque
ncyHz:2450000000}}
> {{(runScript)}{location:flash}{status:Running}}
rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:13033}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enab
led}}
> settxlength 20
{{(setTxLength)}{TxLength:20}}
> settxpayload 7 20
{{(setTxPayload)}{len:20}{payload: 0x0f 0x0e 0x11 0x22 0x33 0x44 0x55
 0x14 0x77 0x88 0x99 0xaa 0xbb 0xcc 0xdd 0xee 0x10 0x11 0x12 0x13}}
> setzwaveregion 6
{{(setZWaveRegion)}{ZWaveRegion:JP-Japan}{ZWaveRegionIndex:6}}
> setpower 50 raw
{{(setPower)}{powerLevel:50}{power:80}}
> setchannel 0
{{(setchannel)}{channel:0}}
> settxtone 1
> {{(setTxTone)}{Tone:Enabled}{None:Disabled}{Time:435376}}
```

Figure 3.24. Execution of setTxTone script

Please notice that each of the command lines are acknowledged by RailTest as if they were directly typed on the CLI.

Note: It is only after a reset / power-cycle event that the validity of a Script can be proven. So all Scripts should be validated by means of a reset event, followed by a visual inspection of the RailTest outputs as well as a functional test by means of a measurement.

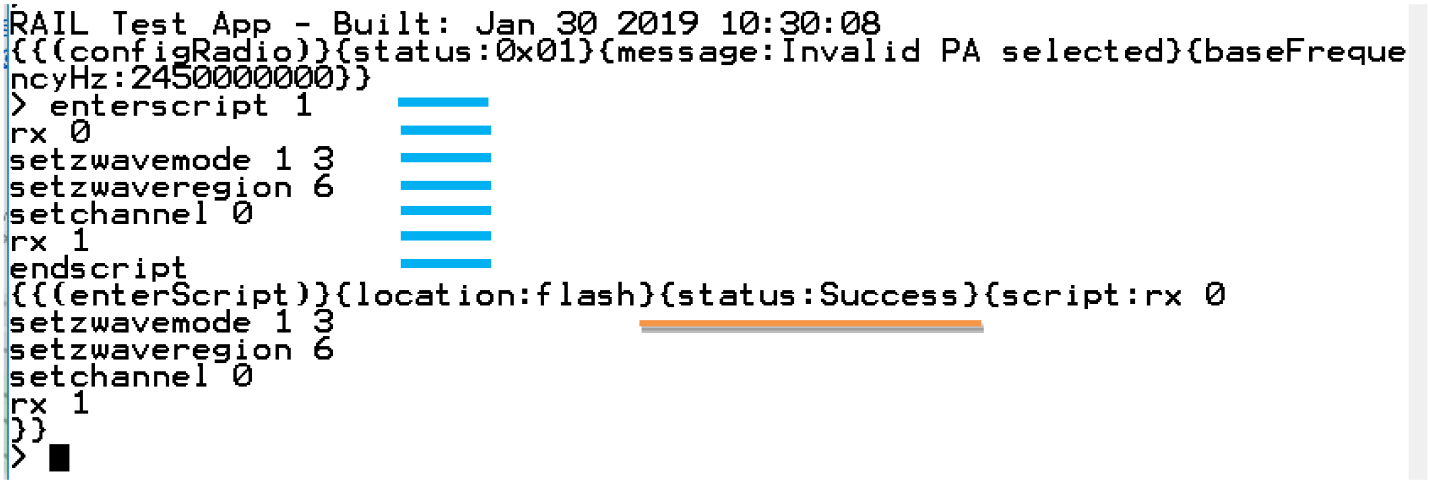
3.5.13.4 RX Mode Script

If the LO leakage is to be measured by the RF regulatory authorities, this can be done by entering a Script in the Z-Wave device of the product, and all the authorities must do is apply power to the product and measure the LO leakage. No interaction with the product will be needed.

Below is an example where the Z-Wave device is initialized for RX operation:

```
'enterscript 1'         ;; Enter Script mode
'rx 0'                  ;; Disable RX mode
'SetZwaveMode 1 3'      ;; Setup for Z-Wave mode
'setzwaveregion 6'      ;; Setup Z-Wave region, Japan
'setchannel 0'          ;; Setup channel 0
'rx 1'                  ;; Enable RX mode
'endscript'             ;; Exit script mode
```

The figure below shows an example where the above script is typed into RailTest. RailTest commands are marked with blue.



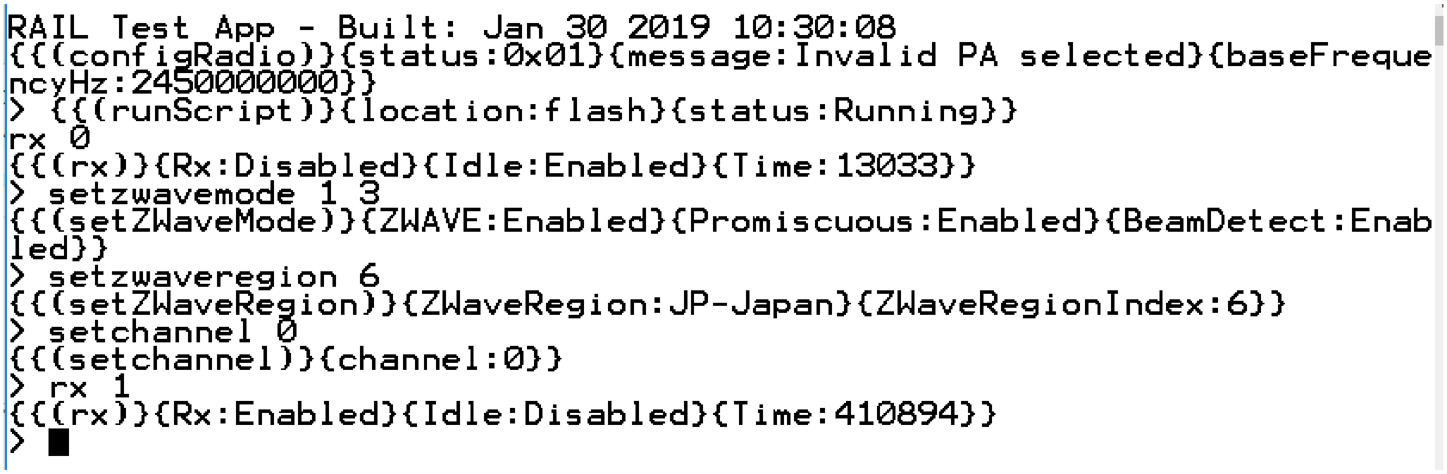
```
RAIL Test App - Built: Jan 30 2019 10:30:08
{{(configRadio)}{status:0x01}{message:Invalid PA selected}{baseFreque
ncyHz:2450000000}}
> enterscript 1
rx 0
setzwavemode 1 3
setzwaveregion 6
setchannel 0
rx 1
endscript
{{(enterScript)}{location:flash}{status:Success}{script:rx 0
setzwavemode 1 3
setzwaveregion 6
setchannel 0
rx 1
}}
> 
```

Figure 3.25. Scripting RX Mode

Please notice that when in Script mode, commands are *not* acknowledged by RailTest.

When the letter "t" in the command 'endscript' is typed, the status of the Script operation is shown as well as the content of the script stored. The Script is now stored in the flash memory.

When the Z-Wave device is either reset or power-cycled, the content of the Script will be executed. Please refer to the figure below (Scripting RX Mode) to see what RailTest outputs when the script from Figure 3.24 Execution of setTxTone script on page 38 is executed by means of a reset pulse.



```
RAIL Test App - Built: Jan 30 2019 10:30:08
{{(configRadio)}{status:0x01}{message:Invalid PA selected}{baseFreque
ncyHz:2450000000}}
> {{(runScript)}{location:flash}{status:Running}}
rx 0
{{(rx)}{Rx:Disabled}{Idle:Enabled}{Time:13033}}
> setzwavemode 1 3
{{(setZWaveMode)}{ZWAVE:Enabled}{Promiscuous:Enabled}{BeamDetect:Enab
led}}
> setzwaveregion 6
{{(setZWaveRegion)}{ZWaveRegion:JP-Japan}{ZWaveRegionIndex:6}}
> setchannel 0
{{(setchannel)}{channel:0}}
> rx 1
{{(rx)}{Rx:Enabled}{Idle:Disabled}{Time:410894}}
> 
```

Figure 3.26. Execution of RX Mode Script

Please notice that each of the command lines are acknowledged by RailTest as if they were directly typed on the CLI.

Note: It is only after a reset / power-cycle event that the validity of a Script can be proven. So all Scripts should be validated by means of a reset event, followed by a visual inspection of the RailTest outputs as well as a functional test by means of a measurement.

3.5.14 How to Read UUID of a 700 Series Device

Each Z-Wave device is programmed with a unique UUID during the manufacturing of the device. This UUID can be used to track the device, correlate production test measurements with the individual devices, or for other purposes.

RailTest can be used to read the UUID from the Z-Wave device.

Below is an example on how to read the UUID of a 700 series device using RailTest:

```
‘getmemw 0x0FE081F0’         ;; Read lower 32 bits of UUID
‘getmemw 0x0FE081F4’         ;; Read upper 32 bits of UUID
```

The output of the “getmemw `0x0FE081F0`” will give you the lower 32 bits of the UUID, the output of the “getmemw `0x0FE081F4`” will give you the upper 32bits of the UUID, so the entire UUID will be:

UUID = ((getmemw `0x0FE081F4 << 32) || (`getmemw `0x0FE081F0))`

3.5.15 How to Read UUID of a 800 Series Device

Each Z-Wave device is programmed with a unique UUID during the manufacturing of the device. This UUID can be used to track the device, correlate production test measurements with the individual devices, or for other purposes.

RailTest can be used to read the UUID from the Z-Wave device.

Below is an example on how to read the UUID using RailTest:

```
‘getmemw 0x0FE08048’         ;; Read lower 32 bits of UUID
‘getmemw 0x0FE0804C’         ;; Read upper 32 bits of UUID
```

The output of the “getmemw `0x0FE08048`” will give you the lower 32 bits of the UUID, the output of the “getmemw `0x0FE0804C`” will give you the upper 32bits of the UUID, so the entire UUID will be:

UUID = ((getmemw `0x0FE0804C << 32) || (`getmemw `0x0FE08048))`

3.6 Tips and Tricks

Using RailTest requires a lot of command typing to setup the correct parameters. It can be an advantage to find a UART terminal program that can be scripted or using a scripting programming language like Perl or Python. Using scripted control of RailTest has several advantages:

1. Once created, setting up for repeated measurements is much faster since the typing of the individual commands can be omitted.
2. Once debugged, the scripts will ensure identical setup from measurement session to measurement session, eliminating the risk of a type-error to ruin the measurement results.
3. Scripts can be handed over to third parties, e.g., RF regulatory authorities, and this limits the amount of instructions needed for the third party.

If a product can only be tested by the RF regulatory authorities when disconnected from a UART connection, the scripting functionality of RailTest, as described in section 3.5.13 Scripting RailTest, is the solution to use. With the scripting mode, all non-interactive operations are stored in the Z-Wave device flash and executed by the Z-Wave device after a reset / power-cycle.

4. Guidance for Power Spectral Density (PSD) Regulatory Testing

Deciding on the appropriate testing method and the data pattern to use is a crucial prerequisite of regulatory testing. Without a clear description of such, measurement results cannot be interpreted definitively and can bring up doubts regarding credibility. Therefore, a mandatory set of instructions must be proposed for regulatory testing that best represents the common use case of the Device Under Test (DUT).

4.1 Testing Method

The FCC 15.247 testing procedure recommendation is to follow ANSI C631.0-2020 Chapter 11.10.3. This method (AVGPSD-1) allows the measurement of the average (rms) PSD instead of peak PSD, resulting in a more favorable margin to the 8 dBm / 3 kHz limit. The procedure may be used when the average (rms) conducted output power was used to determine compliance with the total output power limit. The method AVGPSD-1 uses trace averaging while the DUT is transmitting at full power throughout every sweep. If the instrument has a power averaging (rms) detector, then it must be used; otherwise, a sample detector must be used.

The following list of instructions is from the referenced chapter of ANSI C63.10-2020:

1. Set instrument center frequency to DTS channel center frequency.
2. Set span to > 1.5 times the OBW.
3. Set RBW to: 3 kHz ≤ RBW ≤ 100 kHz.
4. Set VBW ≥ [3 × RBW].
5. Detector = power averaging (rms) or sample detector (when rms not available).
6. Ensure that the number of measurement points in the sweep ≥ [2 × span / RBW].
7. Sweep time = auto couple.
8. Use trace averaging (rms) mode over a minimum of 100 traces.
9. Use the peak marker function to determine the maximum amplitude level.
10. If the measured value exceeds requirement, then reduce RBW (but no less than 3 kHz) and repeat. Note that this might require zooming in on the emission of interest and reducing the span to meet the minimum measurement point requirement as the RBW is reduced.

4.2 Selecting the Appropriate TX Packet Type

The DUT must be configured to transmit continuously, which means a continuous modulated PN9 sequence (with no preamble) is sufficient and is the packet type recommended by Silicon Labs.

4.3 Railtest Example

A complete Railtest example for the recommended continuous modulated PN9 stream is shown below:

```
'setzwavemode 1 3'                    ;; setup for Z-Wave mode
'setzwaveregion 11'                   ;; set Z-Wave region to
                                         11 (region 12 could also be used)
'setchannel 3',                       ;; set Z-Wave channel to 3
'setpower xx raw'                     ;; set PA output power to setting number xx
'settxstream 1'                       ;; enable modulated PN9 stream
```

Note: AVGPSD-1A (alternative) method can be used instead of AVGPSD-1. If a continuous (D > 98%) modulated PN9 stream is not possible, then sweep/gate triggering methods are required if the recommended AVGPSD-1 or its alternative versions are the chosen test methods. If the requirements are not met, AVGPSD-2, AVGPSD-3 or their alternative versions must be followed.

5. References

1. UG162: Simplicity Commander Reference Guide
2. https://www.silabs.com/wireless/z-wave/global-regions
3. UG522: Mandatory Crystal Adjustment for EFR32ZG14/EFR32ZG23 Based Products
4. UG409: RAILtest User’s Guide

6. Revision History

Revision 12

July 2022

- Added section 4. Guidance for Power Spectral Density (PSD) Regulatory Testing

Revision 11

December 2021

- Added 800 Series content
- Updated document's format and replacing INS14283 "Bring-up/Test HW Development"

Revision 10

June 2021

- Update example code in Section 3.5.9

Revision 9

November 2020

- Reviewed all sections that were added or revised since the last Tech Pub's review

Revision 8

November 2020

- Added suppprt for Z-Wave Long Range
- Removed binary of RailTest as a prerequisite
- Table 2 (in INS14283): Changed to Kbit/s; Added comment that chapter 2 (in INS14283) is only for Region 11 and 12
- Figure 15 (in INS14283): Changed figure text to correct region
- Added reference to RailTest UG in section.

Revision 7

November 2019

- Fixed broken references in the text.
- Added description of how to read UUID from Z-Wave device.
- Functionality of PF0 and PF1 swapped in drawings to match the datasheet and pin-mapping.
- Technical publications review

Revision 6

March 2019

- Added a product with matching circuit to Figure 1
- Added section 4.4 about how to get help in RailTest
- Added frequency table reference and elaborated on frequency selection
- Moved Section 4.5.1 to create a more logical reading flow.
- Changed wording about how to set RF attenuator (must be set to 0dB) and how to build setup.
- Added weather conditions to possible sources of RF performance variations

Revision 5

February 2019

- Added description of the RailTest Scripting feature.
- Corrected LBT parameters.

Revision 4

December 2018

- Added section about RSSI threshold adjustment

Revision 3

December 2018

- Corrected Z-Wave device name, added scripting languages like Perl and Python to section and changed the wordings.

Revision 2

November 2018

- Updates to document due to review comments.
- All pages affected. Added new sections.
- Updated all drawings with 0 Ohms resistor and a GND symbol for landing pad #3.
- Changed description of Z-Wave device.

Revision 1

November 2018

- Initial version of the document

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