



Instruction

Micro RF LinkX for 500 Series

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1 ABBREVIATIONS

Abbreviation	Explanation
APM	Auto Programming Mode
DUT	Device Under Test
IF	Intermediate Frequency. The IF is a frequency to which the carrier frequency is shifted as an intermediate step in reception
LBT	Listen Before Talk. In Z-Wave a logarithmic average of RSSI measurement is performed over at least 128us
LO	Local Oscillator
NVR	Non Volatile Registers
PA	Power Amplifier
PHY	Physical Layer – Refer to the Open Systems Interconnection reference model (OSI-model)
RF	Radio Frequency
RX	Receiver
RSSI	Received Signal Strength Indicator
RxD	Received eXchange Data. UART RX pin
SDK	Software Development Kit
sfr	Special function register (bits), internal 8051 control register bits
SOF	Start of frame indicator byte
TxD	Transmitted eXchange Data. UART TX pin
TX	Transmitter
UART	A universal asynchronous receiver/transmitter (usually abbreviated UART)

2 INTRODUCTION

2.1 Purpose

The purpose of this document is to describe how to use the Micro RF LinkX tool on devices based on the 500-series chip.

The document does not cover programming of the chip or how to use a terminal / host controller.

2.2 Audience and prerequisites

The audience of this document is developers within and outside Silicon Labs using the 500-series chip. No special prerequisites are required prior to reading this document.

3 MICRO RF LINKX

3.1 General Description

Micro RF LinkX is a program (software) that runs on 500 series based devices. It acts as a tool which is able to:

- Check the RF performance of a 500 series based device during development
- Check the link quality between two 500 series based devices during development or in a 500 series based product
- Debug the RF performance of a 500 series based product
- Conduct RF regulatory tests on a 500 series based product.

The tool is designed with the same RF PHY as used by the Z-Wave protocol, this ensures, that what is measured when using the tool is also valid for Z-Wave systems.

The only requirement for using the tool is that the programming interface to the chip must be available in order to be able to download the tool and preferably also the UART0 interface for communication.

The **Micro RF LinkX** tool can be configured to receive or transmit data frames or a RF carrier wave. In order to measure e.g. the sensitivity of a device, the DUT must be downloaded with the **Micro RF LinkX** tool and configured as a receiver and another 500 series based device must be downloaded with the tool and configured as a transmitter. The sensitivity of the DUT can now be measured by attenuating the RF path between the DUT and the transmitter. However, the program can also be used as standalone program to measure RF performance such as RSSI levels, LO leakage, transmitter characteristics etc. of a 500 series based product.

Once the **Micro RF LinkX** program is downloaded to a target and the target is configured as wanted, this configuration stays valid until it is changed. This means, that a device can be configured to perform a certain and needed operation, switched off, and when the device is repowered, the configuration will become active and the device does not need to be re-configured.

Micro RF LinkX can also be remote-controlled. Once **Micro RF LinkX** is downloaded to a device, no UART interface to this device is needed in order to configure the settings of **Micro RF LinkX**. This can be used whenever the UART interface of the DUT is not present, either because a UART is not present on the device or if the device is out of reach for a UART connection. In order to utilize the remote control option, a device (a "master device") loaded with **Micro RF LinkX** and connected to a host through a UART connection is needed and the DUT to be remote-controlled must be able to be reset or power-cycled.

To summarize, **Micro RF LinkX** can be;

- used as a stand-alone program
- used in connection with another **Micro RF LinkX** enabled device
- controlled through a UART interface
- remote-controlled using another **Micro RF LinkX** enabled device connected to a host through a UART.

3.2 Getting started

In order to run the tool, the **Micro RF LinkX** must be programmed into the Flash of the 500 series module. The **Micro RF LinkX** program supports ZM5101, ZM5202, ZM5304, SD3502 and SD3503 based modules. **Notice** that **Micro RF LinkX** determines the type of module used based on the content of NVR.

The **Micro RF LinkX** hex file (micro_rf_linkX_ZM050x_ALL.hex) must be downloaded to the target either over the SPI interface, the UART interface or the USB interface. Please refer to the programming tool documentation to learn about how to perform the actual programming [1].

The **Micro RF LinkX** software (a tool) runs entirely in the DUT. Using the tool requires a connection to a terminal on a computer for communication or some kind of a host controller. A good example of a terminal that works with **Micro RF LinkX** is **TeraTerm** that can be downloaded from the internet. The **Micro RF LinkX** connects to the terminal using UART0 on the chip. The terminal must be set up for:

Table 1, Terminal settings

Parameter	Setting
Baud rate	115.2 kBaud
Parity	No
Number of start bit	1
Number of stop bit	1
Flow control	No
Terminal emulation	VT100
Local echo	Off

For usage with a host controller in a production setup, please refer to Appendix A.

As mentioned, the **Micro RF LinkX** can be remotely setup, but the device performing this remote configuration must be connected to a UART as just described.

Once the device is correctly programmed and connected to a terminal through the UART connection, the following will be shown on the terminal screen after a chip reset or a power-on event:

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      One-way
TX baudrate    9K6
TX power       32
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (23,18)
LBT reading    34
:

```

Figure 1, Micro RF LinkX initial startup screen

The first three lines indicate the version of the program and the release date of the program. This will change from one release to the next release.

The next information is how to invoke the build-in help menu of the program.

Here after the current configuration of the chip is shown:

Table 2, Initial screen snapshot from Micro RF LinkX after reset/power-on

Item #	Item	Description
1	Frequency	The RF transmit frequency currently selected, followed by the LO-injection setting (l or h for low- or high-site LO injection), and followed by the transmission speed (in this case 9.6 kBit)
2	Link type	“One-way” or “two-way” RF communication, depending on the configuration of the system.
3	TX baudrate	The TX band-rate of the device. Can be selected to 9.6, 40 or 100 kBit
4	TX power	The PA setting of the system when transmitting RF.
5	LBT Threshold	Listen Before Talk Threshold, valid for 3-channel systems
6	XTAL cal.	Crystal calibration value of the system as read from the NVR memory
7	TX cal.	TX calibration value of the system, performed after boot-up of the chip
8	LBT reading	RSSI value, sampled right after boot-up of the chip

How to change the above settings and how to setup different systems will now be described in details.

After the section 4 (Micro RF LinkX commands) which is describing each of the commands, a section “How to” will further describe how to setup **Micro RF LinkX** for various common scenarios.

4 MICRO RF LINKX COMMANDS

The **Micro RF LinkX** program is configured through different commands from a terminal program (or remotely, please refers to section 6) to the DUT.

The commands are either a single letter or multiple letters, followed by the “enter key”. Multiple letter commands may also have one or more parameters.

The notion in this section is:

x + “enter key”:	Type the letter x followed by pressing the “enter key”
[Num] + “enter key”:	Type a number, e.g., 1 or 5 or 100 or 231 followed by pressing “enter key”
[$Command$] + “enter key”:	A command or commands followed by pressing “enter key”

The commands can be given to the DUT whenever “:” (colon sign) is shown, as presented in Figure 2 (a terminal screen snapshot).

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      One-way
TX baudrate    9K6
TX power       32
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (23,18)
LBT reading    35
:

```

Figure 2, Command prompt of Micro RF LinkX, the “:”

Note: The prompt can always be invoked again by pressing the “enter key”.

Note: Pressing the “enter key” will always stop the current action and make **Micro RF LinkX** return to a prompt.

4.1 Help command, *h*

Command syntax: h + “enter key”

Usage: Shows the on-screen help on the terminal

Exceptions: No exceptions

Command description: At the command prompt of **Micro RF LinkX** i.e., “:”, type the letter h followed by the “enter key” in order to show the help menu of **Micro RF LinkX**.

A terminal screen snapshot for the on-screen help of the **Micro RF LinkX** is shown below:

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
h
-----
500 Series Commands
-----
!          Repeat the previous command.
apm       Enter Auto Programming Mode.
d         Reset to default state.
f         Set frequency in kHz, LO injection side, and bit rate in
         kbps.
h         Display this help.
hist      Shows a histogram of sampled (1.33kHz) RSSI measurements.
         Each line shows the RSSI range of 15 samples.
l         Select between a one-way or two-way communicating link.
p         Set the RFPower setting to change the TX power.
r         Resets the chip and starts up again. NB the configuration
         is maintained unless a remote configuration is received.
rng r     Continuously receive modulated Micro Link frames and
         transmit an acknowledge with the RSSI of the received frame.
rng t [NUM] Transmit NUM amount of modulated Micro Link frames with
         non-zero inter-frame gap.
rx        Continuously receive modulated Micro Link frames and echo
         the success rate in %.
rx a      Continuously receive all modulated frames and show the raw
         data. The fields are: Frame type, RSSI of frame, bit rate in
         kbps and raw data. Frame type is 'M' Micro Link or 'Z' all
         other.
         NB: Due to time spent on displaying, some frames may
         not be shown if the inter-frame gap is too low.
rx r [NUM] Continuously receive modulated Micro Link frames and roll
         over every NUM amount of frames to a new line. The fields
         are Number of successful frames, arithmetic mean of RSSI of
         successful frames, arithmetic mean of background RSSI of
         last received frame, and bit rate in kbps.
rxsweep   Show the RSSI measurements swept through a range of
         frequencies. Reception is 5ms per step.
s         Show current configuration and status.
settcals  Automatically derive the TX calibration constants
         NOTE: the value is only kept until reset and not stored
         in NVM!
setxcals  Automatically derive the XTAL calibration constant (BETA
         version) when a strong unmodulated carrier is provided.
         NOTE: the value is only kept until reset and not stored
         in NVM!
tx        Continuously transmit modulated Micro Link frames with
         non-zero inter-frame gap.
tx [NUM]  Transmit NUM amount of modulated Micro Link frames with
         non-zero inter-frame gap.
tx c      Continuously transmit unmodulated carrier.
tx m      Continuously transmit modulated carrier with pseudo-random
         data.
tx p      Continuously transmit modulated carrier with a preamble
         pattern (alternating 1s and 0s).
tx r [NUM] Continuously transmit modulated frames and roll over every
         NUM amount of frames on a new line.
txsweep   Transmit an unmodulated carrier that sweeps through a
         specified range of frequencies. The transmission is 5ms per
         step.

Remote configuration:
send [COMMAND] Broadcast the current setup at 896000kHz and an optional
         command. The first node which receives the setup
         configuration and returns an ACK terminates the broadcast.
-----
:■

```

Figure 3, On-screen help of Micro RF LinkX

4.2 Repeat command, !

Note: This command is not implemented yet.

4.3 Auto programming mode, *apm*

This command is mainly used for chip-programming test purposes.

Command syntax: *apm* + "enter key"

Usage: Enable Auto Programming Mode of the device using sfr-bits, please refer to the programming tool documentation.

Exceptions: No exceptions

Command description: This command enables the APM mode of the device, which means that the device can now be programmed without asserting the RESET_N pin of the 500 series chip. At the command prompt “:”, write the letters *apm* and press the “enter key”. Once this is done, the DUT can now be programmed over the USB connection, the UART connection, or the SPI connections. If the DUT is not reprogrammed while being in APM mode, power cycling the DUT will disable the APM mode. The DUT will boot-up normally and show the **Micro RF LinkX** prompt.

A terminal screen snapshot for the command *apm* is shown in Figure 4.

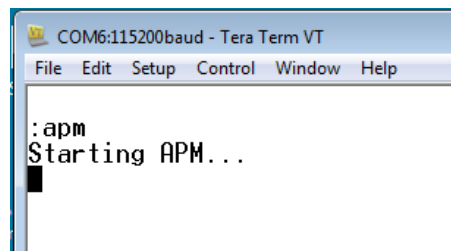


Figure 4, APM mode

Please refer to the programming tool documentation to learn how to use APM mode.

4.4 Default state, *d*

This command is used whenever a “clean sheet” / “known state” in the DUT is needed.

Command syntax: *d* + “enter key”

Usage: Used to clear all previous settings in the DUT and return to the default settings (shown in Figure 5) of **Micro RF LinkX**

Exceptions: No exceptions

Command description: Since all settings are stored in the DUT, sometimes it can be useful to clear the settings and start from scratch when configuring the DUT. At the command prompt “:”, type the letter *d* and press the “enter key”. All previous settings will now be erased from the module and the default settings will be setup.

A terminal screen snapshot for the command *d* is shown in Figure 5.

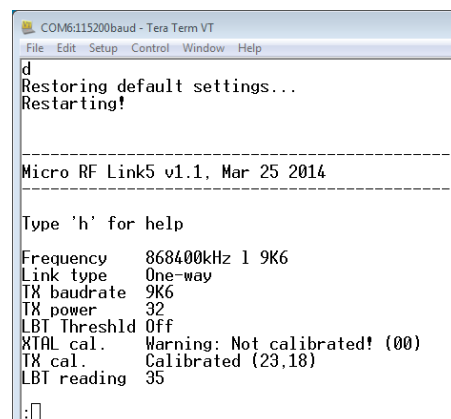


Figure 5, Restoring to default state

4.5 Set frequency, *f*

This command is used whenever the radio of the 500 series device is to be configured.

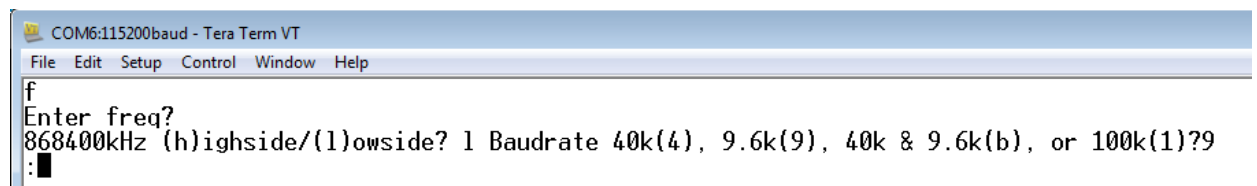
Command syntax: *f* + “enter key”

Usage: Used to setup the RF frequency of the **Micro RF LinkX**. The frequency is entered in kHz, and it is valid for both TX and RX operation.

Exceptions: Frequencies below 800 MHz or above 999 MHz are not supported by **Micro RF LinkX**. So the boundary limits are; 800000 < frequency < 999000.

Command description: This command is used to set up the RF system of the 500 series DUT. Once setup, the DUT can transmit or receive at the selected frequency. The **Micro RF LinkX** handles all radio setup calculations, so the frequency to write is the actual transmit frequency. At the command prompt “:”, type the letter *f* and press the “enter key”. Now write the desired frequency in kHz followed by the “enter key”. The system prompts for the LO injection side (*h*)ighside/(*l*)owside, so depending on the required LO injection side (please refer to Table 3), write either the letter *l* or the letter *h*. Now the communication speed is prompted, so depending on the required communication speed (please refer to Table 3), type either the number 4 (40kBit), 9 (9.6kBit) or 1 (100kBit). Once the number has been typed, the **Micro RF LinkX** returns to the prompt and is ready to receive the next command. Now the DUT is setup for the desired parameters (i.e., frequency, LO injection side, and communication speed) to start the radio communication.

A terminal screen snapshot for the command *f* is shown in Figure 6.



```
COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
f
Enter freq?
868400kHz (h)ighside/(l)owside? l Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:
```

Figure 6, Radio frequency configuration

When setting up a DUT for e.g., RF approval measurements, it is very important that the DUT is initialized to perform as a Z-Wave product. **Micro RF LinkX** gives the flexibility to setup any kind of RF settings on the DUT, including the ones which are not supported by the official Z-Wave settings and the ones not allowed by local RF authorities.

When setting up the DUT to perform as a Z-Wave enabled device, the following TX frequencies, LO injection sides and communication speeds must be used:

Table 3, Z-Wave regions, frequencies, communications rates, LO settings

Z-Wave region	Z-Wave Channel	Frequency [kHz]	Communication rate [kBit]	LO injection side
EU	0	869850	100	(h)igh
	1	868400	9.6/40	(l)ow
RU	0	869000	100	(h)igh
	1	869000	9.6/40	(l)ow
US	0	916000	100	(h)igh
	1	908400	9.6/40	(l)ow
HK	0	919800	100	(h)igh
	1	919800	9.6/40	(l)ow
ANZ	0	919800	100	(l)ow
	1	921400	9.6/40	(l)ow
MY	0	868100	100	(h)igh
	1	868100	9.6/40	(l)ow
IN	0	865200	100	(h)igh
	1	865200	9.6/40	(l)ow
JP	0	922500	100	(l)ow
	1	923900	100	(l)ow
	2	926300	100	(l)ow
KR	0	920900	100	(l)ow
	1	921700	100	(h)igh
	2	923100	100	(h)igh
IL	0	916000	100	(l)ow
	1	916000	9.6/40	(l)ow
CN	0	868400	100	(h)igh
	1	868400	9.6/40	(l)ow

Note: 20 kHz is automatically added to the frequency, when the communication rate 9.6 kBit is selected.

4.6 RSSI histogram, hist

Note : This command is not implemented yet.

4.7 Link setting, l

Command syntax: / + "enter key"

Usage: Used to setup the link functionality of **Micro RF LinkX** to a "one-way" link or a "two-way" link

Exceptions: No exception

Command description: This command is used whenever link budget measurement or link quality assessment between two **Micro RF LinkX** enabled devices is to be performed.

If a one-way link is setup, communication will flow from a transmitter to a receiver without any acknowledgment upon received frames.

If a two-way link is setup, communication will flow from a transmitter to a receiver and from the receiver back to the transmitter. In other words, all the frames transmitted are acknowledged by the receiver.

At the command prompt “:”, type the letter *l* and press the “enter key”. The **Micro RF LinkX** will now prompt for the link type. Type the letter *o* for one-way link or type the letter *t* for two-way link. Once the link type is selected, the command-prompt will be shown again and the system is ready to accept new commands.

A terminal screen snapshot for the command *l* is shown in Figure 7.

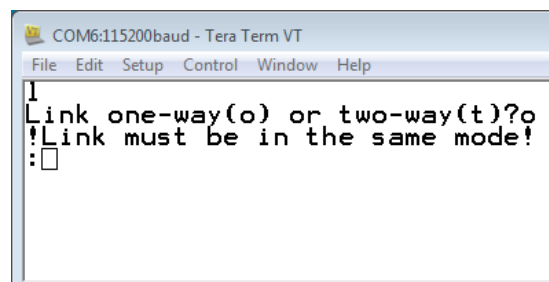


Figure 7, Link configuration

Since all Z-Wave enabled devices acknowledge incoming Z-Wave frames, two-way link mode must be selected if a “Z-Wave like” setup is to be assessed.

4.8 PA power setting and LBT setting, *p*

Command syntax: *p* + “enter key”

Usage: Used to setup the output power of the 500 series chip and to set/disable the LBT (Listen Before Talk) threshold for 3 channel systems.

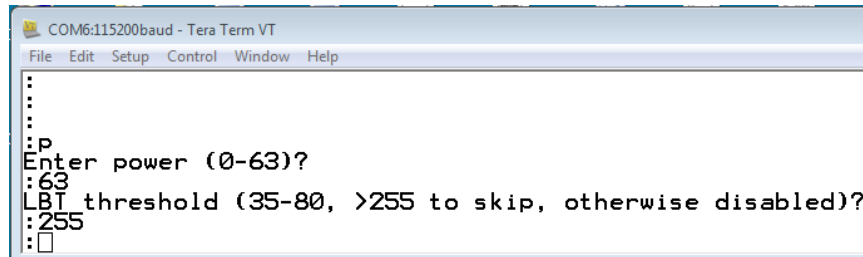
Exceptions: Valid PA settings range from 0 to 63 (0 = minimum power, 63 = maximum power). Valid LBT settings range from 35 to 80, and 255 to disable LBT.

Command description: The RF output level of the PA in the 500 series chip can be configured in 64 steps. Please refer to the relevant datasheet in order to get a “number to dBm” mapping of the PA setting. Each DUT has its own RF path loss, so in order to get the maximum output power out to the antenna, the PA output power of the DUT must be optimized so that the RF regulations are not violated but the best possible link-budget is obtained.

Furthermore, in some regions of the world, LBT must be performed before transmission is allowed. The LBT level is also setup in this command. Please refer to the relevant data sheet for a “RSSI number to dBm” mapping.

At the command prompt “:”, type the letter *p* and press the “enter key”. The **Micro RF LinkX** now prompts for a PA setting. Type a number and press the “enter key”. A LBT threshold number is now prompted for. Type a number (255 for NO LBT) and press the “enter key”. The **Micro RF LinkX** will now show the prompt and be ready for new commands.

A terminal screen snapshot for the command *p* is shown in Figure 8.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
:
:
:p
Enter power (0-63)?
:63
LBT threshold (35-80, >255 to skip, otherwise disabled)?
:255
:
:

```

Figure 8, Power and LBT settings

If LBT is enabled, the DUT will not turn on the PA in order to transmit, if a RSSI level above the LBT threshold is sampled prior to the transmission. In other words, if LBT is enabled, prior to any future transmissions, a RSSI value is sampled, compared with the LBT threshold setting, and if the sampled RSSI value is below the threshold, the transmission is allowed. If the RSSI value is above the threshold, the transmission is postponed until a valid RSSI value is sampled.

4.9 Chip reset, *r*

Command syntax: *r* + “enter key”

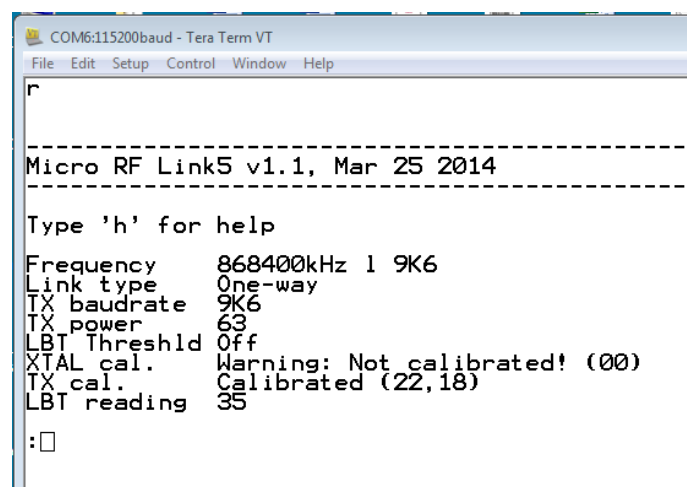
Usage: Software enabled reset of the DUT. Unless remote control is used (please refer to section 6), all configured settings are preserved after the reset.

Exceptions: No exceptions

Command description: This command can be used to reset the DUT through the terminal. At the command prompt “:”, type the letter *r* and press the “enter key”. The DUT will now reboot and startup with the actual settings preserved.

This command is equal to a hardware reset of the DUT, that is, assertion of the RESET_N pin. If the DUT shares the RESET_N pin with other components in this system, the other components will *not* be affected by this reset.

A terminal screen snapshot for the command *r* is shown in Figure 9.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
r
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      One-way
TX baudrate    9K6
TX power       63
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (22,18)
LBT reading    35
:

```

Figure 9, Reset of DUT

4.10 Range mode, far-site device, *rng r*

Command syntax: *rng r* + “enter key”

Usage: Configures the DUT into a mode, where received frames are acknowledged to the transmitter with the received RSSI value pr. frame appended to the data frame.

Exceptions: It only works if the link mode is “two-way”. Furthermore, it works only together with another **Micro RF LinkX** device, setup with the same RF settings and set to “*rng t*” mode.

Command description: This command can be used, if a link budget between two **Micro RF LinkX** enabled devices is to be measured. When this mode is enabled, the DUT will acknowledge all received frames from a “*rng t*” enabled device, and the received RSSI value will be embedded in the acknowledged frame. At the command prompt “:” type the letters *rng r* and press the “enter key”. The DUT will now await RF frames to acknowledge to the transmitter. Whenever 10 frames are received, the statistics for these received 10 frames are displayed to the terminal. The mode is aborted by pressing the “enter key”.

When a range test is to be performed or a link budget between two **Micro RF LinkX** enabled devices is to be conducted, the *rng r* mode is used to configure the far-site DUT in the link setup. Figure 10 shows a setup to perform the range test.

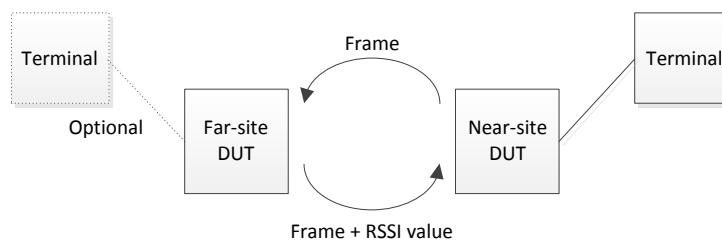
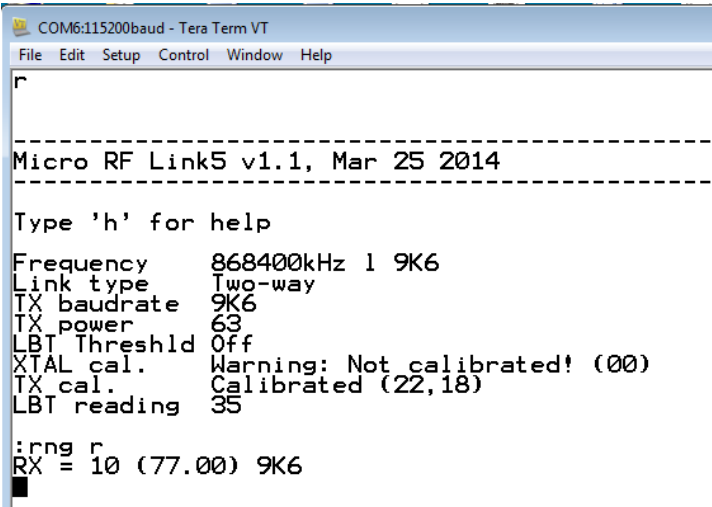


Figure 10, Range test setup

As seen in Figure 10, the far-site DUT can optionally be connected to a terminal, but the near-site DUT (configured with the *rng t*, please see section 4.11) must be connected to a terminal for reading out the results of the link test.

When configured to two-way communication and put in *rng r* mode, the DUT will output statistics for every 10 received frames. The statistics tells about number of correct received frames, the average RSSI level, and the communication rate valid for the received frames. A terminal screen snapshot for the command *rng r* is shown in Figure 11.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
r
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      Two-way
TX baudrate    9K6
TX power       63
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (22,18)
LBT reading    35

:rng r
RX = 10 (77.00) 9K6

```

Figure 11, Range mode, *rng r*

4.11 Range mode, near-site device, *rng t [NUM]*

Command syntax: *rng t [NUM]* + “enter key”

Usage: Configures the DUT into a mode, where [NUM] number of frames are transmitted to a far-site DUT. Acknowledged frames from the far-site DUT are RSSI measured and displayed to the terminal.

Exceptions: It only works if the link mode is “two-way”. Furthermore, it works only together with another **Micro RF LinkX** device setup with the same RF settings and set to “*rng r*” mode.

Command description: This command can be used, if a link budget between two **Micro RF LinkX** enabled devices is to be measured. When this mode is enabled, the DUT will transmit [NUM] number of frames to a “*rng r*” enabled device. The replies from the far-site device will be RSSI measured, and statistics from the far-site DUT and this device will be displayed on the terminal. At the command prompt “:”, type the letters *rng t* and optionally write the number of frames to transmit, then press the “enter key”. If a number of frames were not typed, then the default number i.e., 10 frames will be transmitted, and the statistics will be displayed on the terminal. If a number of frames were typed, then the DUT will transmit the selected number of frames, and upon end of transmission, display the statistics on the terminal. The mode is automatically aborted when the selected number of frames has been transmitted, or if the “enter key” is pressed during transmission.

When a range test is to be performed or a link budget between two **Micro RF LinkX** enabled devices is to be conducted, the *rng t* mode is used to configure the near-site DUT in the link setup. Figure 12 shows a setup to perform the range test.

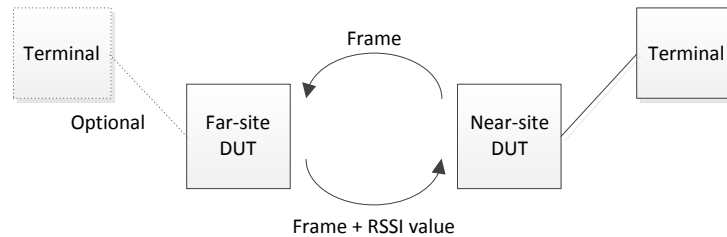


Figure 12, Range test setup

As seen in Figure 12, the near-site DUT must be connected to a terminal, but the far-site DUT can optionally be connected to a terminal.

When configured to two-way communication and put in *rng t* mode, the DUT will transmit frames and output statistics for the selected number of transmitted frames. The statistics tells about the number of correct received frames at the far-site together with its RSSI value, and number of correct received frames at the near-site together with its RSSI value.

A terminal screen snapshot for the command *rng t* is shown in Figure 13. The first set of numbers (TX =) are valid for the far-site DUT, whereas the second set of numbers (RX =) are valid for the near-site DUT. For the current version of **Micro RF LinkX**, the RSSI values (the numbers in the parenthesis) are not symmetrical, as they ideally should be.

```

COM17:115200baud - Tera Term VT
File Edit Setup Control Window Help
:f
Enter freq?
868400kHz (h)ighside/(l)owside? | Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:l
Link one-way(o) or two-way(t)?t
!Link must be in the same mode!
:rng t
TX = 10 (77.00) , RX = 10 (81.00)
:
  
```

Figure 13, Range mode, rng t

4.12 Receive mode, rx

Command syntax: *rx* + “enter key”

Usage: Configures the DUT into receive mode, where frames transmitted at the configured frequency and communication rate are received, and the success-rate of the reception is calculated and displayed on the terminal.

Exceptions: No exceptions

Command description: This command can be used, if a link budget between two **Micro RF LinkX** enabled devices is to be measured. When this mode is enabled, the DUT will receive all frames transmitted from a **Micro RF LinkX** enabled device, if the frequency and communication rate of the two devices are equal. The success-rate of the reception is calculated and displayed on the terminal along with the average RSSI value. At the command prompt “:”, type the letters *rx* and press the “enter key”. The DUT will receive and calculate the success-rate until the operation is aborted by pressing the “enter key”.

This mode can be operated in two ways; either in one-way link mode or in two-way link mode (please refer to section 4.7). If operated in one-way link mode, the DUT only receive the frames. However, if

operated in two-way link mode, the DUT acknowledges every received frame to the transmitter. A setup shown in Figure 14 illustrates one-way and two-way modes.

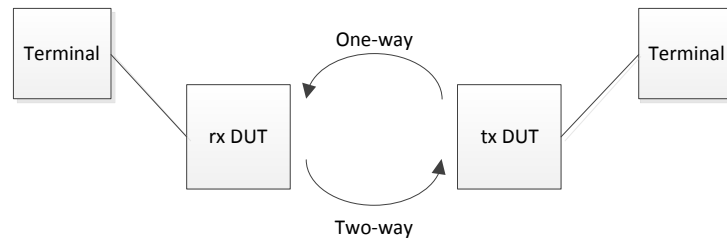


Figure 14, Receive mode, rx

A terminal screen snapshot for the command `rx` is shown in Figure 15. The number following the RX is the success rate of the reception. The number in the parenthesis is the average RSSI value of the received frames.

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
r
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      Two-way
TX baudrate    9K6
TX power       63
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (22,18)
LBT reading    35

:l
Link one-way(o) or two-way(t)?o
!Link must be in the same mode!
:rx
RX = 100.00% (77.09)

```

Figure 15, rx mode

4.13 Receive and demodulate frames, `rx a`

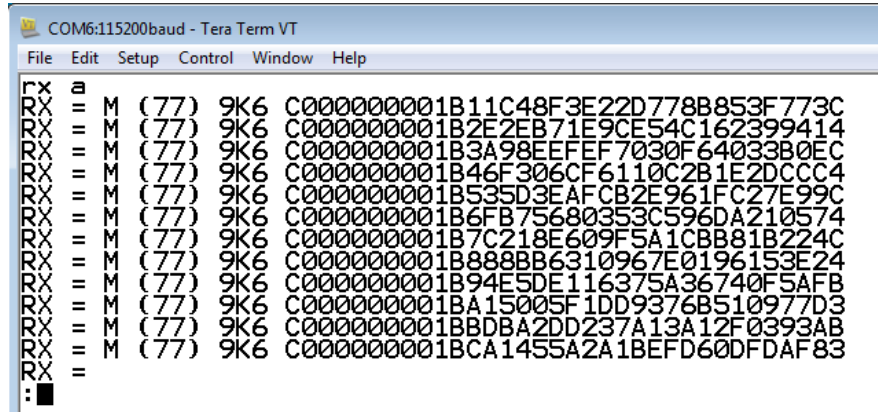
Command syntax: `rx a` + “enter key”

Usage: Configures the DUT into receive mode. All received frames are demodulated, and the frame content is displayed to the terminal. If the received frame is a **Micro RF LinkX** frame, the frame is tagged with the letter **M**. If the received frame is a Z-Wave frame, the framed is tagged with the letter **Z**.

Exceptions: Z-Wave data is not time-stamped or interpreted.

Command description: This command can be used as a raw and simple Ziffer device. Enabling this mode, the user is able to analyze whether the transmitted frames at a configured frequency are Z-Wave frames or other types of frames. At the command prompt “:”, type the letters `rx a` and press the “enter key”. The DUT will now demodulate and display the received frames on the terminal. The displayed information is the RSSI value, the communication rate, and the ASCII content of the frame. The operation is aborted by pressing the “enter key”.

A terminal screen snapshot for the command `rx a` is shown in Figure 16. The data following the RX is frame mode (**M** for **Micro RF LinkX** frames, and **Z** for Z-Wave frames), the RSSI value, the communication rate, and the ASCII frame content.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
RX a
RX = M (77) 9K6 C000000001B11C48F3E22D778B853F773C
RX = M (77) 9K6 C000000001B2E2EB71E9CE54C162399414
RX = M (77) 9K6 C000000001B3A98EFFF7030F64033B0EC
RX = M (77) 9K6 C000000001B46F306CF6110C2B1E2DCCC4
RX = M (77) 9K6 C000000001B535D3EAF CB2E961FC27E99C
RX = M (77) 9K6 C000000001B6FB75680353C596DA210574
RX = M (77) 9K6 C000000001B7C218E609F5A1CBB81B224C
RX = M (77) 9K6 C000000001B888BB6310967E0196153E24
RX = M (77) 9K6 C000000001B94E5DE116375A36740F5AFB
RX = M (77) 9K6 C000000001BA15005F1DD9376B510977D3
RX = M (77) 9K6 C000000001BBDBA2DD237A13A12F0393AB
RX = M (77) 9K6 C000000001BCA1455A2A1BEFD60DFDAF83
RX =
:

```

Figure 16, rx a mode

4.14 Receive mode, rolling mode reception, `rx r [NUM]`

Command syntax: `rx r [NUM] + "enter key"`

Usage: Configures the DUT into receive mode and repeatedly display the statistics of `[NUM]` number of received frames

Exceptions: No exceptions

Command description: This command can be used to find the link-budget between two **Micro RF LinkX** enabled devices. If the DUT is set in this mode, and the path-loss between the transmitter and the DUT is increased, it is easy to see the effect of this on the DUT terminal due to the rolling printout of statistics. At the command prompt ":", type the letters `rx r [NUM]` and press the "enter key". The DUT will now start to receive at the configured frequency and communication rate, and display statistics for every `[NUM]` number of received frames.

The mode can be used when performing range measurements or sensitivity measurements, as illustrated in Figure 17.

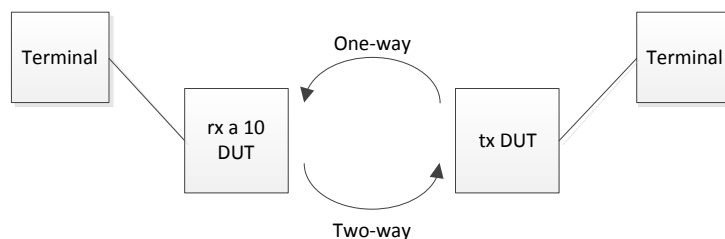


Figure 17, Range or sensitivity test setup

The output from the `rx a` enabled DUT shows the number of correct received frames, the average RSSI value, the RSSI value read when NOT receiving any frames (i.e., the back-ground noise in the receiver), and the communication rate of the received frames.

A terminal screen snapshot for the command `rx a` is shown in Figure 18. In this example, the command `rx r 10` results in a statistics display on the terminal whenever 10 frames are received.

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
:rx r 10
RX = 10 (77.20) BKGND (41.33) 9K6
RX = 10 (68.70) BKGND (39.00) 9K6
RX = 10 (45.70) BKGND (39.00) 9K6
RX = 10 (44.50) BKGND (38.00) 9K6
RX = 10 (44.10) BKGND (39.00) 9K6
RX = 10 (44.70) BKGND (37.00) 9K6
RX = 10 (44.40) BKGND (37.00) 9K6

```

Figure 18, rx r [NUM]

4.15 RSSI values across channels, *rxsweep*

Command syntax: *rxsweep* + “enter key”

Usage: Configures the DUT into receive mode and enables RSSI reception in a number of configurable RF channels. All numbers must be entered in kHz. The dwell time pr. channel is 5 ms.

Exceptions: Start-frequency must be greater than 800 MHz, stop-frequency must be smaller than 999 MHz, and channel bandwidth must be greater than 1 KHz.

Command description: This command can be used as a simple implementation of a spectrum analyzer. When configured, the DUT will show the measured RSSI value for a range of RF channels, given by a start frequency value, a stop frequency value and a channel bandwidth. The number of channels to be measured are calculated as; (stop frequency – start frequency) / step size. At the command prompt “:”, type the letters *rxsweep* and press the “enter key”. The **Micro RF LinkX** now prompts for the start frequency, type the start frequency as a number in kHz and press the “enter key”. **Micro RF LinkX** prompts for the stop frequency, type the stop frequency in kHz and press the “enter key”. Now enter the step size in kHz and press the “enter key”. The **Micro RF LinkX** now prompts for the output type, type “y” for comma separated output and “n” for graph. If you choose “y” The **Micro RF LinkX** will out put the readings as shown in the following format.

```

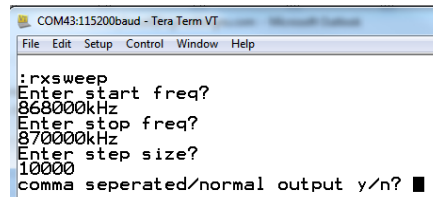
frequency(start); sampling_time_ms; min_rssi_reading; max_rssi_reading
frequency(start + step) ; sampling_time_ms ;min_rssi_reading;
max_rssi_reading
:
:
frequency (stop – step); sampling_time_ms ;min_rssi_reading;
max_rssi_reading

```

If you enter “n”, the **Micro RF LinkX** will output a graph on the terminal, showing the RSSI value measured at the selected channels. The operation can be aborted by pressing the “enter key”.

This mode is very useful if the RF power present in the air is to be measured and a spectrum analyzer is not at hand. The DUT is setup to cover the frequency interval of interest, and then it scan the spectrum and display the RSSI value measured at each frequency step given by the formula; (stop frequency – start frequency) / step size.

Below is the terminal screen snapshot during the configuration of the *rxsweep* mode:



```

COM43:115200baud - Tera Term VT
File Edit Setup Control Window Help
:rxsweep
Enter start freq?
868000kHz
Enter stop freq?
870000kHz
Enter step size?
10000
comma seperated/normal output y/n? █

```

Figure 19, rxsweep mode configuration

After configuration, i.e., the configuration screen will be erased from the terminal, and the terminal will display the RSSI graph if you choose “n” at the last configuration step, as shown in Figure 20.

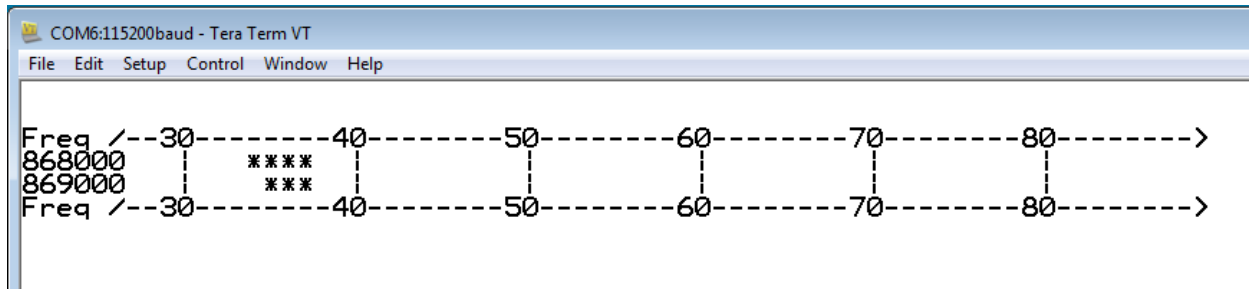
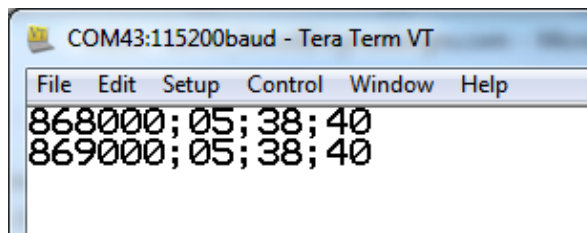


Figure 20, rxsweep output mode (graph)

In this example, the RSSI level at 868 MHz is measured below 40, and the RSSI level at 869 MHz is measured to the same value as for the 868 MHz channel. If noise / RF energy was present at 869 MHz, then the measured value would be larger at this channel, giving a larger RSSI value.

Note: The number of lines in the terminal window may limit the number of frequency steps which can be displayed.

If you press “y” at the last configuration step, the terminal will display the reading as shown in figure.



```

COM43:115200baud - Tera Term VT
File Edit Setup Control Window Help
868000; 05; 38; 40
869000; 05; 38; 40

```

Figure 21, rxsweep output mode (comma separated)

4.16 Show configuration and status, s

Command syntax: s + “enter key”

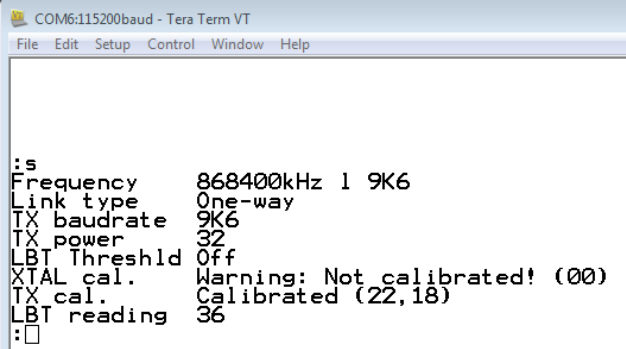
Usage: Show the current configuration of the DUT

Exceptions: No exceptions

Command description: This command is used when an overview of the actual configuration is needed. It may be that one is unsure if the DUT is configured correctly. The configuration of a DUT can be verified by issuing this command. At the command prompt “:”, type the letter s and press the “enter key”. The **Micro RF LinkX** outputs the

current settings on the terminal and performs a RSSI measurement. The **Micro RF LinkX** is ready for new command after the execution of the `s` command.

A terminal screen snapshot for the command `s` is shown in Figure 22. The output of the status command is equal to the boot-up information. Please refer to section 3.2.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help

:s
Frequency      868400kHz 1 9K6
Link type      One-way
TX baudrate    9K6
TX power       32
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (22,18)
LBT reading    36
:□

```

Figure 22, Status, `s`

4.17 TXCalibration, `settc`

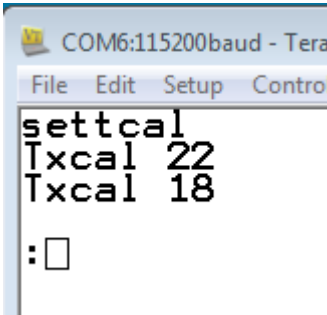
Command syntax: `settc` + “enter key”

Usage: Performs a TX calibration and stores the calibrated values in the **Micro RF LinkX**. The values are valid until a power-cycle event.

Exceptions: No exceptions.

Command description: All 500 series based Z-Wave systems must be TX Calibrated in order to ensure proper RF operations. All modules sold by *Silicon Labs* are by default TX Calibrated, whereas *SD3502* and *SD3503* chips must be calibrated by the customer. The command forces the DUT to be TX calibrated. The calibrated values are only valid for the **Micro RF LinkX**, since they cannot be stored in the NVM memory. Non-calibrated chips must be correctly programmed with the TX Calibration values before they are used in a Z-Wave system. At the command prompt “:”, type the letters `settc` and press the “enter key”. The **Micro RF LinkX** will output the calibrated values on the terminal and store them internally for RF operations.

A terminal screen snapshot for the command `settc` is shown in Figure 23. It shows that the command `settc` results in two TX calibration values; one having the value 22 and the other having the value of 18. These values are valid until a power-cycle event happens.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help

settc
Txcal 22
Txcal 18
:□

```

Figure 23, Output from `settc` command

4.18 Crystal calibration, *setxcal*

Command syntax: *setxcal* + “enter key”

Usage: Performs (wirelessly) the crystal calibration of the DUT in the presence of a strong and precise RF carrier signal

Exceptions: Requires an un-modulated input RF signal above RSSI level 60 and a frequency precision of +/- 3ppm.

Command description: All 500 series based Z-Wave systems must be crystal calibrated in order to ensure proper RF operations. All modules sold by *Silicon Labs* are by default crystal calibrated, whereas *SD3502* and *SD3503* chips must be calibrated by the user. The command forces the DUT into RX mode, and if a strong carrier is detected (i.e., RSSI > 60), the **Micro RF LinkX** performs a crystal calibration based on the received frequency. The calibrated value is only valid for the **Micro RF LinkX**, since it cannot be stored in the NVM memory. Non calibrated chips must be correctly programmed with the crystal calibration value before they are used in a Z-Wave system. At the command prompt “:”, type the letters *setxcal* and press the “enter key”. The **Micro RF LinkX** will display the calibrated value on the terminal and store it internally for RF operations. If no RF signal is detected, the **Micro RF LinkX** will display the message “- No carrier detected!” on the terminal. In the case, where no suitable RF signal is detected, the operation can be aborted by pressing the “enter key”.

Crystal calibration can be performed in two different ways. Either using some IO pins (please refer to the relevant documentation regarding calibration, document INS12524) or using a precise and strong RF carrier signal.

With **Micro RF LinkX**, the crystal calibration is performed wirelessly by using a precise RF carrier signal. Figure 24 shows the crystal calibration setup, whereas Figure 25 shows the terminal screen snapshot for the command *setxcal*.

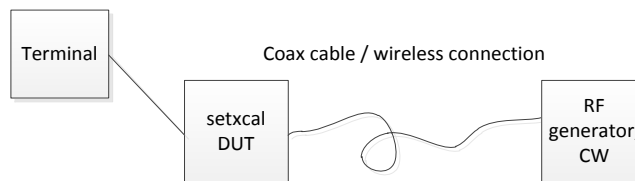


Figure 24, Crystal calibration setup

```
COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
setxcal
Provide unmodulated 100kbit/s carrier at 868400kHz to measure! (minimum RSSI of 60)
Deviation = 00.58 kHz, New calibration is = 01
:□
```

Figure 25, *setxcal* command

4.19 Frame transmission, *tx*

Command syntax: *tx* + “enter key”

Usage: Transmit the **Micro RF LinkX** frames at a configured frequency and communication rate. Frames are not transmitted back to back.

Exceptions: No exception

Command description: This command can be used when the link budget between two **Micro RF LinkX** devices is to be measured, or if the RF output power of the DUT is to be measured. At the command prompt “:”, type the letters *tx* and press the “enter key”. The DUT will transmit **Micro RF LinkX** frames until the user aborts the transmission by pressing the “enter key”. The number of transmitted frames is displayed on the terminal. If the DUT is part of a two-way communication link, the number of received acknowledgement frames is displayed too.

If a range measurement is to be performed or a link budget is to be evaluated, the following **Micro RF LinkX** system can be setup.

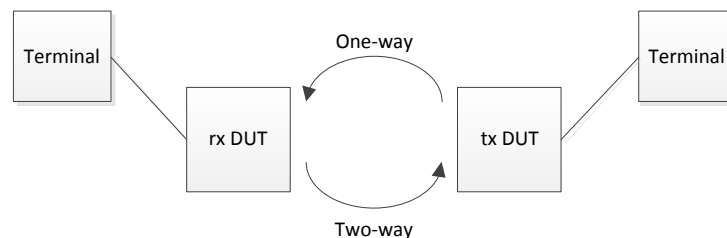


Figure 26, Range / Link budget measure setup

A terminal screen snapshot for the command *tx* is shown in Figure 27. The TX and ack values are updated according to the number of transmitted frames and number of received acks, respectively. The ack values are only updated, if the DUT is a part of a two-way communication system. In the example, shown in Figure 27, the number of received acknowledgement frames is zero. If the RF path is symmetrical, then the number of TX frames should be equal to the number of received acknowledgement frames.

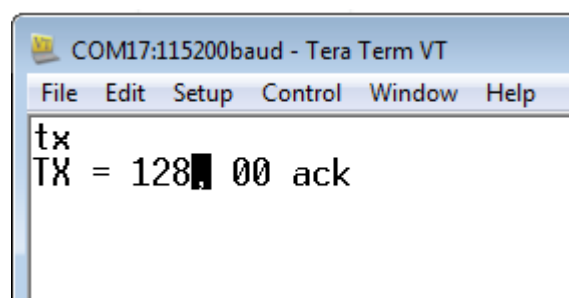


Figure 27, tx command

4.20 Limited frame transmission, *tx* [NUM]

Command syntax: *tx* [NUM] + “enter key”

Usage: Transmission of a limited number of **Micro RF LinkX** frames at a configured frequency and communication rate. Frames are not transmitted back to back.

Exceptions: No exception

Command description: This command can be used when the link budget between two **Micro RF LinkX** devices is to be measured, or if the RF output power of the DUT is to be

measured. At the command prompt “:”, type the letters `tx [NUM]` and press the “enter key”. The DUT will now transmit `[NUM]` number of **Micro RF LinkX** frames. The number of frames transmitted is displayed on the terminal. If the DUT is part of a two-way communication link, the number of received acknowledgement frames is displayed too.

If a range measurement is to be performed or a link budget is to be evaluated, the following **Micro RF LinkX** system can be setup.

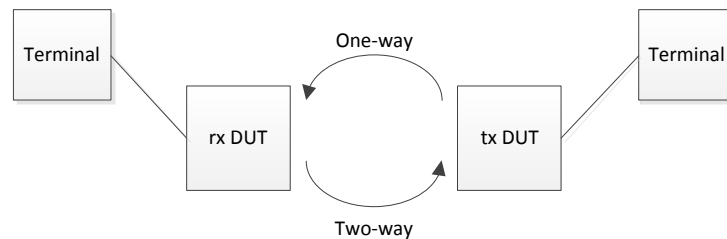


Figure 28, Range / Link budget measure setup

A terminal screen snapshot for the command `tx [NUM]` is shown in Figure 29. In this example, 10 frames are transmitted, and then the transmission stopped. If the DUT is part of a two-way communication system, the number of received acknowledgement is updated too. In this example, the number of received acknowledgement frames is zero. If the RF path is symmetrical, then the number of TX frames should be equal to the number of received acknowledgement frames.

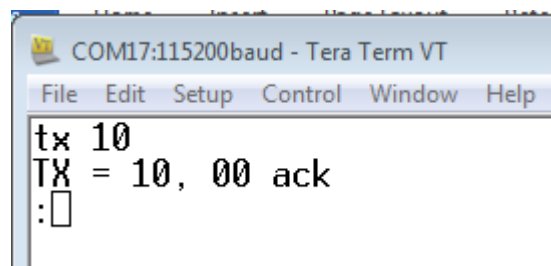


Figure 29, tx [NUM] command

4.21 Transmit carrier wave, `tx c`

Command syntax: `tx c` + “enter key”

Usage: Start to transmit an un-modulated and constant carrier at a configured frequency and output power

Exceptions: No exception

Command description: This command can be used when the output power of a DUT system or the RF harmonics of the DUT system has to be evaluated / measured. At the command prompt “:”, type the letters `tx c` and press the “enter key”. The **Micro RF LinkX** will turn on the transmitter, and transmit an un-modulated carrier wave until aborted by a “enter key” press. When the command is aborted, the **Micro RF LinkX** returns to the prompt “:”.

A terminal screen snapshot for the command `tx c` is shown in Figure 30.

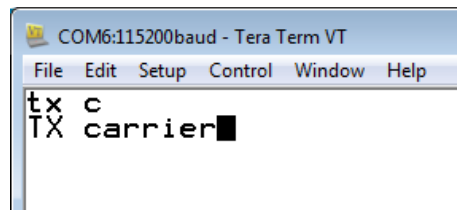


Figure 30, tx c command

4.22 Transmit modulated RF signal containing pseudo random data, *tx m*

Command syntax: *tx m* + “enter key”

Usage: Start to transmit a modulated RF signal with pseudo random data at a configured frequency, communication rate, and output power.

Exceptions: No exception

Command description: This command can be used when the output power of a DUT system or the occupied channel bandwidth of the DUT system has to be evaluated / measured. At the command prompt “:”, type the letters *tx m* and press the “enter key”. The **Micro RF LinkX** will turn on the transmitter, and transmit pseudo random data until aborted by a “enter key” press. When the command is aborted, the **Micro RF LinkX** returns to the prompt “:”.

A terminal screen snapshot for the command *tx m* is shown in Figure 31.

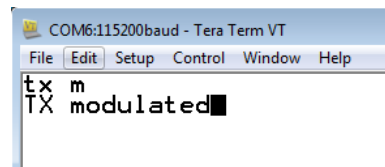


Figure 31, tx m command

4.23 Transmit modulated RF signal containing preamble data, *tx p*

Command syntax: *tx p* + “enter key”

Usage: Start to transmit a modulated RF signal with a preamble pattern (0101...) at a configured frequency, communication rate, and output power.

Exceptions: No exception

Command description: This command can be used when the output power of a DUT system or the occupied channel bandwidth of the DUT system has to be evaluated / measured. At the command prompt “:”, type the letters *tx p* and press the “enter key”. The **Micro RF LinkX** will turn on the transmitter, and transmit a preamble pattern until aborted by a “enter key” press. When the command is aborted, the **Micro RF LinkX** returns to the prompt “:”.

A terminal screen snapshot for the command *tx p* is shown in Figure 32.

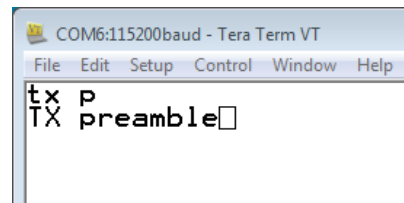


Figure 32, tx p command

4.24 Rolling frame transmission, *tx r [NUM]*

Command syntax: *tx r [NUM]* + “enter key”

Usage: Repeatedly transmission of *[NUM]* number of **Micro RF LinkX** frames at a configured frequency and communication rate. For every *[NUM]* number of transmitted frames, the statistics is displayed on the terminal. The frames are not transmitted back to back.

Exceptions: No exception

Command description: This command can be used when the link budget between two **Micro RF LinkX** devices is to be measured, or if the RF output power of the DUT is to be measured. At the command prompt “:”, type the letters *tx r* and then type how many frames are to be transmitted (at a time before the line in the terminal is shifted) and press the “enter key”. The DUT will transmit **Micro RF LinkX** frames until the user aborts the transmission by pressing the “enter key”. The number of transmitted frames is displayed on the terminal. If the DUT is part of a two-way communication link, the number of received acknowledgement frames is displayed too.

If a range measurement is to be performed or a link budget is to be evaluated, the following **Micro RF LinkX** system can be setup.

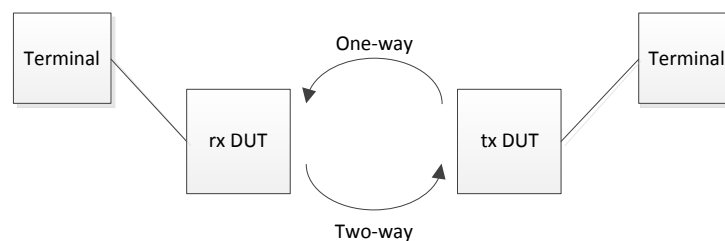
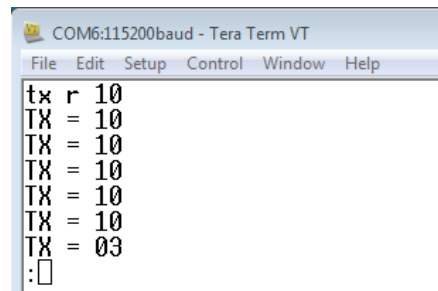


Figure 33, Range / Link budget measure setup

Figure 34 and Figure 35 show the terminal screen snapshots for the command *tx r [NUM]* for one-way and two-way systems, respectively. TX shows the number of transmitted frames and ack shows the number of received ack frames. The output from **Micro RF LinkX** depends on the link setting. In this example i.e., *tx r 10*, the number of received acknowledgement frames is zero. If the RF path is symmetrical, then the number of TX frames should be equal to the number of received acknowledgement frames.

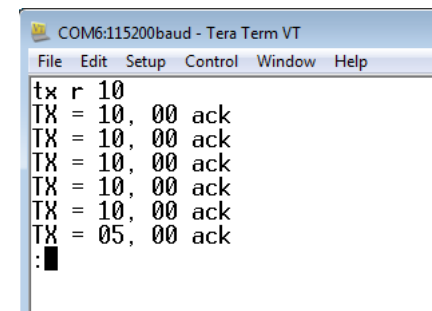


```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
tx r 10
TX = 10
TX = 10
TX = 10
TX = 10
TX = 10
TX = 03
:

```

Figure 34, Tx rolling for one-way mode



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
tx r 10
TX = 10, 00 ack
TX = 10, 00 ack
TX = 10, 00 ack
TX = 10, 00 ack
TX = 10, 00 ack
TX = 05, 00 ack
:

```

Figure 35, Tx rolling for two-way mode

4.25 RF frequency sweeping, *txsweep*

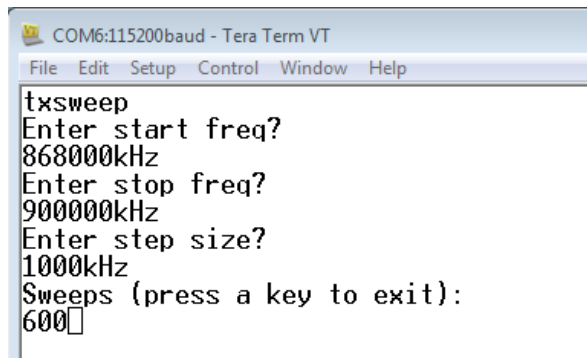
Command syntax: *txsweep* + “enter key”

Usage: Setup the DUT to transmit a RF carrier wave at a number of frequencies specified with the configured output power. The dwell time at each frequency step is 5 ms. Frequencies are given in kHz

Exceptions: Lowest possible frequency setting is 800 MHz, highest possible frequency setting is 999 MHz, and minimum frequency step size is 1 kHz.

Command description: This command can be used when frequency response of the RF path, a SAW filter or the matching circuit of the DUT is to be measured. At the command prompt “:”, type the letters *txsweep* and press the “enter key”. The DUT will now prompt for a start frequency given in kHz. Type the start frequency and press the “enter key”. The DUT will now prompt for a stop frequency given in kHz. Type the stop frequency and press the “enter key”. Finally, the DUT will prompt for the frequency step size in kHz. Type the frequency step size and press the “enter key”. The **Micro RF LinkX** will now configure the 500 series chip to RF transmission, and will transmit for 5 ms at each frequency given by the formula: (stop frequency – start frequency) / step size. The number of performed sweeps is displayed on the terminal for reference. The command can be aborted by pressing the “enter key”.

A terminal screen snapshot for the command *txsweep* is shown in Figure 36. If the DUT is connected to a spectrum analyzer (which is set to “max hold” mode), then the frequency response of the RF output path can be measured.



```
COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
txsweep
Enter start freq?
868000kHz
Enter stop freq?
900000kHz
Enter step size?
1000kHz
Sweeps (press a key to exit):
600
```

Figure 36, txsweep

5 MICRO RF LINKX, HOW TO

This section presents a number of practical examples of how to use **Micro RF LinkX** in connection with different types of typical RF measurements.

5.1 How to: Measure the RF output power / RF frequency of a 500 series based system

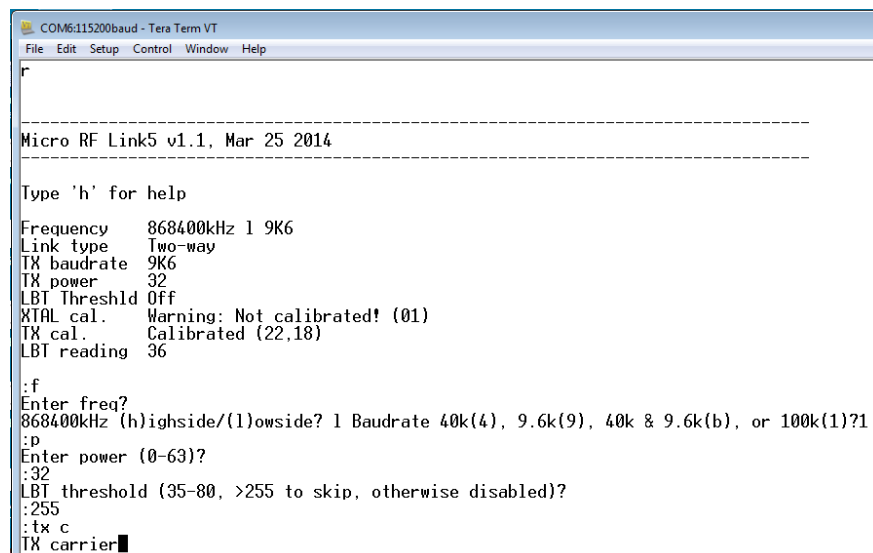
Typically, the RF output power of a Z-Wave system is one of the quality parameters of the system. Maximizing the RF output power while still being able to pass local RF regulations ensures that the link budget of the RF system will be as good as possible.

Furthermore, some RF regulatory tests require measurement of both the fundamental and the harmonics to be performed. The example below covers this scenario too.

Below is a description of how to setup the DUT:

1. Download the correct version of **Micro RF LinkX** to the DUT (please refer to **Error! Reference source not found.**)
2. Setup the correct RF frequency of the DUT (please refer to Table 3, Z-Wave regions, frequencies, communications rates, LO settings) by using the *f* command
3. Setup the output power of the DUT by using the *p* command
4. Enable the DUT to transmit an un-modulated RF carrier by using the *tx c* command.

A terminal screen snapshot to setup the DUT for RF output power measurement is presented in Figure 37. In the example, the TX frequency was setup to 868.4 MHz. The LO injection side was set to low. The power level was set to 32, and the LBT was turned off. With these settings, the DUT was configured to transmit a constant carrier until the “enter key” was pressed.



```
COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      Two-way
TX baudrate    9K6
TX power       32
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (01)
TX cal.        Calibrated (22.18)
LBT reading    36

:f
Enter freq?
868400kHz (h)ighside/(l)owside? 1 Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?1
:p
Enter power (0-63)?
:32
LBT threshold (35-80, >255 to skip, otherwise disabled)?
:255
:tx c
TX carrier
```

Figure 37, Setting up for output power/frequency measurement

5.2 How to: Measure the sensitivity of a DUT

The sensitivity of a RF system is the most important quality parameter of the system. The better the RF sensitivity, the better the overall link budget and that will turn into a better range for the product.

When sensitivity is to be measured, two Z-Wave devices are needed. One as a DUT (which is to be investigated) and the other as a transmitter, as illustrated in Figure 38.

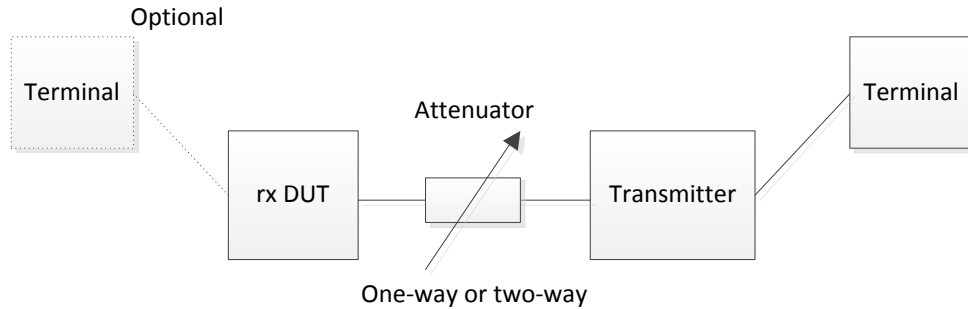


Figure 38, Sensitivity setup

For sensitivity measurements, either a one-way mode or a two-way mode can be selected. In one-way mode, only the sensitivity of the DUT is measured, since the data frames are only transmitted from the transmitter to the DUT. In two-way mode, sensitivity of both the DUT and the transmitter side is measured, since the DUT now replies to the transmitter as well.

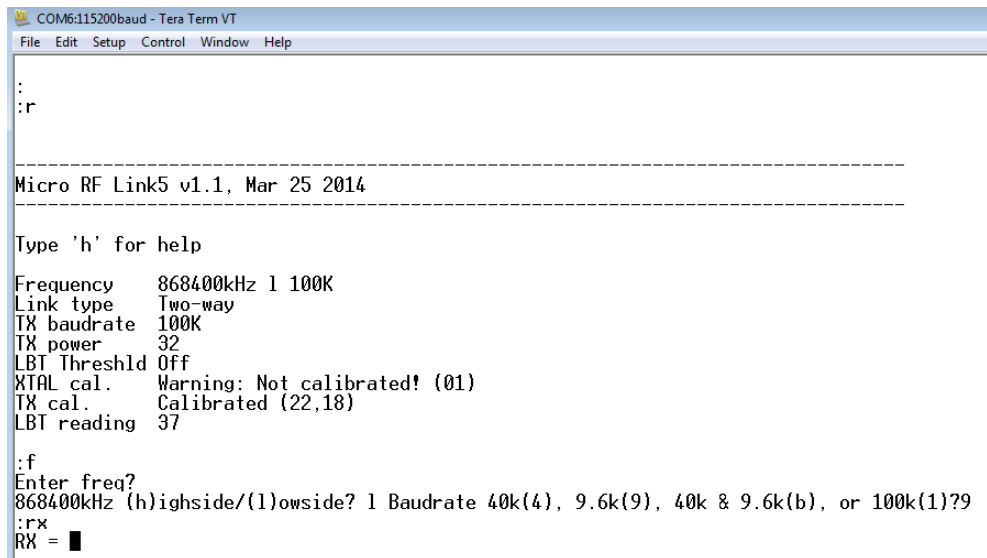
5.2.1 Setting up the DUT for sensitivity measurement

Following describes how to setup the DUT for the sensitivity measurement:

1. Download the correct version of **Micro RF LinkX** to the DUT (please refer to **Error! Reference source not found.**)
2. Setup the correct RF frequency, LO injection side, and communication rate for the DUT (please refer to Table 3, Z-Wave regions, frequencies, communications rates, LO settings) by using the *f* command.
3. If the sensitivity measurement is to be for two-way mode, setup the link type to two-way by using the *l* command.
4. If the sensitivity measurement is to be for two-way mode, setup the output power of the DUT by using the *p* command.
5. Now start the receiver by using the *rx* command or the *rx r [NUM]* command, depending on the required terminal display for the data output from the DUT.

The configuration setup for DUT's sensitivity measurement for one-way and two-way modes are presented in Figure 39 and Figure 40 (terminal screen snapshots), respectively. In both of the modes, the frequency was set to 868.4 MHz, the LO injection side was set to low, and the communication rate was set to 9.6 kBit.

For DUT's sensitivity for one-way mode (where the sensitivity is one-way measurement), a terminal at the DUT is required for its output monitoring, whereas for DUT's sensitivity for two-way mode (where the sensitivity is a two-way measurement), a terminal at the DUT is not required. It is because the output of the measurements can be monitored at the transmitter's terminal.



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help

:
:r

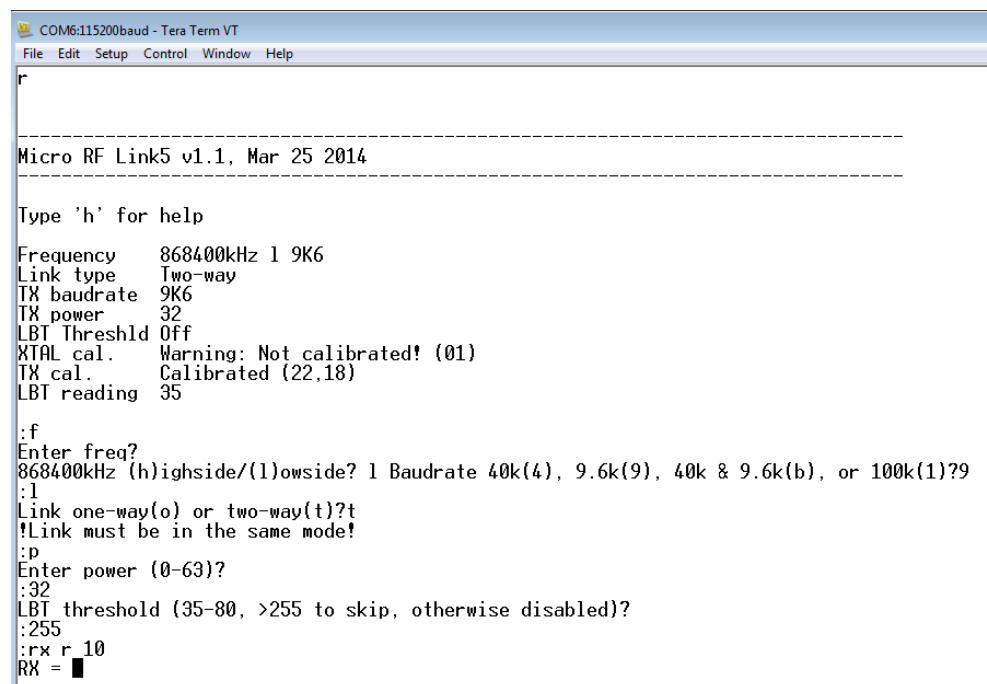
-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help
Frequency      868400kHz l 100K
Link type      Two-way
TX baudrate    100K
TX power       32
LBT Threshold  Off
XTAL cal.      Warning: Not calibrated! (01)
TX cal.        Calibrated (22,18)
LBT reading    37

:f
Enter freq?
868400kHz (h)ighside/(l)owside? l Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:r x
RX = █

```

Figure 39, Settings for DUT sensitivity for One-way mode



```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help

r

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help
Frequency      868400kHz l 9K6
Link type      Two-way
TX baudrate    9K6
TX power       32
LBT Threshold  Off
XTAL cal.      Warning: Not calibrated! (01)
TX cal.        Calibrated (22,18)
LBT reading    35

:f
Enter freq?
868400kHz (h)ighside/(l)owside? l Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:l
Link one-way(o) or two-way(t)?t
!Link must be in the same mode!
:p
Enter power (0-63)?
:32
LBT threshold (35-80, >255 to skip, otherwise disabled)?
:255
:r x r 10
RX = █

```

Figure 40, Settings for DUT sensitivity for Two-way mode

5.2.2 Setting up the transmitter for sensitivity measurement

The transmitter can be a Z-Wave development Board, e.g., *ZDB5101* / *ZDB3502* or *ZDB5304*.

Following describes the setup of transmitter for the sensitivity measurement:

1. Download the correct version of **Micro RF LinkX** to the transmitter (please refer to **Error! Reference source not found.**)
2. Setup the correct RF frequency, LO injection side and communication rate for the transmitter (please refer to Table 3, Z-Wave regions, frequencies, communications rates, LO settings) by using the *f* command.
3. Setup the output power of the transmitter using the *p* command

4. If the sensitivity measurement is to be for two-way mode, setup the link type to two-way by using the `/` command
5. Start the transmission of frames using the `tx` command.

The transmitter will now transmit frames until the operation is aborted by pressing the “enter key”.

The configuration commands for setting up a transmitter for the sensitivity measurement are presented in Figure 41 (a terminal screen snapshot). In this example, the transmitter has been set to 868.4 MHz, LO injection side is low and the communication rate is 9.6 kBit. The output power is set to 32, LBT is turned off and the link mode is set to two-way. The transmitter is turned on by the `tx` command. The output to the terminal shows that 172 frames have been transmitted and 171 are acknowledged by the DUT.

```

COM17:115200baud - Tera Term VT
File Edit Setup Control Window Help

:r

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help
Frequency      868400kHz h 100K
Link type      Two-way
TX baudrate    100K
TX power       32
LBT Threshld   Off
XTAL cal.     Warning: Not calibrated! (00)
TX cal.        Calibrated (23,18)
LBT reading    37

:f
Enter freq?
868400kHz (h)ighside/(l)owside? 1 Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:p
Enter power (0-63)?
:32
LBT threshold (35-80, >255 to skip, otherwise disabled)?
:255
:l
Link one-way(o) or two-way(t)?t
!Link must be in the same mode!
:tx
TX = 172 171 ack

```

Figure 41, Setting up the transmitter for sensitivity measurement

5.3 How to: Measure RF noise

The presence of RF noise at the Z-Wave channel can significantly reduce the performance of a Z-Wave system. It is possible to measure the noise present in the RF channel using a spectrum analyzer, but such a device is costly and bulky.

With the use of **Micro RF LinkX** and a 500 series based device connected to a terminal, RF noise can be measured using the `rxsweep` command. Following describes the setup for RF noise measurement:

1. Download the correct version of **Micro RF LinkX** to the transmitter (please refer to **Error! Reference source not found.**)
2. Type the command `rxsweep` and press “enter key”
3. Type the lowest frequency to examine and press the “enter key”
4. Type the highest frequency to examine and press the “enter key”
5. Type the frequency step size and press the “enter key”

Please notice that all frequencies are given in kHz.

Once the parameters are typed in, the terminal will show a graph of the measured RSSI values at each frequency, i.e., starting from the start-frequency to the end-frequency having the frequency intervals equal to step size. The RSSI values are displayed as “*”.

Figure 42 is a terminal screen snapshot which shows the measured RSSI values in a graph for the frequencies ranging from 860 MHz to 870 MHz with a step size of 1 MHz. The graph presents a RSSI analysis for 10 frequencies. It can be seen that some RF power is measured at 864 MHz. If this system was based in the EU region, the noise at 864 MHz would not pose a problem, since the Z-Wave frequency in the EU region is at 868.4 MHz.

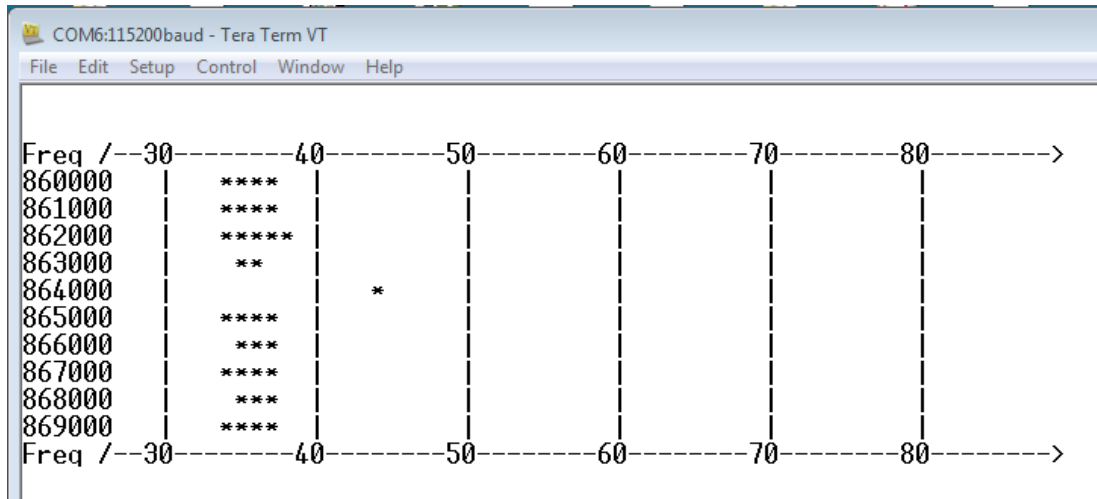


Figure 42, rx sweep example

5.4 How to: Measure the radiation patter of a DUT

Radiation patterns can be measured in anechoic chambers, typically located at a RF test house. This will give a very precise and accurate measurement. If a less accurate and perceive measurement can be accepted, **Micro RF LinkX** can be used to perform an adequate radiation pattern measurement.

For such a measurement setup, two **Micro RF LinkX** enabled devices are needed. The one whose radiation pattern is to be measured is referred as far-end DUT, whereas the one whose is controlling the RF communication, is referred as near-end controller.

Figure 42 shows a setup for the range measurement. The far-end DUT can be setup through a terminal and then disconnected from the terminal once setup correctly. The near-end controller needs to be connected to the terminal through-out the measurement session in order to obtain the results. The curved arrow indicates that the far-end DUT should be rotated during the measurement in order to measure the radiation pattern of the DUT.

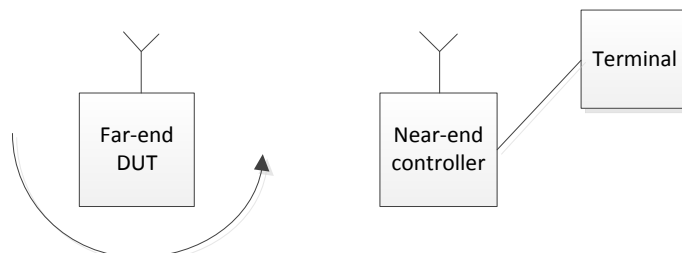


Figure 43, Setting up a range measurement

5.4.1 Setting up the far-end DUT

Below is the description for setting up the far-end DUT:

1. Download the correct version of **Micro RF LinkX** to the transmitter (please refer to **Error! Reference source not found.**)
2. Setup the correct RF frequency, LO injection side and communication rate for the DUT (please refer to Table 3, Z-Wave regions, frequencies, communications rates, LO settings) by using the *f* command.
3. Setup the link mode to two-way link using the *l* command
4. Setup the output power of the transmitter using the *p* command
5. Type the command *rng r* and press the “enter key”.

A terminal screen snapshot of configuration setup for radiation pattern measurement is presented in Figure 44.

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz l 9K6
Link type      Two-way
TX baudrate    9K6
TX power       32
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (01)
TX cal.        Calibrated (22,18)
LBT reading    35

:f
Enter freq?
868400kHz (h)ighside/(l)owside? l Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:l
Link one-way(o) or two-way(t)?t
!Link must be in the same mode!
:p
Enter power (0-63)?
:63
LBT threshold (35-80, >255 to skip, otherwise disabled)?
:255
:rng r
RK = 10 (80.00) 9K6

```

Figure 44, Far-end setting of *rng r*

5.4.2 Setting up the near-end controller

Below is the description for setting up the near-end controller:

1. Download the correct version of **Micro RF LinkX** to the transmitter (please refer to **Error! Reference source not found.**)
2. Setup the correct RF frequency, LO injection side and communication rate for the controller (please refer to Table 3, Z-Wave regions, frequencies, communications rates, LO settings) by using the *f* command
3. Setup the link mode to two-way link using the *l* command
4. Setup the output power of the transmitter using the *p* command.

Type the command *rng t [NUM]* and press the “enter key”. *[NUM]* number of frames will now be transmitted to the far-end and the statistics will be displayed on the terminal.

A terminal screen snapshot for setting up the near-end controller is shown in Figure 45. It shows that 10 frames are transmitted from the near-end controller to the far-end DUT for the range measurement.

```

COM17:115200baud - Tera Term VT
File Edit Setup Control Window Help

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help

Frequency      868400kHz l 9K6
Link type      Two-way
TX baudrate    9K6
TX power       32
LBT Threshold  Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (23,18)
LBT reading    34

:f
Enter freq?
868400kHz (h)ighside/(l)owside? l Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:l
Link one-way(o) or two-way(t)?t
!Link must be in the same mode!
:p
Enter power (0-63)?
:63
LBT threshold (35-80, >255 to skip, otherwise disabled)?
:255
:rng t 10
TX = 10 (80.00) , RX = 10 (81.00)
:█

```

Figure 45, Near-end setting of rng t

Figure 44 shows that the average RSSI level of the received frames **from** the near-end controller is measured as 80, whereas Figure 45 shows that the average RSSI level of the received frames **from** the far-end DUT is measured as 81. Furthermore, it can be seen that 10 frames were received at the far-end (TX = 10) and 10 frames were received at the near-end (RX = 10). As we know that 10 frames were transmitted, so no frames were lost during the transmission.

It is also possible to measure how much RF power is received at the far-end without having a terminal connected to the far-end DUT. The received power at the far-end DUT is displayed on the terminal of the near-end controller after the TX = XX (RSSI level received). In the example shown in Figure 45, Near-end setting of rng t, the average received power at the far-end DUT is measured to RSSI = 80.

6 MICRO RF REMOTE CONTROL

If no UART interface is present in the DUT, **Micro RF LinkX** can still be used to setup most of the commands available if **Micro RF LinkX** is downloaded to the DUT.

In order to utilize the remote control feature of **Micro RF LinkX**, two **Micro RF LinkX** enabled devices are required; the one which is to be remote-controlled is called a far-end DUT and the other which will be the controlling unit is called a near-end controller. One of the development boards provided by *Silicon Labs* can be used as a near-end controller.

Note: The remote control feature is wirelessly performed at a “secret” RF channel located at 899 MHz. Since 899 MHz is outside the pass-band of any current SAW filters the, following considerations must be taken: When working with US or HK modules, two devices using SAW filters must be within close proximity of each other in order for the remote control feature to work. When working with EU modules, the SAW filter of the Near-end controller module must be removed (please refer to appendix C on how to remove a SAW filter) . For all types of SAW filters, the best remote control performance will be obtained if the Near-end controller does not have a SAW filter. The drawing below shows the location of the “secret” RF channel in the RF spectrum and where the passbands of the SAW filters are located:

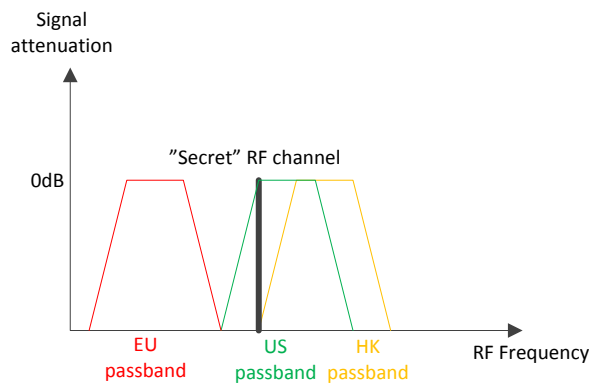


Figure 46, Location of "Secret" RF channel for remote configuration and the passbands of the SAW filters

The near-end controller must be connected to a terminal. The near-end controller is configured as if it was the far-end DUT. Once the near-end controller is correctly configured with the desired configuration for the far-end DUT, the command `send [Command]` is issued. It will repeatedly transmit the configuration to the far-end DUT. At this time, power-cycling or resetting the far-end DUT enables it to receive the transmitted configuration. It acknowledges the successful reception of the configuration to the near-end controller, and then immediately configures itself to start operating in the selected configuration (as send by the near-end controller). A scenario for the remote control operation is presented in Figure 47.

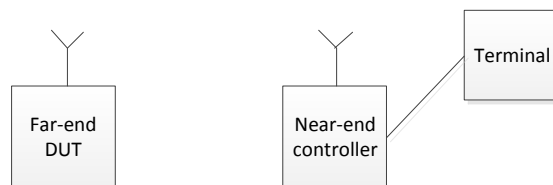


Figure 47, Configure the near-end controller

A terminal screen snapshot for setting up the remote-control operation is presented in Figure 48. In this case, the command `send RX` is used. This will turn the far-end DUT into a receiving device with the configured parameters of 899 MHz, low side LO injection and 9.6 kBit. When the far-end DUT is reset, the response will be “TX setup ok” on the near-end controller terminal which shows that the far-end is now correctly configured.

```

COM17:115200baud - Tera Term VT
File Edit Setup Control Window Help

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      Two-way
TX baudrate    9K6
TX power       63
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (23,18)
LBT reading    34

:f
Enter freq?
868400kHz (h)ighside/(l)owside? 1 Baudrate 40k(4), 9.6k(9), 40k & 9.6k(b), or 100k(1)?9
:send RX
TX setup ok
:█

```

Figure 48, Remote setup, near-end controller

The terminal output from the far-end DUT is shown in Figure 49. It is seen that the DUT is reset and started immediately in RX mode i.e., ready to receive frames from the near-end controller.

```

COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help

:

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help

-----
Micro RF Link5 v1.1, Mar 25 2014
-----

Type 'h' for help
Frequency      868400kHz 1 9K6
Link type      Two-way
TX baudrate    9K6
TX power       63
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (00)
TX cal.        Calibrated (22,18)
LBT reading    35

:rx
RX = █

```

Figure 49, Far-end DUT remotely setup

6.1 Exceptions

The following commands are **not** supported by the remote control option:

- txsweep
- rxswEEP

APPENDIX A : USAGE OF HOST CONTROLLER

The **Micro RF LinkX** may be controlled in an automated way using a host controller on a PC or similar as an alternative to a manually controlled terminal.

Appendix A.1 Definition of control characters

The following symbols and escape characters are used in the **Micro RF LinkX** communication

Symbol	Char	Hex	Remark
\r	(cr)	0x0d	Carriage return
\n	(nl)	0x0a	Newline
:	:	0x3a	Colon Used to signal that Micro RF LinkX is ready to receive a command
!	!	0x21	Exclamation mark Micro RF LinkX reports fail - A single exclamation mark is returned if a unknown command is received - Two following exclamation marks are returned if the RF fails (see section Appendix A.4)
?	?	0x3f	Question mark Signals that the Micro RF LinkX expects an input. - If the question mark was preceded by a carriage return then the Micro PVT expects a number that should be terminated by a newline. - If the question mark was not preceded by a carriage return then the Micro RF LinkX expects a single character respond.
=	=	0x3d	Equal sign All numerical results from Micro RF LinkX are preceded with "=" and a white space.

Table 4: Control Characters

Appendix A.2 Commands to Micro RF LinkX

The **Micro RF LinkX** is ready to accept a command from the host when the character ":" is transmitted from the **Micro RF LinkX** to the host. The **Micro RF LinkX** will stay in standby mode until a command is received from the host.

All the **Micro RF LinkX** commands are initiated by sending a command as described in section 4. Received characters that are not known commands will result in transmission of two characters, a "?" and a "!" followed by a "\r\n:" string.

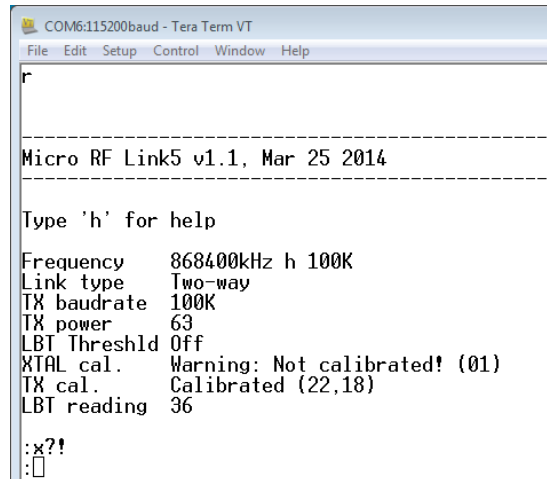
Appendix A.3 Executing continuous commands

Continuous commands are commands that shall be escaped by transmitting a character such as the command TX carrier. The character used to escape the continuous mode is discarded. The **Micro RF LinkX** will then transmit the character ":" when it is ready to accept the next command.

When the **Micro RF LinkX** transmits the output results from a continuous command it will terminate each string with “\r” except for the two rolling modes in the receiver: RSSI histogram and rolling RX mode. The two rolling modes will have each line to be terminated by “\r\n”.

Appendix A.4 Failure reporting

If transmitting an unknown command to the **Micro RF LinkX** it will respond with a “?!”. An example of transmitting an “x” is shown below:



```
COM6:115200baud - Tera Term VT
File Edit Setup Control Window Help
\r
-----
Micro RF Link5 v1.1, Mar 25 2014
-----
Type 'h' for help
Frequency      868400kHz h 100K
Link type      Two-way
TX baudrate    100K
TX power       63
LBT Threshld   Off
XTAL cal.      Warning: Not calibrated! (01)
TX cal.        Calibrated (22,18)
LBT reading    36
\r
:x?!
\r
```

Figure 50, Unknown command

If the **Micro RF LinkX** is set up but the chip is defect, **Micro RF LinkX** may respond with the following string “RF fail, Restart!!\r\n” and restart the program.

APPENDIX B : MICRO RF LINKX FRAME STRUCTURE

The frame transmitted while using the command *tx / tx r / tx r[*NUM*]* is described below:

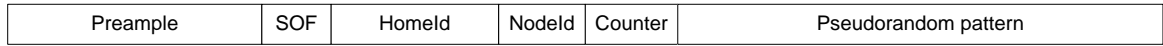


Figure 51: Frame format of Test Frame

The preamble length is 24 bytes in 100 kbit mode, 20 bytes in 40 kbit mode and 10 bytes in 9.6 kbit mode. The preamble byte is *0x55* (hex).

The SOF indicator is *0xF0*, the Homeld is *0xC0000000* and the Nodeld is *0x01*. Following the Nodeld is a rolling counter of one byte and finally 12 bytes of pseudo random pattern. The pseudo random pattern is calculated based on the counter value so the receiver can detect for bit errors.

APPENDIX C : HOW TO REMOVE A SAW FILTER

When working with the remote control option in the Micro RF LinkX program, especially for EU products, the best possible performance is obtained, if the SAW filter of the Near-end controller is removed.

When removing a SAW filter, the input of the SAW filter must be shorted with the output of the SAW filter. If this step is not done, no RF energy will be radiated from the Z-Wave chip to the antenna of the product.

The input / output of the SAW filter can be shorted using a 0 Ohm SMD resistor or a piece of wire. An example of a short is shown below on a ZM5202 module:

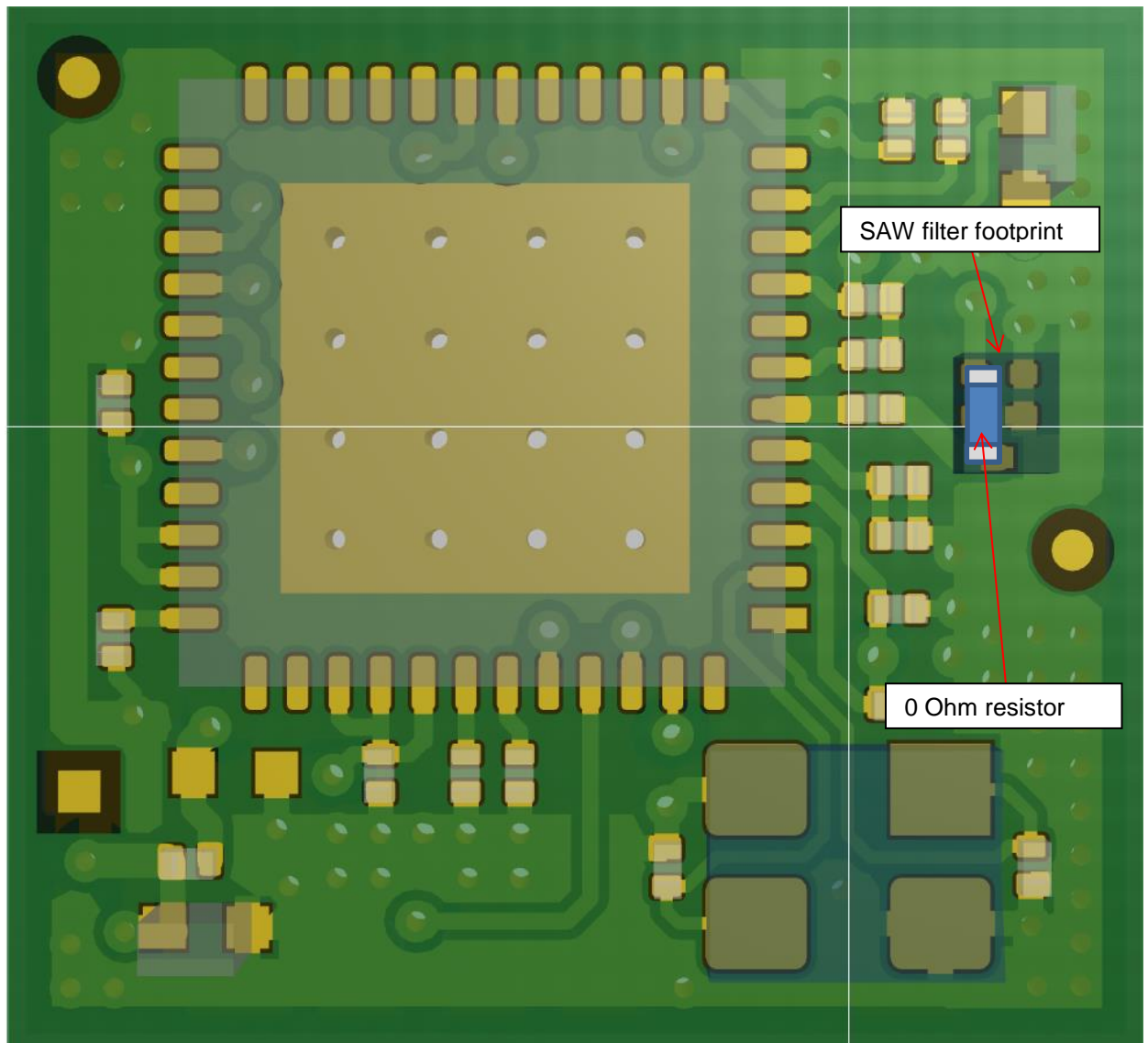


Figure 52, ZM5202 module with SAW filter shorted

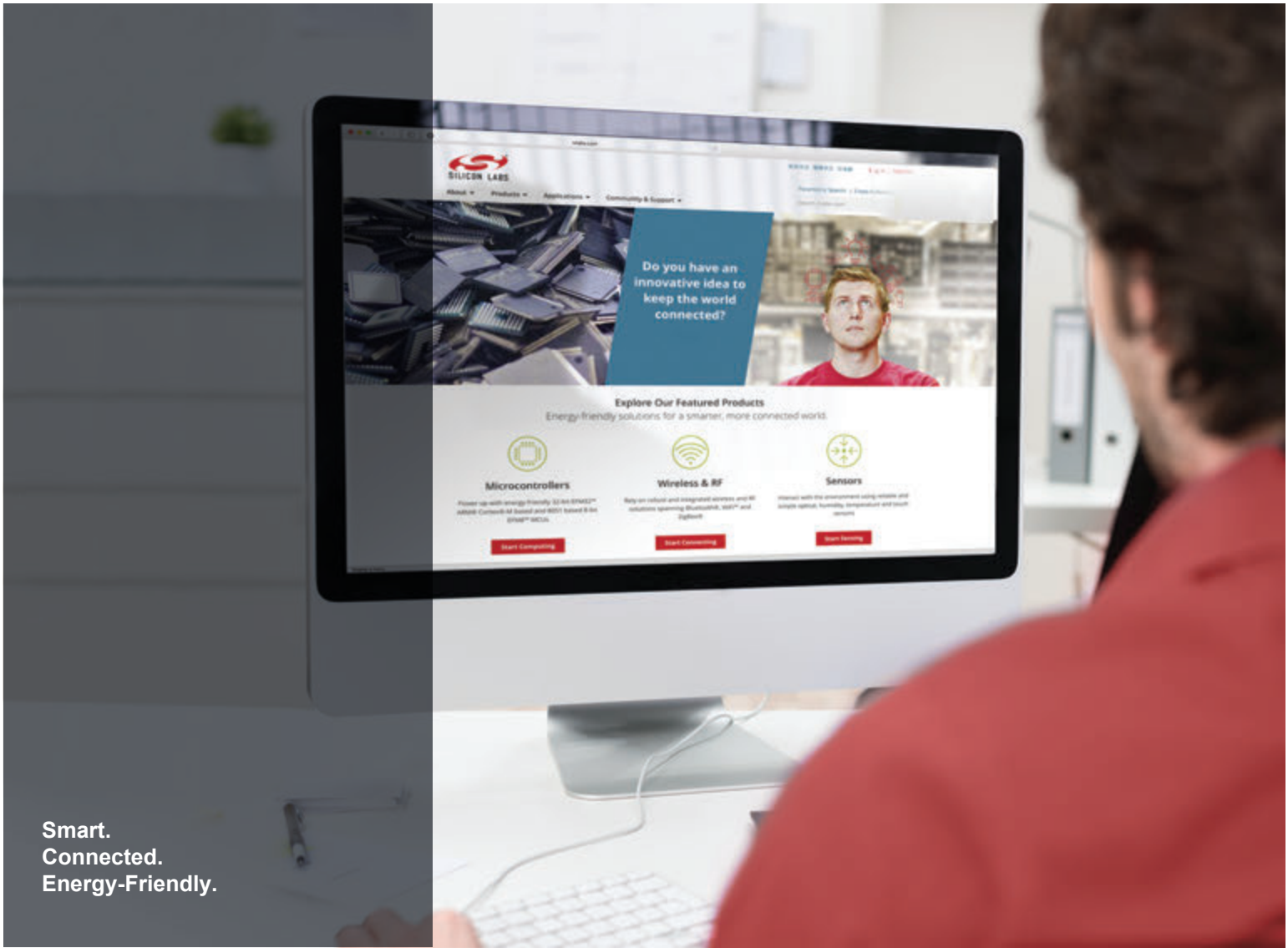
In the above shown example, the input of the SAW filter is shorted to the output by removing the SAW filter component, and soldering a 0 Ohms resistor between the IO pads of the SAW filter footprint.

REFERENCES

- [1] SD, INS10679, Instruction, Z-Wave Programmer User Guide (ZDP03A, PC).

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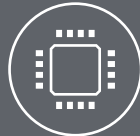
micro_rf_linkX_ZM050x_ALL.hex.....	3
TeraTerm	3



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