Using Radio Test Firmware

RM126x (RM1261, RM1262)

Application Note *v2.0*

1 Introduction

The RM1261 / RM1262 radio test firmware allows for multiple test modes for the RM1261 and RM1262 radio modules. It requires a terminal (e.g. Ezurio's UwTerminal) to send radio test commands over the USB-UART interface.

The purpose of RM1261 or RM1262 radio test firmware is to test the LoRa or FSK radio at the physical layer for behaviors such as transmit RF power and receive RF sensitivity. This is useful for regulatory EMC testing or for co-located radio testing with another radio system.

This document describes the RM1262 and RM1261 radio test firmware to test the BLE RF transmitter and BLE RF receiver:

- **Radio Test Modes**
  - RF TX transmitter
    - TX LoRa 125kHz modulated signal: (RF TX duty cycle is not 100%) i.e. for RM1262.
    - TX LoRa 500kHz modulated signal: (RF TX duty cycle is not 100%) i.e. for RM1262.
    - TX LoRa 250kHz modulated signal: (RF TX duty cycle is not 100%) i.e. for RM1261.
    - TX FSK 50kbps modulated signal: (RF TX duty cycle is not 100%) i.e. for RM1261.
    - TX CW (sine wave) signal: (unmodulated), 100% ON i.e. for RM1262.
  - RF RX modulated constant receive
    - RX LoRa 125kHz modulated signal.
    - RX FSK 50kbps modulated signal.
- **Unidirectional RF Receive PER demo**
  - Unidirectional RX PER demo (AT+TPER).
- **Unidirectional RF Constant Receive PER demo**
  - Unidirectional RX PER demo (AT+TCRX).
- **Bidirectional RF Ping Pong demo**
  - Bidirectional RX Ping Pong demo (AT+TPING).

Item 2 and 4 allows DUT RM126x Receive **number of packets received (OK and NOK)**, RX Timeout, **PER (Packed Error Rate) in %, Frequency Error, Last RSSI, Last S/N**, to be monitored.

This can be used for Europe CE EN301 489 ESD / RF Immunity radio regulatory test for example.

2 Requirements

1. Use the appropriate RM1261 or RM1262 radio test firmware for RM1261 or RM1262 devboard:

Firmware Part Number and Description	Development Kit Part Number and Description
RM1261_Radio_Test_480-00218-R127.4.1.242.gbl Firmware, RM1261 Radio Test Signed UART DFU	453-00140-K1 - RM1261 Development Kit, RM126x, SX1261, MHF4
RM1262_Radio_Test_480-00219-R128.4.1.242.gbl Firmware, RM1262 Radio Test Signed UART DFU	453-00139-K1 - RM1262 Development Kit, RM126x, SX1262, MHF4

2. RM1261 or RM1262 radio test firmware (found at https://github.com/LairdCP/RM126x_Firmware/releases)
   - Windows PC
   - UwTerminalX by Ezurio available at https://github.com/LairdCP/UwTerminalX/release
   - For programming instructions, see Appendix: Programming in the Radio Test Firmware into RM1261 or RM1262 module on RM1261 or RM1262 Development Board

3 Setup

For setup, follow these steps:

1. Connect RF cable to IPEX MHF4 RF connector of the RM126x module.
2. Connect RM126x development board to PC via USB cable.

For more information on the RM126x series development kit, see the RM126x series Development Kit User Guide at:
User Guide - RM126x Development Kit (ezurio.com)

Note: The board shown is for the RM1262 module. Features and interfaces listed are the same for the RM1261 module.

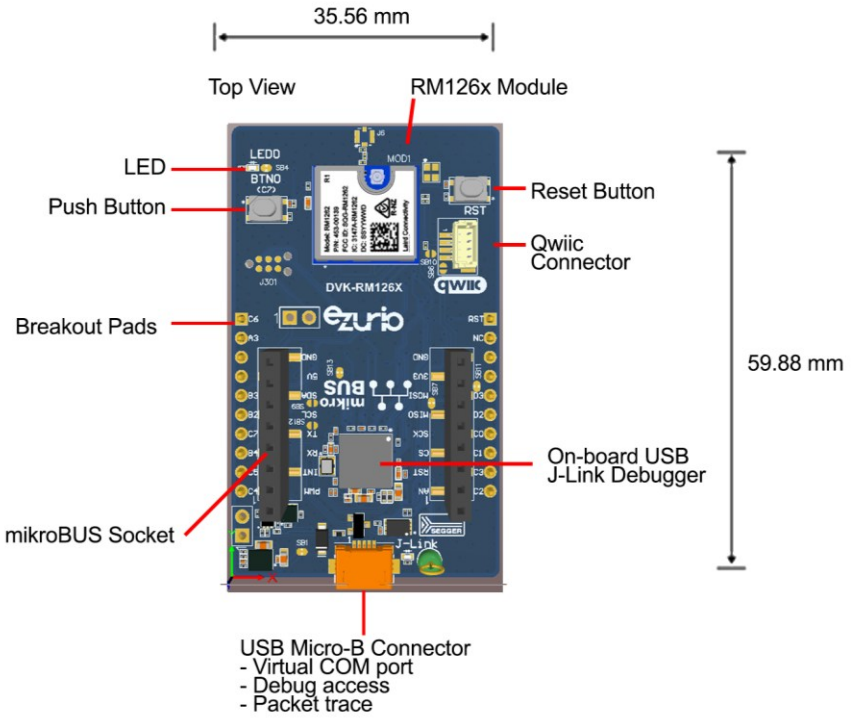


Figure 1: RM126x series development boards

4 Starting RM126x Radio Test Firmware

This guide assumes you've programmed the radio test firmware into the RM1261 or RM1262 module. For instruction on programming the test firmware, see Appendix: Programming in the Radio Test Firmware into RM1261 or RM1262 module on RM1261 or RM1262 Development Board.

4.1 Start RM126x Radio Test Firmware (tool) within UwTerminalX

To begin using RM126x radio test firmware follow these steps:

1. Open UwTerminalX. In the *Config* tab, enter the UART settings shown in Figure 2:
   - COM Port: [Port corresponding to your Development Kit]
   - Baudrate: 115200
   - Parity: None
   - Stop Bits: 1
   - Data Bits: 8
   - Handshaking: CTS/RTS

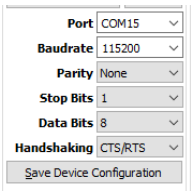


Figure 2: UwTerminalX Settings

2. Click **OK** to connect.
3. Issue command **AT+HELP** and then press return key to send a command. Figure 3 shows response which shows RM1261 or RM1262 hardware, RM1261 or RM1262 radio test firmware version and available AT commands.

```
AT+HELP

RM1262 Regulatory Test Firmware RM126X_PRODUCT_ID.4.1.227
-----------------------------------------

  Available commands are as follows:
  AT+DCDC <dcdc enable> - Enables/disables DCDC/LDO [0:LDO, 1:DCDC]
    Usage AT+DCDC 1
  AT+ENT <Entity> - Selects device entity [0:Master, 1:Slave]
    Usage AT+ENT 0
  AT+LDRO <Mode> - Selects value of Low Data Rate Optimization Mode[0:Off, 1:On, 2:Auto]
    Usage AT+LDRO 1
  AT+PACONF - Manual configuration of PA
    Usage AT+PACONF <SetTxParams.Power>, <SetTxParams.RampTime>, <PADuty>, <HPMax>
    Where - <SetTxParams.Power> [-17...22] (Dependent on device)
        <SetTxParams.RampTime> - Set the radio ramp time [0:10uS, 1:20uS, 2:40uS, 3:80uS, 4:200uS, 5:800uS, 6:1700uS, 7:3400uS]
        <PADuty> [0...255] (Not limited or clamped)
        <HPMax> [0...255] (Not limited or clamped)
        Note 1: deviceSel & paLut values are fixed internally.
        Note 2: RampTime overwrites the value set by AT+RAMP.
        Note 3: Once set, can only be restored to defaults with a reset.
  AT+PCNT <Count> - Set maximum number of packet used in a test [0:Infinite]
    Usage AT+PCNT 1234
  AT+RAMP <RampTime> - Set the radio ramp time [0:10uS, 1:20uS, 2:40uS, 3:80uS, 4:200uS, 5:800uS, 6:1700uS, 7:3400uS]
    Usage AT+RAMP 2
  AT+RPOW <Power> - Sets Transmit power where [-17..22] dB (Dependent on device)
    Usage AT+RPOW 15
  AT+RREG <Register> - Read a byte from the selected register
    Usage AT+RREG 0x08AC
  AT+RXBST <Boost> - Enables/disables Rx Boost [0:Disable, 1:Enable]
    Usage AT+RXBST 0
  AT+TCMOD      - Continuous transmit mode.
  AT+TCONF      - Set radio/modulation parameters
    Usage AT+TCONF=<Mod>:<Payload length>:<Frequency>:<TxPwr>:<Param1>:<Param2>:<Param3>:<Param4>:
    Where - <Mod> LORA or GFSK
        <Payload length> [1..255]
        <Frequency> [868000000...929000000]
        <TxPwr> [-17...22] (Dependent on device)
    If <Mod> = LORA then:
        <Param1> Spreading factor [5:SF5, 6:SF6, 7:SF7, 8:SF8, 9:SF9, 10:SF10, 11:SF11, 12:SF12]
        <Param2> Bandwidth [0:7.8125, 1:15.625, 2:31.25, 3:62.5, 4:125, 5:250, 6:500]kHz
        <Param3> Coding Rate [4/5, 4/6, 4/7, 4/8]
        <Param4> Variable/Fix Payload Length [0:Variable,1:Fixed]
    If <Mod> = GFSK then:
        <Param1> Bitrate [1...50000]bps
        <Param2> Frequency Deviation [4800..467000]Hz
        <Param3> Modulation Filtering [0:OFF, 1:BT-3, 2:BT-5, 3:BT-7, 4:BT-1]
        <Param4> Bandwidth  [0:4.8, 1:5.8, 2:7.3, 3:9.7, 4:11.7, 5:14.6, 6:19.2, 7:23.4,
                             8:29.3, 9:39, 10:46.9, 11:58.6, 12:78.2, 13:93.8, 14:100.0,
                             15:117.3, 16:156.2, 17:187.2, 18:234.3, 19:312, 20:373.6,
                             21: 467.0]kHz
  AT+TCPRE      - Continuous preamble mode.
  AT+TCRX       - Continuous receive mode.
  AT+TOFF       - Stops all operations.
  AT+TPER       - PER Test. (Set required entity first)
  AT+TPING      - PING PONG Test. (Set required entity first)
  AT+TRSSI      - Returns the current RSSI.
  AT+TSEND <DATA> - Sends a single packet configured by AT+TCONF
    Usage AT+TSEND ABCDEF0102030405
    Note: The payload contents may be padded or truncated based on the payload length defined by the AT+TCONF command.
  AT+TTONE      - Produces continuous carrier.
  AT+WREG <Register> <Value>- Write a byte to the selected register
    Usage AT+WREG 0x08AC
  AT+VBSE <Verbose> - Selects device outputs in verbose form [0:Off (Default), 1:On]
    Usage AT+VBSE 1
```

Figure 3: RM1262 Radio Test Firmware AT+HELP response

Note: Always type AT commands in upper case letters.

5 Using RM126x Radio Test Firmware – Radio Test Mode, PER demo mode, ping-pong demo mode

5.1 RM126x radio test mode /PER demo /Ping Pong demo available AT commands and configurations

Table 1 shows available AT commands that were used for the radio test mode and other radio tests (like PER demo and Ping Pong demo).

Table 1: RM126x radio test available AT commands for radio test mode/PER demo/Ping Pong demo

Type and Test	Command	Setting or Description
Set verbose	**AT+VBSE 1**	Verbose allows one to see what parameters (and values) are sent when an AT command is run, especially the RF TX power register values (which are locked and set by Ezurio).
All	**AT+DCDC x**	X=1 enables the DCDC convertor in SX1261/SX1262 chip. X=0 disables the DCDC convertor in SX1261/SX1262 chip, which means LDO is enabled. Default is x=0 (LDO)

TX and RX	**AT+TCONF=<Mod>:<Payload length>:<Frequency>:<TxPwr>:<Param1>:<Param2>:<Param3>:<Param4>**	MUST be set FIRST for any radio test including PER demo, Ping Pong demo.
		This command sets radio/modulation parameters, where the first 3 parameters are:
		• Modulation type (LoRa or FSK),
		• Payload length in bytes (1..255 bytes)
		• TxPwr in dBm (RM1261: -17..+15. RM1262: -9..22)
		If the selected modulation type is LoRa, then remaining 4 parameters are as follows:
		`If <Mod> = LORA then:`
		`<Param1> Spreading factor [5:SF5, 6:SF6, 7:SF7, 8:SF8, 9:SF9, 10:SF10, 11:SF11, 12:SF12]`
		`<Param2> Bandwidth [0:7.8125, 1:15.625, 2:31.25, 3:62.5, 4:125, 5:250, 6:500]kHz`
		`<Param3> Coding Rate [4/5, 4/6, 4/7, 4/8]`
		`<Param4> Variable/Fix Payload Length [0:Variable,1:Fixed]`
		If the selected modulation type is FSK, the remaining 4 parameters are as follows:
		`If <Mod> = GFSK then:`
		`<Param1> Bitrate [1...50000]bps`
		`<Param2> Frequency Deviation [4800..467000]Hz`
		`<Param3> Modulation Filtering [0:OFF, 1:BT-3, 2:BT-5, 3:BT-7, 4:BT-1]`
		`<Param4> Bandwidth [0:4.8, 1:5.8, 2:7.3, 3:9.7, 4:11.7, 5:14.6, 6:19.2, 7:23.4, 8:29.3, 9:39, 10:46.9, 11:58.6, 12:78.2, 13:93.8, 14:100.0, 15:117.3, 16:156.2, 17:187.2, 18:234.3, 19:312, 20:373.6, 21: 467.0]kHz`
		Example 1: Setting up LoRa 125kHz
		`AT+TCONF=LORA:16:920200000:14:7:4:4/5:1`
		• where modulation is LoRa
		• where payload is 16bytes
		• where frequency is 920.2MHz
		• where TxPwr is 14dBm
		For LoRa 125kHz the following four parameters are required:
		• parameter1 is Spreading Factor (bps) =7.
		• parameter2 is Bandwidth (kHz) =4 which is 125kHz.
		• parameter3 is Coding Rate =4/5.
		• Parameter4 is Variable/Fixed Payload Length =1 is Fixed.
		NOTE: For LoRa 125KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz for example is used in LoRaWAN channel plan US902-928, AU915-928, etc.

Type and Test	Command	Setting or Description

Example 2: Setting up LoRa 250kHz

```
AT+TCONF=LORA:16:920300000:14:7:5:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes
- where frequency is 920.3MHz
- where TxPwr is 14dBm

For LoRa 250KHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 250kHz:-

- parameter1 is Spreading Factor (bps) =7.
- parameter2 is Bandwidth (kHz) =5 which is 250kHz.
- parameter3 is Coding Rate =4/5.
- parameter4 is Variable/Fixed Payload Length =1 is Fixed.

Note: For LoRa 250KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz is used in LoRaWAN channel plan AS923, etc.

Example 3: Setting up LoRa 500kHz

```
AT+TCONF=LORA:16:903000000:22:7:6:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes
- where frequency is 903MHz
- where TxPwr is 22dBm

For LoRa 500KHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 500kHz:

- parameter1 is Spreading Factor (bps) =7.
- parameter2 is Bandwidth (kHz) =6 which is 500kHz.
- parameter3 is Coding Rate =4/5.
- parameter4 is Variable/Fixed Payload Length =1 is Fixed.

Note: For LoRa 500KHz Spreading Factors, valid values are as RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz is used in LoRaWAN channel plan US902-928, AU915-928, etc.

Example 4: Setting up FSK 50kbps

```
AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14
```

- where payload is 16bytes
- where frequency is 920.2MHz
- where TxPwr is 14dBm

For FSK there are 4 parameters and for FSK 50kbps signal (that is compliant with page 86-87 of table 4.2.2 FSK settings. You MUST use the below 4 parameter values for setting up FSK 50kbps:-

- parameter1 is bit rate(bps) =50000 (50000bps)
- parameter2 is Frequency Deviation(kHz) =50000 (50kHz)
- parameter3 is Modulation Filtering BT (constant) = 4 (BT-1)
- parameter4 is Bandwidth(kHz) =14 (100kHz)

NOTE: FSK Bandwidth formula is Bandwidth ≥ 2*f_dev + bit rate

Type and Test	Command	Setting or Description
		The valid values for FSK 50kbps bandwidth nearest to 100kHz are shown on page88 of SX1261/SX1262 Datasheet: 93.8kHz (double sideband) and 117.3kHz (double sideband). Since 93.8kHz is below 100kHz, the FW uses 117.3kHz.
Radio TX	**AT+TCMOD**	Start RF TX modulated signal test. Uses the radio parameters configured using AT+TCONF command, MUST set first.
Radio TX	**AT+TTONE**	Start RF TX CW (sinewave) unmodulated signal test. Uses the radio parameters configured using AT+TCONF command, MUST set first.
Radio	**AT+TOFF**	Stop test
PER or ping pong demo	**AT+ENT x**	where x=1 configure radio chip to SLAVE. where x=0 configure radio chip to MASTER
	AT+PCNT x	Set the maximum number of packets used in test. where x=0 is infinite number of packets where x=enter the count number of packets required e.g. AT+PCNT 1234
PER demo	**AT+TPER**	Start PER demo test (on the Slave side). Then start PER demo (on Master side). This can be uses for RF radio receive sensitivity test.
PER demo variation	**AT+TCRX**	Start Constant Receive test (first on Slave test). Then start transmitted modulated packets on TX side (Master side) by sending command AT+TCMOD. **Note:** Only created this setup as the above RM126x PER demo, receives extra 2 packets (which can be ignored), but the drawback of Constant Receive setup is, that it does not display PER and PER has to be calculated after the test
Ping Pong demo	**AT+TPING**	Start Ping Pong demo test (on the Slave side). Then start PER demo (on Master side).

5.2 RF Transmitter Tests

5.2.1 RF Transmit LoRa 125kHz Modulated Signal

This example is for the RM1262.

To perform a transmit test, for RF TX LoRa 125kHz modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, below AT commands should be sent:

1. **(Optional)** Enable verbose by entering **AT+VBSE 1** and press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values (which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio's DCDC (in the radio chip) by sending **AT+DCDC 1** and pressing return. By default, DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You MUST set radio/modulation parameters. Enter **AT+TCONF=LORA:16:902300000:22:7:4:4/5:1** and press return.

```
AT+TCONF=LORA:16:902300000:22:7:4:4/5:1
Image calibration updated.
OK
```

Setting up LoRa 125kHz

```
AT+TCONF=LORA:16:902300000:22:7:4:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 902.3MHz
- where TxPwr is 22dBm (for RM1262)

For LoRa 125kHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 125kHz:-

- parameter1 is Spreading Factor (bps) =7
- parameter2 is Bandwidth (kHz) =4 which is 125kHz
- parameter3 is Coding Rate =4/5
- parameter4 is Variable/Fixed Payload Length =1 is Fixed

Note: For LoRa 125KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz is used in LoRaWAN channel plan US902-928, AU915-928, etc.

Table 2: Transmitter test set radio / modulation parameters for LoRa 125kHz

Modulation	**LORA** Other options are GFSK.
Payload (in bytes)	**16** Other option 1..255
Frequency (in Hz)	**902300000** This 902.3MHz example is a channel from US902-928 is fixed channel plan from LoRaWAN.
TXPwr	**Specified value 22** This is maximum conducted RF TX power setting for RM1262. Other option for TxPwr in dBm (RM1261: -17..+15. RM1262: -9..22).
Parameter1 Spreading Factor	**7** This is spreading factor 7 (DR3) example from US902-928 is fixed channel plan from LoRaWAN.
Parameter1 Bandwidth	**7** This is Bandwidth for LoRa 125kHz.
Parameter3 Coding Rate	**4/5** This is 4/5 coding rate.
Parameter4 Variable / Fixed Payload Length	**1** This is Fixed Payload Length. Other option is Variable Payload Length.

4. Start transmitter test by sending **AT+TCMOD** and press return. Figure 4 shows an active LoRa transmitter test. You can see at the beginning of the screen shot (after command sent) is the various settings and parameters being used.

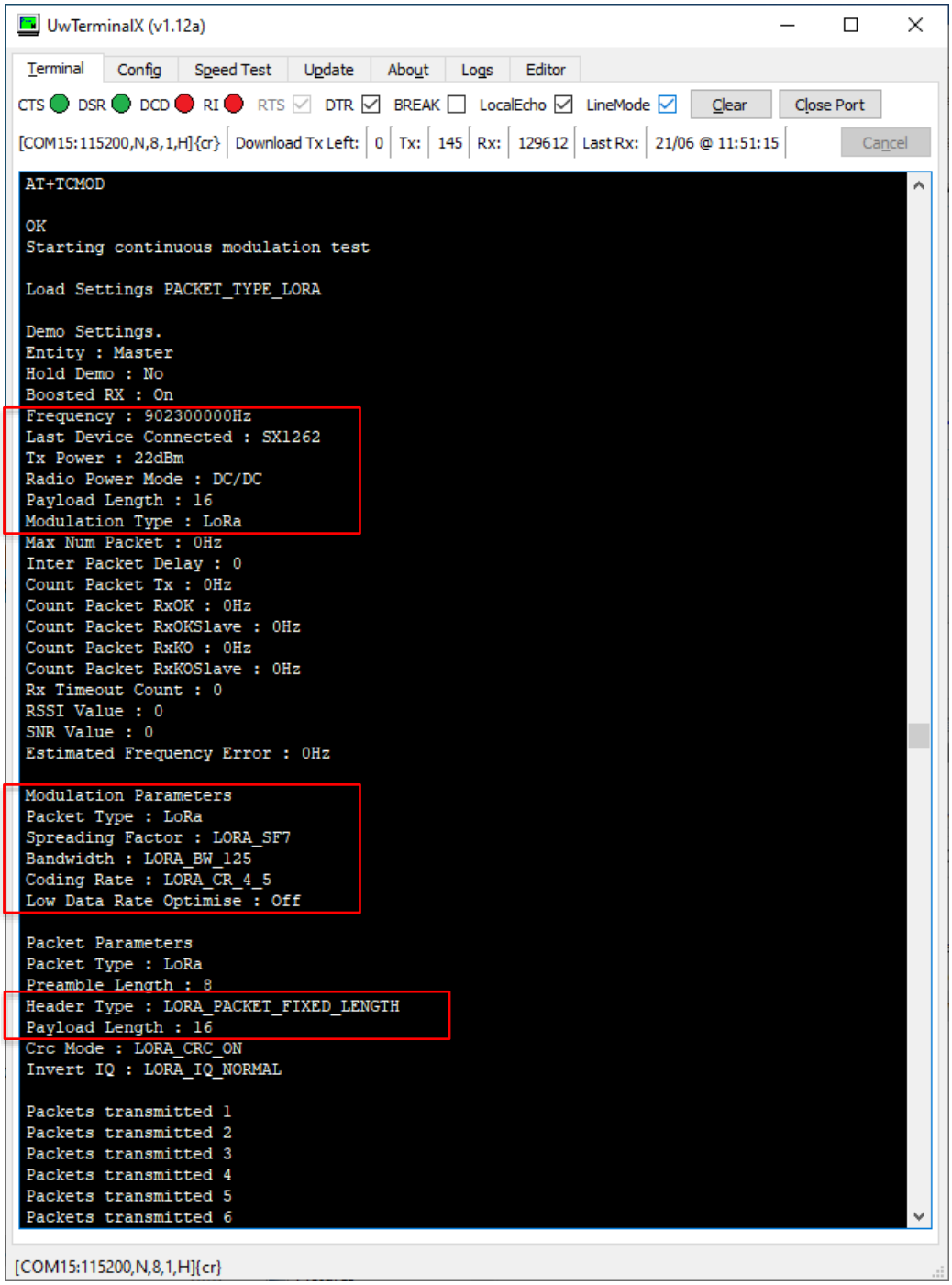


Figure 4: Configured for TX Test LoRa 125kHz Modulated signal (RF duty cycle is not 100%) and Start Test

Check the RF TX LoRa 125kHz modulated signal (RF duty cycle is not 100%) on the spectrum analyser.

Check the RF TX packet duration, RF period of the RF transmission, i.e., RF duty cycle on spectrum analyser (using zero span mode on spectrum analyser (also called time domain mode). The RF TX signal is NOT 100% ON and has a RF TX duty cycle.

5. Once the test is completed, send command **AT+TOFF** and then **press return key**.

```
AT+TOFF
Packets transmitted 39
Packets transmitted 40
Packets transmitted 41

OK
```

5.2.2 RF Transmit LoRa 500kHz Modulated Signal

This example is for the RM1262.

To perform a transmit test, for RF TX LoRa 500kHz modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, below AT commands should be sent:

1. **(Optional)** Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values (which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and pressing return. By default, DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You MUST set radio/modulation parameters. Send **AT+TCONF=LORA:16:903000000:22:7:6:4/5:1** and press return.

```
AT+TCONF=LORA:16:903000000:22:7:6:4/5:1
Image calibration updated.
OK
```

Setting up LoRa 500kHz

```
AT+TCONF=LORA:16:903000000:22:7:6:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 903MHz
- where TxPwr is 22dBm

For LoRa 500KHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 500kHz:-

- parameter1 is Spreading Factor (bps) =7.
- parameter2 is Bandwidth (kHz) =6 which is 500kHz.
- parameter3 is Coding Rate =4/5.
- parameter4 is Variable/Fixed Payload Length =1 is Fixed.

Note: For LoRa 500KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 500KHz is used in LoRaWAN channel plan US902-928, AU915-928, etc.

Table 3: Transmitter test set radio / modulation parameters for LoRa 500kHz

Modulation	**LORA** Other options are GFSK.
Payload (in bytes)	**16** Other option 1..255
Frequency (in Hz)	**903000000** This 903MHz example is a channel from US902-928 is fixed channel plan from LoRaWAN.
TXPwr	**Specified value 22**

Modulation	**LORA** Other options are GFSK.
	This is maximum conducted RF TX power setting for RM1262. Other option for TxPwr in dBm (RM1261: -17..+15. RM1262: -9..22).
Parameter1 Spreading Factor	**7** This is spreading factor 7 (DR3) example from US902-928 is fixed channel plan from LoRaWAN.
Parameter1 Bandwidth	**6** This is Bandwidth for LoRa 500kHz.
Parameter3 Coding Rate	**4/5** This is 4/5 coding rate.
Parameter4 Variable / Fixed Payload Length	**1** This is Fixed Payload Length. Other option is Variable Payload Length.

4. Start transmitter test by sending **AT+TCMOD** and then **press return**. Figure 4 shows an active LoRa transmitter test. You can see at the beginning of the screen shot (after command sent) is the various settings, parameters being used.

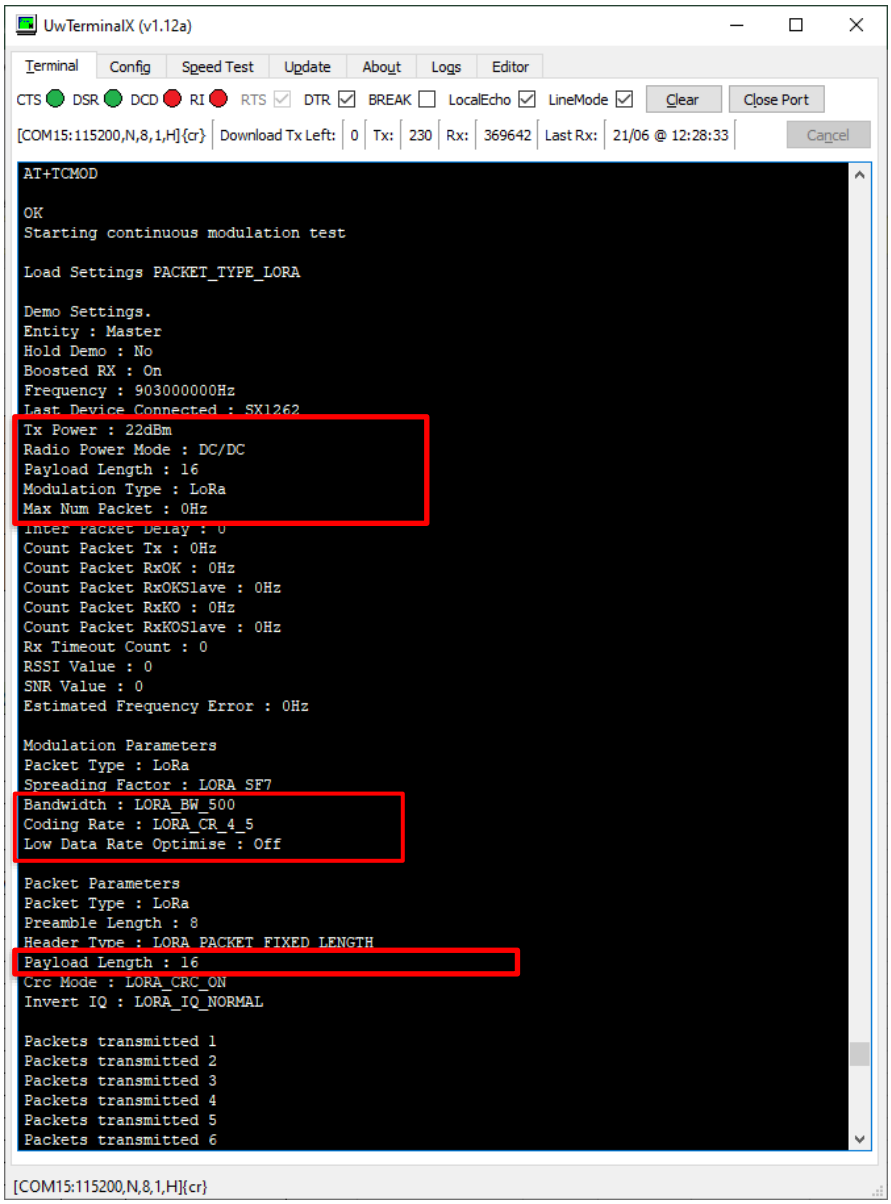


Figure 5: Configured for TX Test LoRa 500kHz Modulated signal (RF duty cycle is not 100%) and Start Test

Check the RF TX LoRa 500kHz modulated signal (RF duty cycle is not 100%) on the spectrum analyser.

Check the RF TX packet duration, RF period of the RF transmission, i.e., RF duty cycle on spectrum analyser (using zero span mode on spectrum analyser (also called time domain mode). The RF TX signal is NOT 100% ON and has a RF TX duty cycle.

5. Once the test is completed, send command **AT+TOFF** and then **press return key**.

```
AT+TOFF
Packets transmitted 39
Packets transmitted 40
Packets transmitted 41

OK
```

5.2.3 RF Transmit LoRa 250kHz Modulated Signal

This example is for the RM1261.

To perform a transmit test, for RF TX LoRa 250kHz modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, below AT commands should be sent:

1. **(Optional)** Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values(which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and pressing return. By default, DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You MUST set radio/modulation parameters. Send **AT+TCONF=LORA:16:920300000:14:7:5:4/5:1** and press return.

```
AT+TCONF=LORA:16:920300000:14:7:5:4/5:1
Image calibration updated.
OK
```

LoRa 250kHz Setup

```
AT+TCONF=LORA:16:920200000:14:7:5:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 920.3MHz
- where TxPwr is 14dBm

For LoRa 250KHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 250kHz:-

- parameter1 is Spreading Factor (bps)=7.
- parameter2 is Bandwidth (kHz) =5 which is 250kHz.
- parameter3 is Coding Rate =4/5.
- parameter4 is Variable/Fixed Payload Length =1 is Fixed.

Note: For LoRa 250KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz used in for example LoRaWAN channel plan AS923 etc.

Table 4: Transmitter test set radio / modulation parameters for LoRa 250kHz

Modulation	**LORA** Other options are GFSK.
Payload (in bytes)	**16** Other option 1..255
Frequency (in Hz)	**902300000** This 920.3MHz example is a channel from AS923. See RM26x datasheet
TXPwr	**Specified value 14** This is 14dBm conducted RF TX power setting for RM1261. Maximum is 15dBm. Other option for TxPwr in dBm (RM1261: -17..+15. RM1262: -9..22).
Parameter1 Spreading Factor	**7** This is spreading factor 7 (DR6) example from AS923 dynamic channel plan from LoRaWAN.
Parameter1 Bandwidth	**5** This is Bandwidth for LoRa 250kHz.
Parameter3 Coding Rate	**4/5** This is 4/5 coding rate.
Parameter4 Variable / Fixed Payload Length	**1** This is Fixed Payload Length. Other option is Variable Payload Length.

4. Start transmitter test by sending **AT+TCMOD** and then **press return**. Figure 4 shows an active LoRa transmitter test. You can see at the beginning of the screen shot (after command sent) is the various settings, parameters being used.

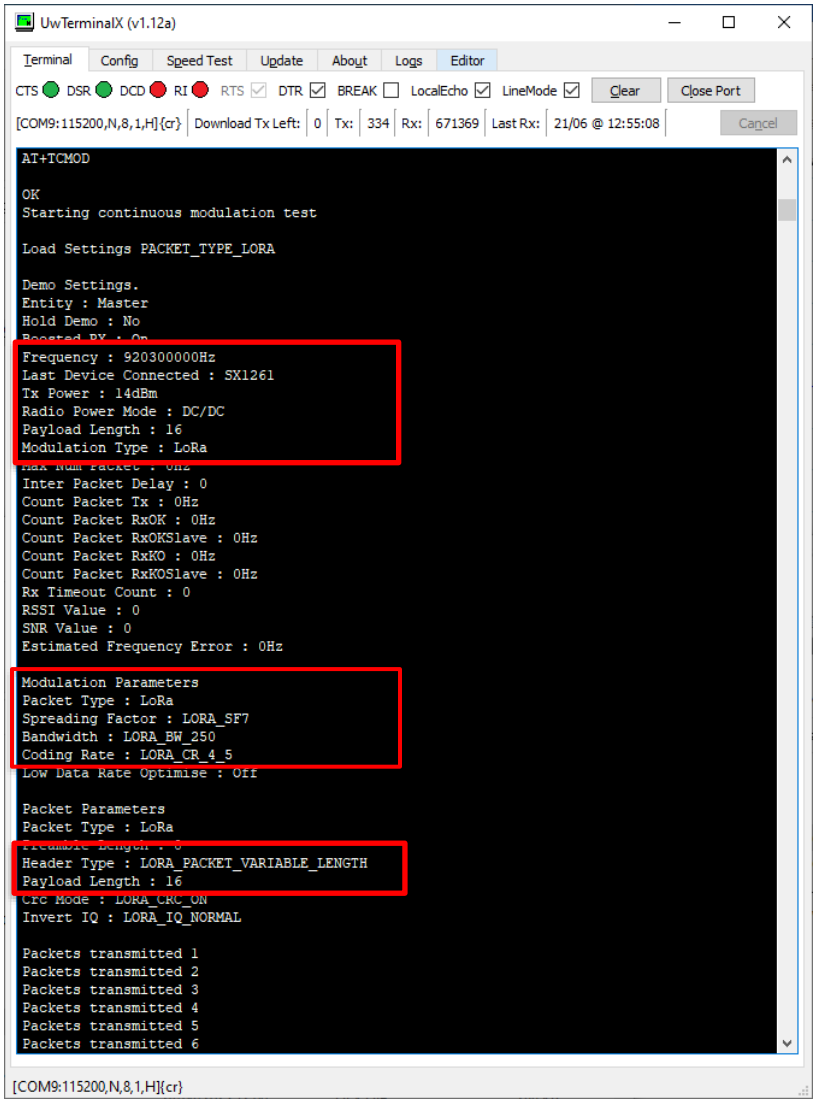
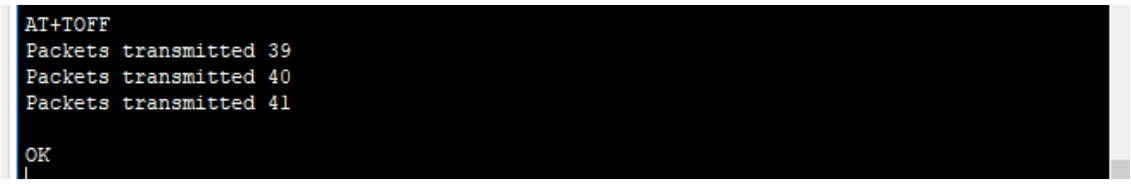


Figure 6: Configured for TX Test LoRa 250kHz Modulated signal (RF duty cycle is not 100%) and Start Test

Check the RF TX LoRa 250kHz modulated signal (RF duty cycle is not 100%) on the spectrum analyser.

Check the RF TX packet duration, RF period of the RF transmission, i.e., RF duty cycle on spectrum analyser (using zero span mode on spectrum analyser (also called time domain mode). The RF TX signal is NOT 100% ON and has a RF TX duty cycle.

5. Once the test is completed, send command **AT+TOFF** and then **press return key**.



5.2.4 RF Transmit FSK 50kbps Modulated Signal

Example is for RM1261.

To perform a transmit test, for RF TX FSK 50kbps modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, below AT commands should be sent:

1. **Optional**: Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values (which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and then **press return**. Default is DCDC off (which is LDO on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. Radio / modulation parameters MUST be set always. Set radio / modulation parameters for FSK 50kbps by sending **AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14** and then **press return**.

```
AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14
Image calibration updated.
OK
```

For example: setting up FSK 50kbps

```
AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14
```

- where payload is 16bytes. Other option 1..255.
- where frequency is 920.2MHz
- where TxPwr is 14dBm

For FSK there are four parameters and for FSK 50kbps signal that is compliant with page 86-87 of table 4.2.2 FSK settings. Use the below values for four parameters for setting up FSK 50kbps:

- parameter1 is Bit Rate(bps) =50000. That is 50000bps
- Parameter2 is Frequency Deviation(kHz) =50000. That is 50kHz
- Parameter3 is Modulation Filtering BT (constant) =4 which is BT-1
- Parameter4 is Bandwidth(kHz) =14 which is 100kHz

Note: The formula for FSK Bandwidth is Bandwidth ≥ 2*f_dev + bitrate

---

The valid values for FSK 50kbps bandwidth nearest to 100kHz are shown on page 88 of SX1261/SX1262 Datasheet: 93.8kHz (double sideband) and 117.3kHz (double sideband). Since 93.8kHz is below 100kHz, the FW uses 117.3kHz

Table 5: Transmitter test set radio / modulation parameters for FSK 50kbps

Modulation	**GFSK** Other options are LORA.
Payload (in bytes)	**16** Other option 1..255
Frequency (in Hz)	**902300000** This 902.3MHz example is a channel from US902-928 is fixed channel plan from LoRaWAN.
TXPwr	**Specified value 22** This is maximum conducted RF TX power setting for RM1262. Other option for TxPwr in dBm (RM1261: -17..+15. RM1262: -9..22).
Parameter1 Bit Rate (in bps)	**50000** This is Bit Rate of 50kbps.
Parameter2 Frequency Deviation (in kHz)	**50000** This is Frequency Deviation of 50kHz.
Parameter3	**4** This is BT-1 for GFSK Modulation Filtering BT constant).

Modulation	**GFSK** Other options are LORA.
Modulation Filtering BT (constant)	
Parameter4 Bandwidth (in kHz)	**14** This is Bandwidth of 100kHz.

4. Start transmitter test by sending **AT+TCMOD** and then **press return**. Figure 4 shows an active LoRa transmitter test. You can see at the beginning of the screen shot (after command sent) is the various settings, parameters being used.

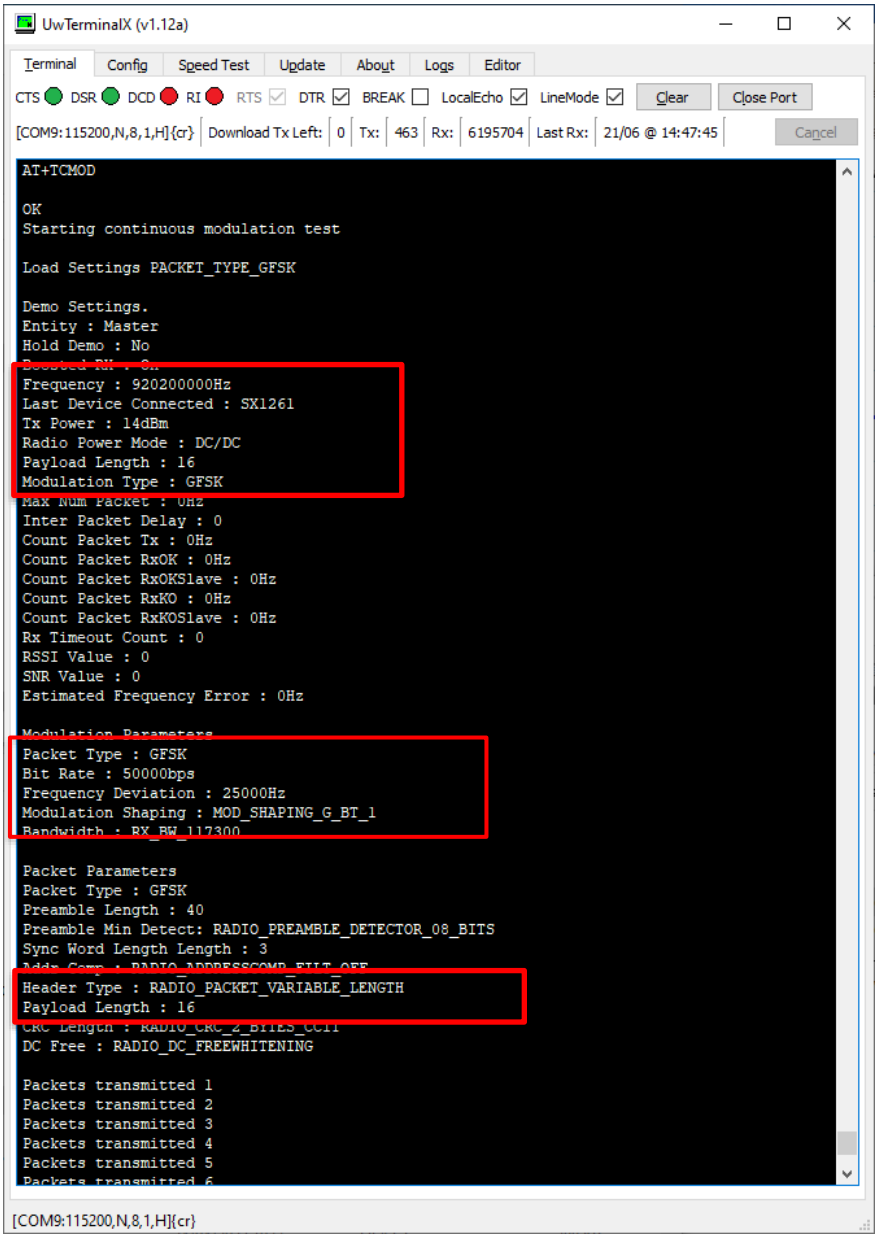


Figure 7: Configured for TX Test FSK 50kbps Modulated signal (RF duty cycle is not 100%) and Start Test

Check the RF TX FSK 50kbps modulated signal (RF duty cycle is not 100%) on the spectrum analyser.

Check the RF TX packet duration, RF period of the RF transmission, i.e., RF duty cycle on spectrum analyser (using zero span mode on spectrum analyser (also called time domain mode). The RF TX signal is NOT 100% ON and has a RF TX duty cycle.

5. Once the test is completed, send command **AT+TOFF** and then **press return key**.

5.2.5 RF Transmit CW (sinewave) Unmodulated Signal (100% on)

Example is for RM1262.

To perform a transmit test, for RF TX CW (carrier wave) sine wave unmodulated signal (100% on) using the radio test firmware AT commands, below AT commands should be sent:

1. **Optional**: Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values (which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and press return. By default, DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You MUST set radio/modulation parameters. Enter **AT+TCONF=LORA:16:902300000:22:7:4:4/5:1** and press return.

```
AT+TCONF=LORA:16:902300000:22:7:4:4/5:1
Image calibration updated.
OK
```

RF TX CW (carrier wave) Sine Wave Unmodulated Signal (100% on) Setup

```
AT+TCONF=LORA:16:902300000:22:7:4:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 902.3MHz
- where TxPwr is 22dBm (for RM1262)

For LoRa 125kHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 125kHz:-

- parameter1 is Spreading Factor (bps) =7.
- Parameter2 is Bandwidth (kHz) =4 which is 125kHz.
- Parameter3 is Coding Rate =4/5.
- Parameter4 is Variable/Fixed Payload Length =1 is Fixed.

Note: For LoRa 125KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz used in LoRaWAN channel plan US902-928, AU915-928, etc.

Table 6: Transmitter test set radio / modulation parameters RF TX CW (carrier wave) sine wave unmodulated signal (100% on)

Modulation	**LORA** Other options are GFSK.
Payload (in bytes)	**16** Other option 1..255
Frequency (in Hz)	**902300000** This 902.3MHz example is a channel from US902-928 is fixed channel plan from LoRaWAN.
TXPwr	**Specified value 22** This is maximum conducted RF TX power setting for RM1262. Other option for TxPwr in dBm (RM1261: -17..+15. RM1262: -9..22).
Parameter1 Spreading Factor	**7** This is spreading factor 7 (DR3) example from US902-928 is fixed channel plan from LoRaWAN.
Parameter1 Bandwidth	**7** This is Bandwidth for LoRa 125kHz.
Parameter3 Coding Rate	**4/5** This is 4/5 coding rate.
Parameter4 Variable / Fixed Payload Length	**1** This is Fixed Payload Length. Other option is Variable Payload Length.

4. Start transmitter test by sending **AT+TTONE** and then **press return**. Figure 4 shows an active RF TX unmodulated sine wave transmitter test. You can see at the beginning of the screen shot (after command sent) is the various settings, parameters being used.

```
AT+TTONE

OK
Starting continuous CW test

Load Settings PACKET_TYPE_LORA
```

Figure 8: Configured for TX Test sine wave unmodulated signal (RF duty cycle is 100%) and Start Test

Check the RF TX CW (carrier wave) sine wave unmodulated signal (100% on) on the spectrum analyser.

Check the RF TX signal duration, i.e., RF duty cycle on spectrum analyser (using zero span mode on spectrum analyser (also called time domain mode).

5. Once the test is completed, send command **AT+TOFF** and press return.

```
AT+TOFF

OK
```

5.3 RF Receive Tests

5.3.1 RF Receive LoRa 125kHz

This example is for the RM1262.

To perform a constant RF receive test, for RF RX LoRa 125kHz modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, send the following AT commands:

1. Optional: Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values(which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and then **press return**. Default is DCDC off (which is LDO on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. Radio / modulation parameters MUST be set always. Set radio / modulation parameters for LoRa 125kHz by sending **AT+TCONF=LORA:16:902300000:22:7:4:4/5:1** as an example and then **press return**.

```
AT+TCONF=LORA:16:902300000:22:7:4:4/5:1
Image calibration updated.
OK
```

LoRa 125kHz Setup

```
AT+TCONF=LORA:16:902300000:22:7:4:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 902.3MHz
- where TxPwr is 22dBm (for RM1262)

For LoRa 125kHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 125kHz:-

- parameter1 is Spreading Factor (bps)=7.
- Parameter2 is Bandwidth (kHz) =4 which is 125kHz.
- Parameter3 is Coding Rate =4/5.
- Parameter4 is Variable/Fixed Payload Length =1 is Fixed.

Note: For LoRa 125KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz used in for example LoRaWAN channel plan US902-928 and AU915-928 etc.

---

1. Configure to SLAVE the DUT RX side by sending **AT+ENT 1** and press return.
2. Configure number of packets to be used in receive test, for example 10 packets, send command **AT+PCNT 10** and then press return.
   Alternatively for infinite packet send **AT+PCNT 0**.
   MUST match the number of packets used on TX side.
3. Start Constant Receive FIRST on Slave side, DUT RX by sending command **AT+TCRX** and then press return.

5.3.2 RF Receive LoRa 500kHz

This example is for the RM1262.

To perform a transmit test, for RF TX LoRa 500kHz modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, send the following commands:

1. **Optional**: Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values(which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and pressing return. By default DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You MUST set radio/modulation parameters. Send **AT+TCONF=LORA:16:903000000:22:7:6:4/5:1** and press return.

```
AT+TCONF=LORA:16:903000000:22:7:6:4/5:1
Image calibration updated.
OK
```

LoRa 500kHz Setup

```
AT+TCONF=LORA:16:903000000:22:7:6:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 903MHz
- where TxPwr is 22dBm

For LoRa 500KHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 500kHz:-

- parameter1 is Spreading Factor (bps) =7.
- Parameter2 is Bandwidth (kHz) =6 which is 500kHz.
- Parameter3 is Coding Rate =4/5.
- Parameter4 is Variable/Fixed Payload Length =1 is Fixed.

> **Note**: For LoRa 500KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 500KHz is used in LoRaWAN channel plan US902-928, AU915-928, etc.

1. Configure to SLAVE the DUT RX side by sending **AT+ENT 1** and then **press return**.
2. Configure number of packets to be used in receive test, for example 10 packets, send command **AT+PCNT 10** and then press return. Alternatively for infinite packet send **AT+PCNT 0**.
   MUST match the number of packets used on TX side.
3. Start Constant Receive FIRST on Slave side, DUT RX by sending command **AT+TCRX** and then press return.

5.3.3 RF Receive LoRa 250kHz

This example is for the RM1261.

To perform a transmit test, for RF TX LoRa 250kHz modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, send the following commands:

1. **Optional**: Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values (which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and pressing return. By default, DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You must set radio/modulation parameters. Send **AT+TCONF=LORA:16:920300000:14:7:5:4/5:1** and press return.

```
AT+TCONF=LORA:16:920300000:14:7:5:4/5:1
Image calibration updated.
OK
```

LoRa 250kHz Setup

```
AT+TCONF=LORA:16:920200000:14:7:5:4/5:1
```

- where modulation is LoRa
- where payload is 16bytes. Other option 1..255.
- where frequency is 920.3MHz
- where TxPwr is 14dBm

For LoRa 250KHz there are 4 parameters MUST use the below values for 4 parameters for setting up LoRa 250kHz:-

- parameter1 is Spreading Factor (bps) =7.
- Parameter2 is Bandwidth (kHz) =5 which is 250kHz.
- Parameter3 is Coding Rate =4/5.
- Parameter4 is Variable/Fixed Payload Length =1 is Fixed.

> **Note**: For LoRa 250KHz Spreading Factors, valid values are as per RP002-1.0.3 LoRaWAN® Regional Parameters. LoRa 125KHz used in LoRaWAN channel plan AS923, etc.

1. Configure to SLAVE the DUT RX side by sending **AT+ENT 1** and then **press return**.
2. Configure number of packets to be used in receive test, for example 10 packets, send command **AT+PCNT 10** and then press return. Alternatively for infinite packet send **AT+PCNT 0**.
   MUST match the number of packets used on TX side.
3. Start Constant Receive FIRST on Slave side, DUT RX by sending command **AT+TCRX** and then press return.

5.3.4 RF Receive FSK 50kbps

This example is for the RM1261.

To perform a transmit test, for RF TX FSK 50kbps modulated signal (RF TX duty cycle is not 100%) using the radio test firmware AT commands, send the following commands:

1. **Optional**: Enable verbose by entering **AT+VBSE 1** and then press return. Verbose mode shows the parameters sent when an AT command is run, especially the RF TX power register values(which are locked and set by Ezurio).

```
AT+VBSE 1
Verbose Mode On

OK
```

2. Turn on the RM126x radio DCDC (in the radio chip) by sending **AT+DCDC 1** and pressing return. By default, DCDC is off (and LDO is on).

```
OK
AT+DCDC 1
DCDC Enabled

OK
```

3. You MUST set radio/modulation parameters. Send **AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14** and press return.

```
AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14
Image calibration updated.
OK
```

FSK 50kbps Setup

```
AT+TCONF=GFSK:16:920200000:14:50000:25000:4:14
```

- where payload is 16bytes. Other option 1..255.
- where frequency is 920.2MHz
- where TxPwr is 14dBm

For FSK there are 4 parameters and for FSK 50kbps signal (that is compliant with page 86-87 of table 4.2.2 FSK settings. You MUST use the below parameter values for setting up FSK 50kbps:-

- parameter1 is Bit Rate(bps) =50000. That is 50000bps.
- Parameter2 is Frequency Deviation(kHz) =50000. That is 50kHz
- Parameter3 is Modulation Filtering BT (constant) =4 which is BT-1.
- Parameter4 is Bandwidth(kHz) =14 which is 100kHz.

Note: The formula for FSK Bandwidth is Bandwidth ≥ 2*f_dev + bit rate

---

The valid values for FSK 50kbps bandwidth nearest to 100kHz are shown on page 88 of SX1261/SX1262 Datasheet: 93.8kHz (double sideband) and 117.3kHz (double sideband). Since 93.8kHz is below 100kHz, the FW uses 117.3kHz.

1. Configure to SLAVE the DUT RX side by sending **AT+ENT 1** and then **press return**.
2. Configure number of packets to be used in receive test, for example 10 packets, send command **AT+PCNT 10** and then press return.
   Alternatively for infinite packet send **AT+PCNT 0**.
   MUST match the number of packets used on TX side.

- Start Constant Receive FIRST on Slave side, DUT RX by sending command **AT+TCRX** and then press return.

6 Using RM126x Radio Test Firmware – Unidirectional RF Receive PER Demo (AT+TPER)

6.1 Unidirectional RF Receive PER Demo Description

A Packet Error Rate (PER) test is a unidirectional test where one kit is configured as a Master and the other as a Slave. In this case the Master will assume the role of transmitter and the Slave that of receiver. The aggregate PER of the packets received by the Slave, expressed as a percentage, is calculated and displayed on the receiver (Slave). Given that this is a unidirectional test, the packet error rate is not displayed on the transmitter (Master).

The DUT Slave side shows **Receive number of packets received (OK and NOK)**, RX Timeout, **PER (Packed Error Rate) in %, Frequency Error, Last RSSI, Last S/N**, to be monitored.

This can be used for Europe CE EN301 489 ESD / RF Immunity radio regulatory test for example.

6.2 Unidirectional RF Receive PER Demo Running Steps

1. Below Figure TBD shows the AT commands to send each side when using a pair of RM1261 development boards.
   In this RM1261 example, configure (with AT+TCONF), LoRa: 16byte packet: 868MHz: 14dBm: Spreading factor 7: 125kHz LoRa bandwith:4/5 coding rate: 0 means variable length.

(Slave side, DUT RX) Running PER Demo (AT+TPER)	(TX side, Master) Running PER Demo (AT+TPER)

Configure the Slave and test settings as follows:
▪ Configure
`AT+CONF=LORA:16:868000000:14:7:4:4/5:0`
in below example means we set LoRa=modulation, 16=16byte packet, 868000000=868MHz, 14=14dBm RF TX power, 7=Spreading Factor 7, 4=125kHz bandwidth LoRa, 4/5=Coding Rate 4/5, 0=Variable Payload length.
▪ Configure to SLAVE the **DUT RX**
`AT+ENT 1`
▪ Configure number of packets to be used in test, in below example 10 packets, MUST match the number of packets used on TX side.
`AT+PCNT 10`
`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
`Image calibration updated.`
`OK`
`AT+ENT 1`
`Slave Mode Selected`
`OK`
`AT+PCNT 10`
`Packet count set to 10`
	Configure the Master and test settings as follows:
	▪ Configure
	`AT+CONF=LORA:16:868000000:14:7:4:4/5:0`
	in below example means we set LoRa=modulation, 16=16byte packet, 868000000=868MHz, 14=14dBm RF TX power, 7=Spreading Factor 7, 4=125kHz bandwidth LoRa, 4/5=Coding Rate 4/5, 0=Variable Payload length.
	▪ Configure to MASTER the **TX side**
	`AT+ENT 0`
	▪ Configure number of packets to be used in test, in below example 10 packets, MUST match the number of packets used on TX side.
	`AT+PCNT 10`
	`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
	`Image calibration updated.`
	`OK`
	`AT+ENT 0`
	`Master Mode Selected`
	`OK`
	`AT+PCNT 10`
	`Packet count set to 10`

2. Start PER demo test FIRST on Slave side, DUT RX by sending command AT+TPER. Then Start PER demo test on TX side, Master by sending command AT+TPER.

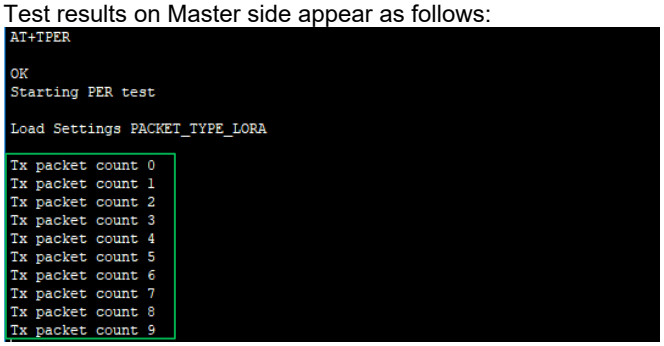
Test results on Slave side appear as follows:

You can see 10 packets received (and have 0% PER).
The extra 2 packets at the end can be ignored as we only sent 10 packets.

RMX1261 PER demo works and PER is reported on the fly. The result of test is displayed here on the Slave unit:

- **Rx OK**: # of packets completely received
- **Rx KO**: # of packets not completely received
- **Rx PSR**: # Percentage Packet Success Rate for the last packet exchange
- **Rx PER**: # Percentage Packet Error Rate for the last packet exchange.
- **Last RSSI**: Received Signal Strength Indication dBm
- **Last SNR**: Signal to Noise Ratio for the last packet exchange (dB)

Test results on Master side appear as follows:



The 10 packets sent appear in the terminal.

Set packet count at both ends to same number of packets (in the example above, 10 packets), start Slave (DUT) side, then start Master side (TX). Once the 10 TX packets are sent, the test ends and the number of packets sent (TX side, Master) and received (Slave side, DUT RX) should match. The Slave side will not continue to count packets.

7 Using RM126x Radio Test Firmware – Unidirectional Constant RF Receive Demo (AT+TCRX)

7.1 Unidirectional Constant RF Receive Demo Description

This setup was created as the above RM126x PER demo, receives extra packets (which can be ignored), but the drawback of below Constant Receive setup is, that it does not display PER and PER has to be calculated after the test.

7.2 Unidirectional Constant RF Receive Demo Running Steps

1. The table below shows the AT commands to send to each side when using a pair of RM1261 development boards.
   In this RM1261 example, configure (with AT+TCONF): LoRa: 16byte packet: 868MHz: 14dBm: Spreading factor 7: 125kHz LoRa bandwith:4/5 coding rate: 0 means variable length.

(Slave side, DUT RX) constant receive running AT+TCRX	(TX side, Master) running AT+TCMOD

Configure with the following commands:
`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
`Image calibration updated.`
`OK`
`AT+ENT 1`
`Slave Mode Selected`
 	
`OK`
`AT+PCNT 10`
`Packet count set to 10`
	Configure with the following commands:
	`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
	`Image calibration updated.`
	`OK`
	`AT+ENT 0`
	`Master Mode Selected`
	
	`OK`
	`AT+PCNT 10`
	`Packet count set to 10`

2. Start Constant Receive FIRST on Slave side, DUT RX by sending command AT+TCRX. Then Start Transmit modulated packets test on TX side, Master by sending command AT+TCMOD.

```
AT+TCRX

OK
Start RunDemoRxContinuous

Load Settings PACKET_TYPE_LORA

Demo Settings.
Entity : Slave
Hold Demo : No
Boosted RX : On
Frequency : 868000000Hz
Last Device Connected : SX1261
Tx Power : 14dBm
Radio Power Mode : DC/DC
Payload Length : 16
Modulation Type : LoRa
Max Num Packet : 10Hz
Inter Packet Delay : 78
Count Packet Tx : 0Hz
Count Packet RxOK : 0Hz
Count Packet RxOKSlave : 0Hz
Count Packet RxKO : 0Hz
Count Packet RxKOSlave : 0Hz
Rx Timeout Count : 1
RSSI Value : -102
SNR Value : 9
Estimated Frequency Error : 343Hz

Modulation Parameters
Packet Type : LoRa
Spreading Factor : LORA_SF7
Bandwidth : LORA_BW_125
Coding Rate : LORA_CR_4_5
Low Data Rate Optimise : Off

Packet Parameters
Packet Type : LoRa
Preamble Length : 8
Header Type : LORA_PACKET_VARIABLE_LENGTH
Payload Length : 16
Crc Mode : LORA_CRC_ON
Invert IQ : LORA_IQ_NORMAL

Rx packet count 1 Freq Error Est :343 SNR :7 RSSI :-105
Rx packet count 2 Freq Error Est :343 SNR :7 RSSI :-104
Rx packet count 3 Freq Error Est :343 SNR :8 RSSI :-104
Rx packet count 4 Freq Error Est :343 SNR :8 RSSI :-104
Rx packet count 5 Freq Error Est :343 SNR :8 RSSI :-104
Rx packet count 6 Freq Error Est :343 SNR :7 RSSI :-104
Rx packet count 7 Freq Error Est :343 SNR :8 RSSI :-104
Rx packet count 8 Freq Error Est :343 SNR :7 RSSI :-105
Rx packet count 9 Freq Error Est :343 SNR :7 RSSI :-105
Rx packet count 10 Freq Error Est :343 SNR :7 RSSI :-105
```

The 10 received packets are shown, with no extra packets as in the previous test. PER is not shown,and must be calculated manually.

```
AT+TCMOD

OK
Starting continuous modulation test

Load Settings PACKET_TYPE_LORA

Demo Settings.
Entity : Master
Hold Demo : Yes
Boosted RX : On
Frequency : 868000000Hz
Last Device Connected : SX1261
Tx Power : 14dBm
Radio Power Mode : DC/DC
Payload Length : 16
Modulation Type : LoRa
Max Num Packet : 10Hz
Inter Packet Delay : 78
Count Packet Tx : 0Hz
Count Packet RxOK : 0Hz
Count Packet RxOKSlave : 0Hz
Count Packet RxKO : 0Hz
Count Packet RxKOSlave : 0Hz
Rx Timeout Count : 0
RSSI Value : 0
SNR Value : 0
Estimated Frequency Error : 0Hz

Modulation Parameters
Packet Type : LoRa
Spreading Factor : LORA_SF7
Bandwidth : LORA_BW_125
Coding Rate : LORA_CR_4_5
Low Data Rate Optimise : Off

Packet Parameters
Packet Type : LoRa
Preamble Length : 8
Header Type : LORA_PACKET_VARIABLE_LENGTH
Payload Length : 16
Crc Mode : LORA_CRC_ON
Invert IQ : LORA_IQ_NORMAL

Packets transmitted 1
Packets transmitted 2
Packets transmitted 3
Packets transmitted 4
Packets transmitted 5
Packets transmitted 6
Packets transmitted 7
Packets transmitted 8
Packets transmitted 9
Packets transmitted 10
```

The 10 sent packets are shown.

8 Using RM126x Radio Test Firmware – Bidirectional RF Receive Ping Pong Demo (AT+TPING)

8.1 Bidirectional Ping Pong Demo Description

A Ping Pong Test is a bidirectional test between a pair of RM1261/RM1262 kits. One kit needs to be configured as the Ping Pong Master and the other kit as the Ping Pong Slave. Communication is initiated by the Master whose packet is received by the Slave from which the PER may be calculated.

In response to this packet the Slave sends an acknowledgement, which also contains statistical information about the link calculated by the Slave. The Master, upon receiving this response, will then display both the PER for the Master to Slave and the Slave to Master packet exchanges.

8.2 Bidirectional Ping Pong Demo Running Steps

1. The table below shows the AT commands to send to each side when using a pair of RM1261 development boards.
   In this RM1261 example configure (with AT+TCONF), LoRa: 16byte packet: 868MHz: 14dBm: Spreading factor 7: 125kHz LoRa bandwith:4/5 coding rate: 0 means variable length.

(Slave side, DUT RX) running PING-PONG Demo (AT+TPING)	(TX side, Master) running PING-PONG Demo (AT+TPING)

Configure with the following commands:
`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
`AT+ENT 1`
`AT+PCNT 10`
`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
`Image calibration updated.`
`OK`
`AT+ENT 1`
`Slave Mode Selected`
`OK`
`AT+PCNT 10`
`Packet count set to 10`
	Configure with the following commands:
	`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
	`AT+ENT 0`
	`AT+PCNT 10`
	`AT+TCONF=LORA:16:868000000:14:7:4:4/5:0`
	`Image calibration updated.`
	`OK`
	`AT+ENT 0`
	`Master Mode Selected`
	`OK`
	`AT+PCNT 10`
	`Packet count set to 10`

2. Start PING-PONG demo test FIRST on Slave side, DUT RX by sending command AT+TPING. Then Start PING-PONG demo test on TX side, Master by sending command AT+TPING.

```
AT+TPING

OK
Load Settings PACKET_TYPE_LORA

Start RunDemoApplicationPingPong.

(Slave) Rx OK 1   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 2   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 3   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 4   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 5   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 6   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 7   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 8   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 9   Rx KO 0     PSR   0.00  Rx Timeout 0
(Slave) Rx OK 10  Rx KO 0     PSR   0.00  Rx Timeout 0
```

```
AT+TPING

OK
Load Settings PACKET_TYPE_LORA

Start RunDemoApplicationPingPong.

(Master)Tx Count 1      (M) Rx OK 1 (S) Rx OK 1 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 2      (M) Rx OK 2 (S) Rx OK 2 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 3      (M) Rx OK 3 (S) Rx OK 3 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 4      (M) Rx OK 4 (S) Rx OK 4 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 5      (M) Rx OK 5 (S) Rx OK 5 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 6      (M) Rx OK 6 (S) Rx OK 6 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 7      (M) Rx OK 7 (S) Rx OK 7 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 8      (M) Rx OK 8 (S) Rx OK 8 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 9      (M) Rx OK 9 (S) Rx OK 9 (M) Rx KO 0       (S) Rx KO 0
(Master)Tx Count 10     (M) Rx OK 10      (S) Rx OK 10      (M) Rx KO 0
```

Both units exchange data until test is stopped on either unit or packet count value reached.

The results of the test are displayed as follows:

- Rx OK: # of packets completely received.
- Rx KO: # of packets not completely received.
- Rx PSR: Percentage Packet Success Rate for the last packet exchange.
- Rx PER: Percentage Packet Error Rate for the last packet exchange.
- Last RSSI: Received Signal Strength Indication in dBm.
- Last SNR: Signal to Noise Ratio for the last packet exchange (dB).

Set the packet count at both ends to same number of packets (in the above example, 10 packets). Then first start Slave (DUT) side, then start Master side (TX). Once the 10 packets TX ended both the test stops automatically on both sides and number of packets sent (TX side, Master) and received (Slave side, DUT RX) matches.

9 Appendix: Programming in the Radio Test Firmware into RM1261 or RM1262 module on RM1261 or RM1262 Development Board

To load the RM1261 or RM1262 Radio Test firmware onto the RM1261 or RM1262 module on the RM1261 or RM1262 development board, follow these steps:

1. Download the RM1261 or RM1262 Radio Test firmware, which can be found at: https://github.com/LairdCP/RM126x_Firmware/releases
   Save in a local folder, such as C:\temp1

2. To load RM1261 or RM1262 radio test firmware, refer to section 6.1 https://www.ezurio.com/documentation/user-guide-firmware-options-and-upgrading-rm126x-series for loading RM1261 or RM1262 radio test fw via uart_dfu_tool available via the product Github page.

10 Revision History

Version	Date	Notes	Contributor(s)	Approver
1.0	8 Aug 2023	Initial Release	Raj Khatri	Senthooran Ragavan
1.1	14 Dec 2023	Updated section 2 for radio test FW part numbers. Updated section 9 on how to load RM1261 or RM1262 radio test fw via uart_dfu tool.	Raj Khatri	Senthooran Ragavan
2.0	22 Apr 2025	Ezurio rebranding	Sue White	Senthooran Ragavan

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