AN5973

Application note

Guidelines for bringing up on STM32WL3x MCUs

Introduction

STM32WL3x is a high performance ultra-low power wireless programmable MCU intended for RF wireless applications in the sub-1 GHz band. It is designed to operate in both the license-free ISM and SRD frequency bands such as:

- 159 - 185 MHz
- 413 - 479 MHz
- 826 - 958 MHz

In order to achieve maximum performance, some procedures must be carried out before finalizing the application. This document summarizes these fundamental steps:

- Power supply test
- HSE centering test
- LSE centering test
- Output power test
- RSSI measurement
- Packet exchange test

To perform some of the tests, the STM32CubeWiSE-RadioExplorer GUI is required. Refer to document [4] for more information on how to prepare the board to be used with the GUI.

1 General information

This application note applies to STM32WL3x devices that are Arm® Cortex®-M0+core-based devices.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

Reference documents

Number	Reference	Title
[1]	UM3399	STM32CubeWiSE-RadioCodeGenerator Software description
[2]	DS15018	STM32WL33Rx datasheet
[3]	DS14221	STM32WL33xx datasheet
[4]	UM3248	User manual *Getting started with STM32CubeWL3 software package for STM32WL3x microcontrollers* (UM3248)

Measurement equipments

The following equipment were used for the measurements.

Table 1. Measurement equipments

Measurement	Instrument Type	Instrument model
RX	Signal generator	Agilent ESG E4438C
TX	Spectrum analyzer	R&S FSW-13
Consumption test	DC energy analyzer	Joulescope JS110

2 Power supply test

2.1 Test description

The aim of these tests is to ensure that the STM32WL3x is correctly powered.

2.2 Test case specification identifier

`SUPPLY_TEST`

2.3 Test setup

2.3.1 Test prerequisite

In order to perform this test, check if the voltages on the pins listed in Section 2.4 are as expected.

2.3.2 Hardware

Use a multimeter to perform this test.

2.3.3 Software

Load the CLI project into the STM32WL3x device to perform this test.

Note: This firmware is located within the `Demonstrations\Command_Line_Interface\CLI` *directory of the STM32Cube_FW_WL3 software package*

2.4 Test procedure

Power up the board and measure the voltage in:

- VDD_1
- VDD_2
- VDDRF
- VDDSD
- VFBSD
- VCAP

The measured pins voltage must be aligned with the following values if SMPS is ON.

Table 2. Supply test results

Pin	Expected value
VDD_1, VDD_2, VDDRF, VDDSD	V_{BAT}(1)
VLXSD	Square waves around 0 V - V_{BAT}
VFBSD	From 1.2 V to 2.4 V(2)
VCAP	1.2 V

1. *The operating supply voltage varies from 1.7 V to 3.6 V*
2. *The SMPS output voltage can be controlled by the PWRC_CR5.SMPSLVL[3:0] register. For more details, see chapter 5.8.2 SMPS output level re-programming in STM32WL3x reference manual.*

If the SMPS OFF configuration has been chosen, the VLXSD pin is left floating and the VFBSD pin is connected directly to V_{BAT}.

Note: If some of the measured values are not aligned with the expected values, it is recommended to double-check the integrity of the board connection.

3 HSE centering test

The STM32WL3x integrates a high-speed external reference clock (HSE) that can be provided by 48 MHz or 50 MHz crystal oscillator. Since the inaccuracy of the HSE is directly transferred to the RF clock, it is necessary to adjust the load capacitance at crystal terminals to achieve best RF performances.

The device includes internal programmable capacitances set by a software that can be used to tune the crystal frequency to compensate the PCB parasitic one. In this way, no external capacitors are needed, with the advantage of BOM reduction and customer board dimension optimization.

3.1 Test description

For the reasons previously explained, the crystal frequency must be centered, and the optimum load capacitor values can be found through experimentation.

An easy way to verify the correct centering of the HSE crystal oscillator is to program the device with a carrier wave at the desired frequency (for example, 868 MHz), then measure the accuracy of the tone frequency with a spectrum analyzer.

It is possible to easily find the frequency offset by measuring the difference between the measured tone and the desired one.

3.2 Test case specification identifier

HSOSC_center_TEST

3.3 Test setup

3.3.1 Test prerequisite

For this test, the SMA connector is mandatory.

3.3.2 Hardware

Use a spectrum analyzer to perform this test.

3.3.3 Software

No software is required for this test.

3.4 Test procedure

The following iterative procedure reduce the XTAL frequency offset:

1. Connect the board to the spectrum analyzer, and set the desired center frequency, Res. BW, Span and Ref. level on the instrument.
2. Power up the board and generate a carrier wave tone at the desired center frequency.
3. Measure the difference between the measured tone and the desired one to find the frequency offset.
4. Stop the carrier wave transmission.
5. In the reset and clock controller (RCC) peripheral registers, modify the value of the following registers, step by step:
   a. In the clock sources control register (RCC_CR), set to 0 the bit 16 (HSEON) to disable the external high-speed clock. Then verify that the bit 17 (HSERDY) is set to 0. This means that the HSE stop procedure has been completed successfully.
   b. In the RF software high speed external register (RCC_RFSWHSECR), change the value of the SWXOTUNE field (six bits register) to a value between 0 to 63. This range can cover from 7.58 pF to 15.12 pF step 0.12 pF crystal load capacitors.
   c. In the RF software high speed external register (RCC_RFSWHSECR), enable the bit 7 (SWXOTUNEEN) to use the trimming value written in the SWXOTUNE field as trimming value on HSE.
   d. In the clock sources control register (RCC_CR), enable the external high-speed clock, setting to one the bit 16 (HSEON). Then verify that the bit 17 (HSERDY) is set to one: this means that the HSE is ready.
6. Start the carrier wave transmission and measure the frequency offset. Repeat all the previous steps until an acceptable offset is reached.

4 LSE centering test

The low frequency clock can be supplied either by a 32.768 kHz oscillator that uses an external crystal or by an internal ring oscillator, which does not require any external components. The advantage of using the external 32.768 kHz clock is that it consumes less power than internal RO, and is more accurate.

4.1 Test description

This test lets the user set the LSE frequency centering to change the crystal capacitance.

By putting the LSE signal to PA4 (or PA10), and measuring this frequency with an oscilloscope, the frequency offset can easily be measured.

4.2 Test case specification identifier

LSOSC_center_TEST

4.3 Test setup

4.3.1 Test prerequisite

For this test, get access to the PA4 (or PA10) pin.

4.3.2 Hardware

Use an oscilloscope (or a frequency meter) to perform this test.

4.3.3 Software

No software is required for this test.

4.4 Test procedure

To enable the external low-speed clock:

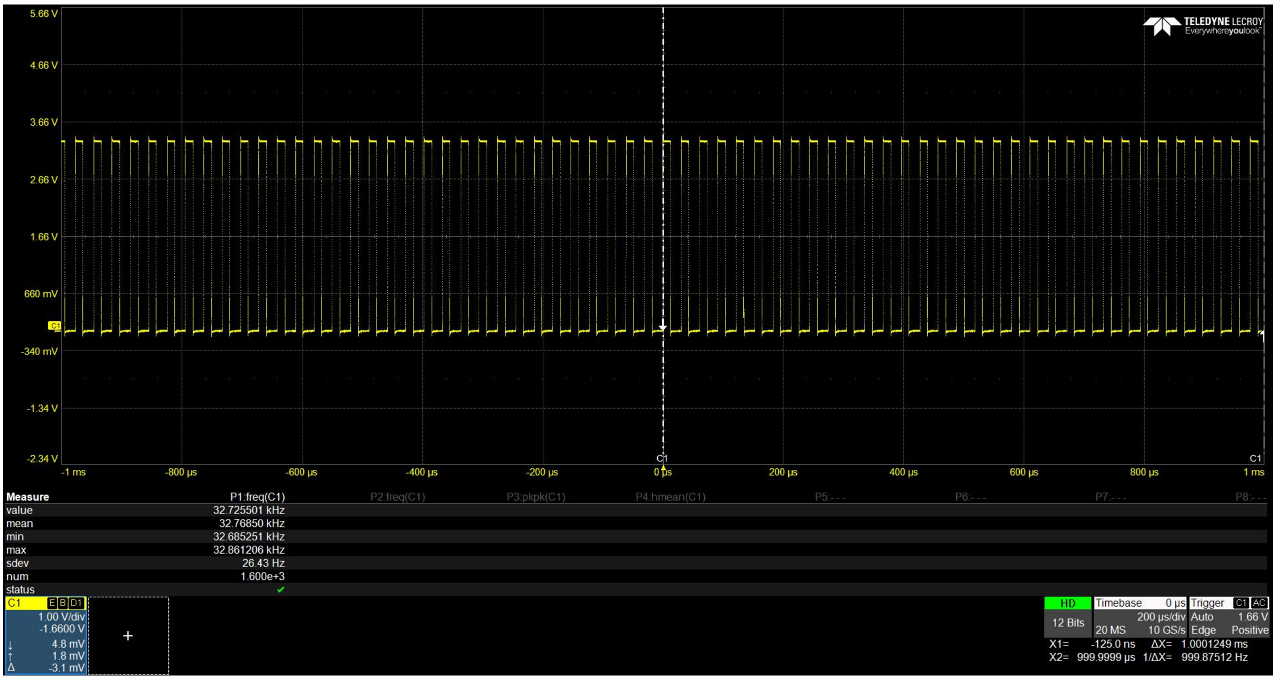
1. In the clock sources control register (RCC_CR), set to 0 the bit 2 (LSION) to disable the internal low-speed RC clock.
2. In the clock sources control register (RCC_CR), set to 1 the bit 4 (LSEON) to enable the external low-speed clock. Verify that the bit 5 (LSERDY) is set to 1: this means that the LSE is ready.

To put the LSOSC signal on PA4 (or PA10), configure this pin in alternate function mode, and set the low-speed configurable clock output selection bits (LCOSEL) inside the clocks configuration register (RCC_CFGR) to 3.

Connect an oscilloscope probe to the configured pin, and power up the board. Set the scope to capture a consistent number of 32 kHz waveform periods (for example for 64 cycles, set the time base at 200 µs). This way, the influence of the jitter in the measure is minimized.

At this point, the 32.768 kHz waveform is visible on the oscilloscope's screen.

Figure 1. **Measured low-speed external clock waveform**



If the DUT frequency is greater than f = 32.768 kHz, then tune the external XTAL capacitors.

To find the frequency offset of the crystal oscillator in ppm, use the following formula:

$$ppm = \frac{\Delta f}{f}10^6 \tag{1}$$

Where Δf is the difference between the target value (f = 32.768 kHz) and the measured one. The total accuracy of the crystal oscillator is the sum of two parts: the accuracy, due to the offset, and the accuracy, due to temperature and aging, as reported in the crystal datasheet.

5 Output power test

5.1 Test description

This test lets the user verify TX output power.

5.2 Test case specification identifier

OUTPUT_TEST

5.3 Test setup

5.3.1 Test prequisite

For this test, the SMA connector is mandatory.

5.3.2 Hardware

Use a spectrum analyzer to perform this test.

5.3.3 Software

Load the CLI project into the STM32WL3x device to perform this test.

Note: This firmware is located within the `Demonstrations\Command_Line_Interface\CLI` *directory of the STM32Cube_FW_WL3 software package*

Use the STM32CubeWiSE-RadioExplorer GUI to control the device.

5.4 Test procedure

The test procedure is described below:

1. Connect the board to a spectrum analyzer through a SMA male to SMA male connector adapter, or through an RF cable. (In this case, a characterization is needed to compensate cable losses.)
2. Set the desired center frequency, Res. BW, Span and Ref. level on the instrument.
3. Power up the board.
4. Open the STM32CubeWiSE-RadioExplorer GUI, and connect with the device by selecting the corresponding COM port
   (`File->Connect Device`).

5. Use the system panel and the radio panel to configure the radio settings.

Figure 2. STM32CubeWiSE-RadioExplorer GUI connection panel

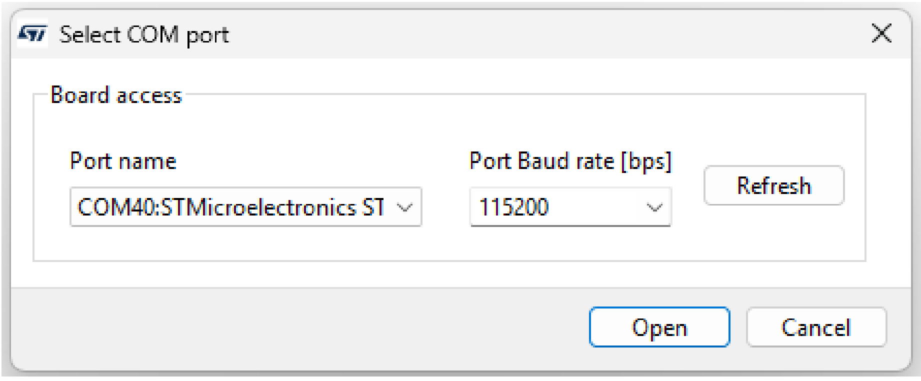


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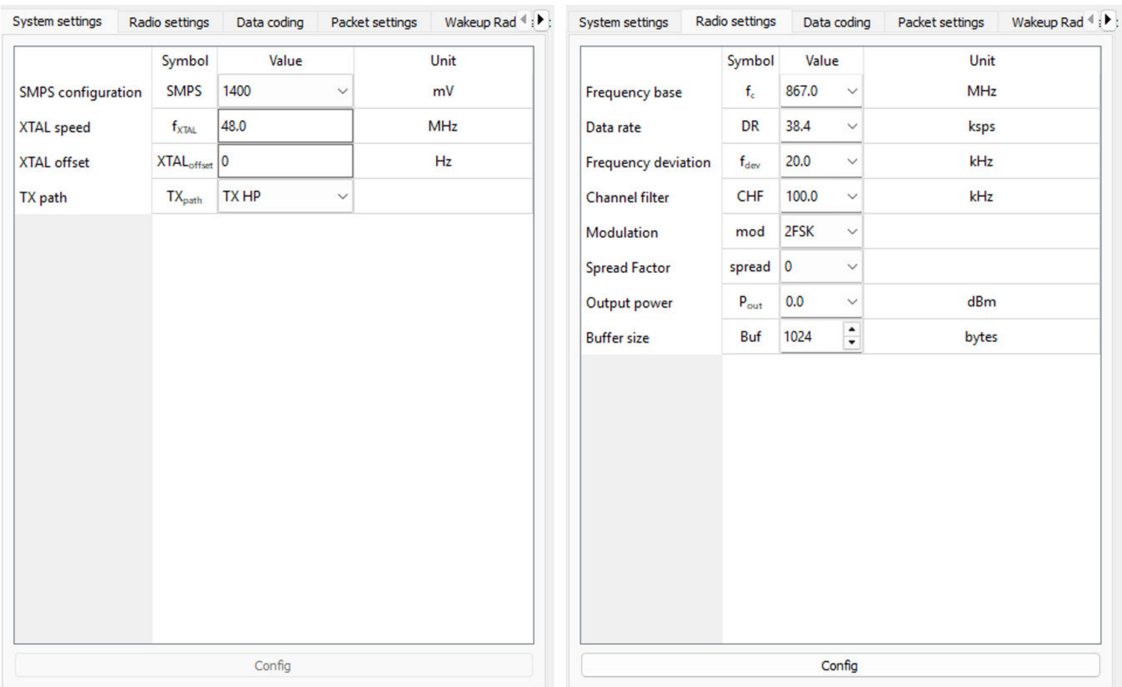
Figure 3. STM32CubeWiSE-RadioExplorer GUI system setting and radio setting panel



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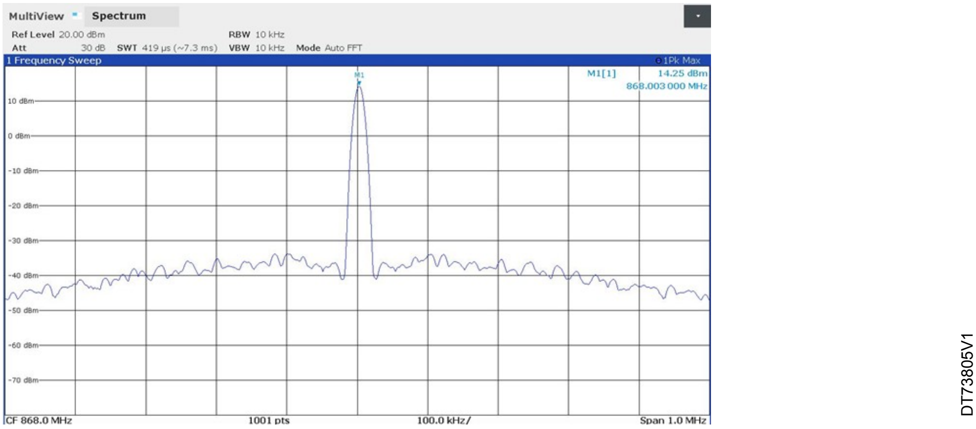
6. Generate a carrier wave tone clicking on TX start button in the radio test panel.

Figure 4. Measured output power at 14 dBm



The figure above shows the measured output power of a NUCLEO-WL3CC1, after configuring the following parameters:

- Center frequency = 868 MHz
- V_{SMPS} = 1.4 V
- TX path = TX_HP
- Output power = 14 dBm

The spectrum analyzer must measure a power value of around 14 dBm.

Note: The results are strongly dependent on the matching network used. If the measured output power is not aligned with the expected programmed value, the matching network must be tuned.

6 RSSI measurements

6.1 Test description

The aim of this test is to measure the noise floor of the board.

This test also helps to understand if the sensitivity of the customer board is aligned with the STM32WL3x datasheet reference value.

6.2 Test case specification identifier

RSSI_TEST

6.3 Test setup

6.3.1 Test prerequisite

For this test, the SMA connector is mandatory.

6.3.2 Hardware

No hardware is required for this test.

6.3.3 Software

Load the CLI project into the STM32WL3x device to perform this test.

Note: This firmware is located within the `Demonstrations\Command_Line_Interface\CLI` *directory of the STM32Cube_FW_WL3 software package*

Use the STM32CubeWiSE-RadioExplorer GUI to control the device.

6.4 Test procedure

The test procedure is described below:

1. Connect a 50 Ohm load on the board SMA connector.
2. Power up the board.
3. Open the STM32WL3x GUI and connect with the device.
4. Use the system panel and the radio panel to configure the radio settings.
5. Compare the measured RSSI level with the theoretical value of floor noise given by the following equation:

$$Noise\ floor = 10 \times \log_{10}\left[K \times T \times BW \times 10^{3}\right] + NF \quad (2)$$

Where:

– K is the Boltzmann constant

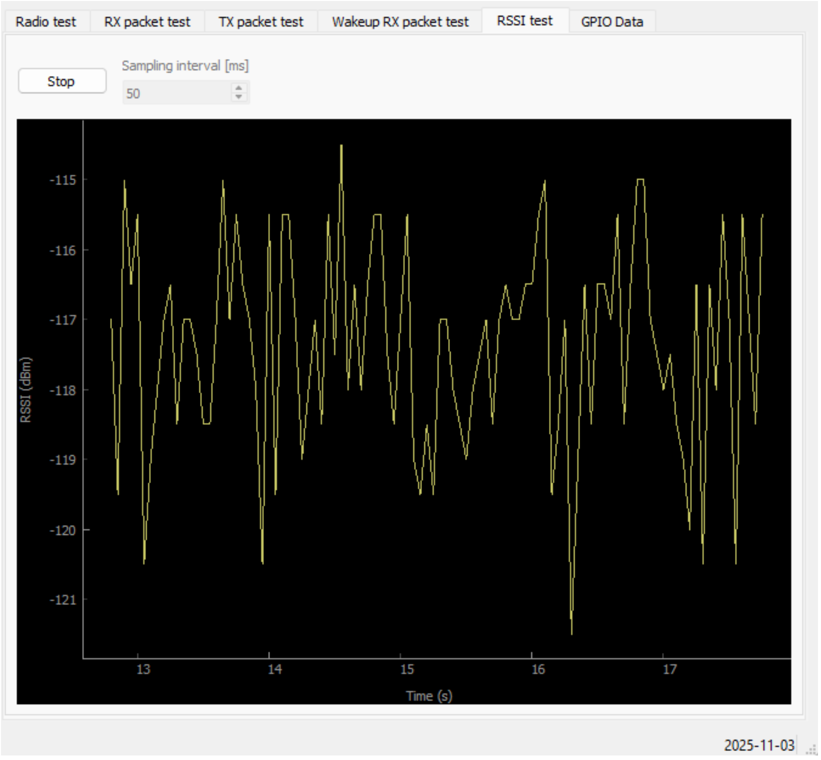
$$1.38064852 \times 10 - 23\mathrm{m}^{2}\mathrm{kg}\ \mathrm{s}^{-2}\mathrm{K}^{-1} \quad (3)$$

– T is the temperature expressed in kelvin.

– BW is the receiver bandwidth in Hz.

This comparison gives a good indication of the impact of the whole circuitry on the noise floor level and about the sensitivity.

Figure 5. **STM32CubeWiSE-RadioExplorer GUI RSSI test panel**

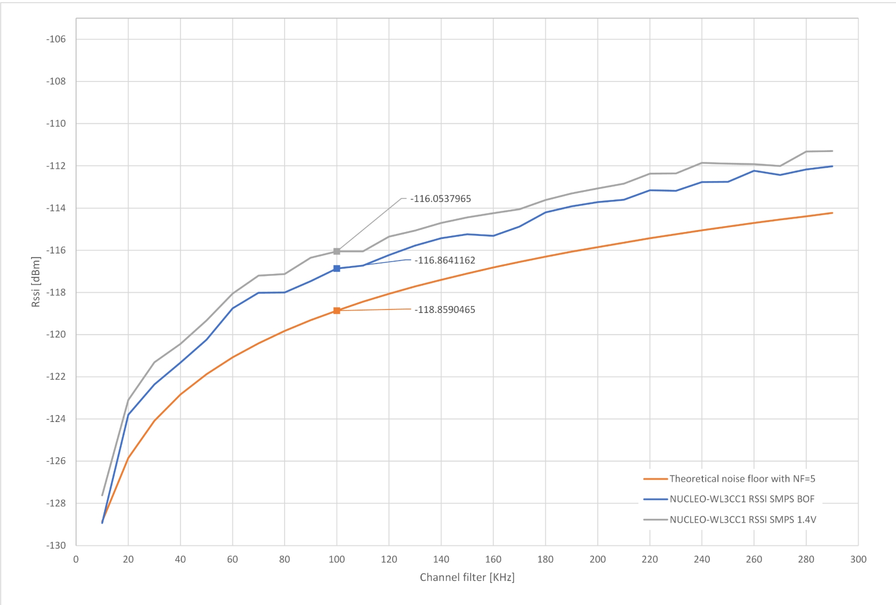


The graphic below shows the curve of the RSSI level measured for the NUCLEO-WL3CC1 with 50 Ohm load (with SMPS in BOF mode and equal to 1.4 V), and the theoretical curve of the noise floor (NF = 5 and temperature 25 °C) compared to channel filter bandwidth.

The impact of the circuitry of a NUCLEO-WL3CC1 is 2 dB with SMPS in BOF mode and 3 dB with SMPS equal to 1.4 V.

Note: This impact is constant at the channel filter bandwidth variation.

Figure 6. **Noise floor vs channel filter bandwidth**



For example, with a channel filter equal to 100 kHz, the RSSI of the NUCLEO-WL3CC1 is -117 dBm: since 6 dB are needed to demodulate the received signal (typically in 2-(G)FSK modulation), the sensitivity at 100 kHz of a channel filter bandwidth, with SMPS in BOF mode, may be equal to -111 dB.

Note: If the customer board RSSI deviates from our reference, the RF performances indicated in the datasheet is not achieved and the layout must be reviewed.

7 Packet exchange test

7.1 Test description

The aim of this test is to verify that the DUT is able to send and receive packets correctly.

7.2 Test case specification identifier

PACKET_TEST

7.3 Test setup

7.3.1 Test prerequisite

In order to perform these tests, two STM32WL3x boards are needed: one for the tester, and a second one as the DUT. The tester must be a verified working board.

7.3.2 Hardware

No hardware is required for this test.

7.3.3 Software

Load the CLI project into the STM32WL3x device to perform this test.

Note: This firmware is located within the `Demonstrations\Command_Line_Interface\CLI` *directory of the STM32Cube_FW_WL3 software package*

Use the STM32CubeWiSE-RadioExplorer GUI to control the device.

7.4 Test procedure

To perform this test, two boards are needed: one in TX and the other one in RX mode (DUT). The TX board must be a verified working board.

This test is in over the air mode, so two dipole antennas are needed.

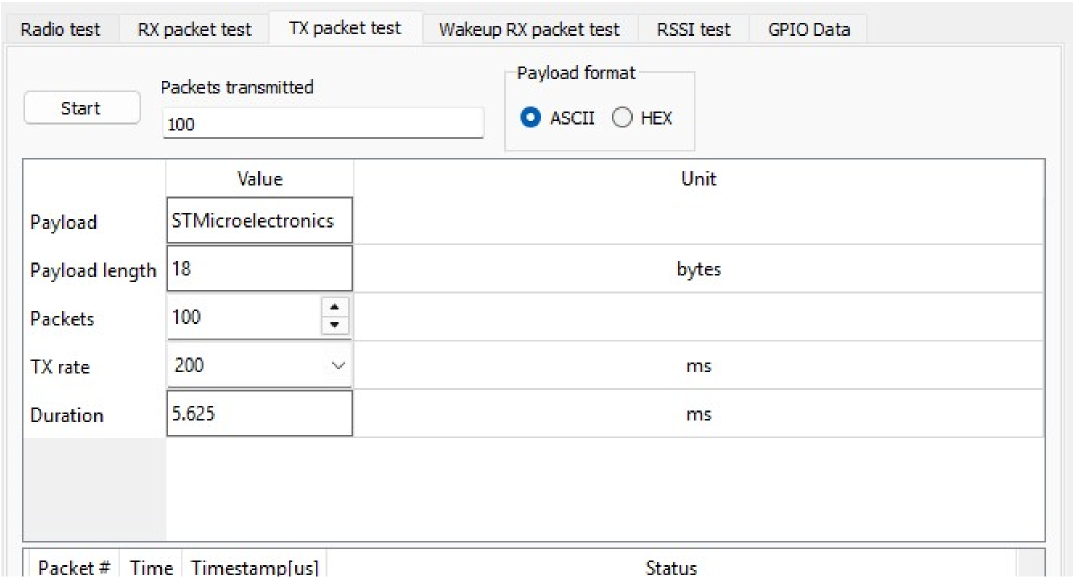
Power up the two boards and follow these steps to verify that the DUT is able to receive.

In the GUI related to the TX device:

- Configure the radio setting by the system and the radio panels.
- In the packet setting panel, configure the packet structure (preamble, sync word, payload, CRC mode, postamble).

- In the TX packet test, configure the payload to send the number of packets and the TX rate.

Figure 7. STM32CubeWiSE-RadioExplorer GUI TX packet test panel



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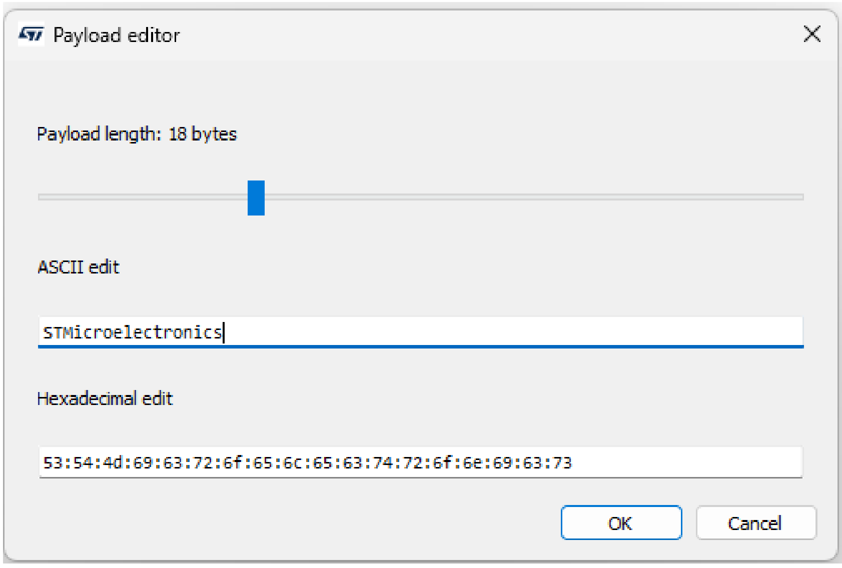
It is also possible to double click on the payload window to edit the payload length and the payload itself as shown in the figure below.

Figure 8. STM32CubeWiSE-RadioExplorer GUI payload editor panel



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- As soon as the DUT is in RX mode, click on the Start button to start to transmit packets.

In the GUI related to the RX device:

- Configure the radio setting by the system and the radio panels.
- In the packet setting panel, configure the packet structure (preamble, sync word, payload, CRC mode, postamble).
- In the RX packet test, push the start button to configure the DUT in RX mode.

- The number of received packets is shown in the RX packet test panel.

Figure 9. STM32CubeWiSE-RadioExplorer GUI TX packet test and RX packet test panels

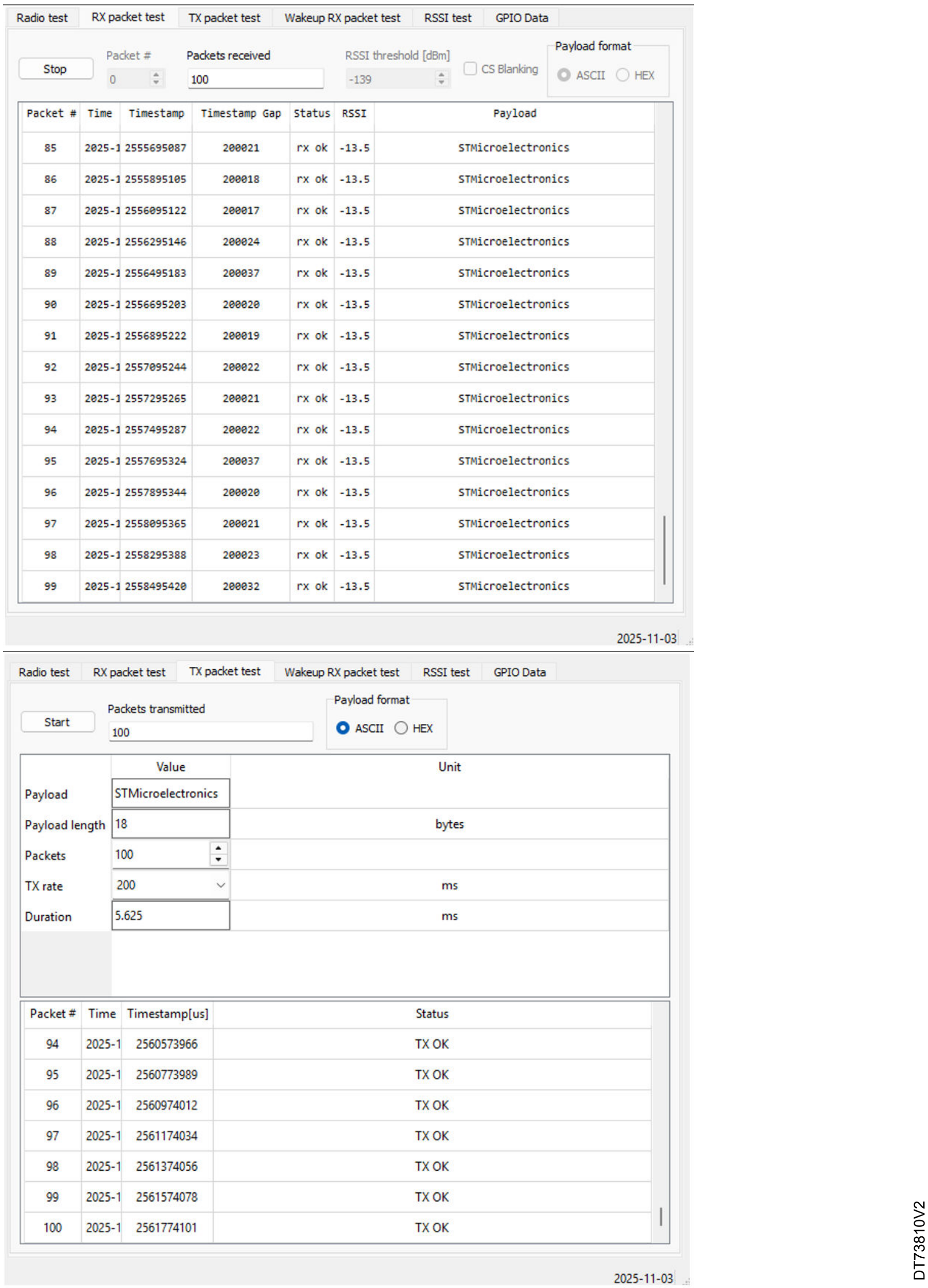

Figure 9 shows an example of a packet exchange test.

The TX board transmits #50 packets, and the DUT has received all the packets transmitted, as shown in the RX packet test panel.

In a clean RF environment (that is, with no interference), the number of packets received over-the-air must be equal to the number of packets sent by the TX board.

Note: The tester may be replaced by a signal generator which sends X packets or a spectrum analyzer which acts as a receiver.

To verify if the DUT is able to send X packets, repeat the previous procedure setting the DUT as TX and the tester as RX.

Revision history

Table 3. **Document revision history**

Date	Version	Changes
04-Apr-2024	1	Initial release.
19-Nov-2024	2	Updated: • Section Introduction • Section 2.4: Test procedure • Section 5.3.3: Software • Section 5.4: Test procedure • Figure 3. STM32CubeWiSE-RadioExplorer GUI system setting and radio setting panel • Figure 5. STM32CubeWiSE-RadioExplorer GUI RSSI test panel • Figure 7. STM32CubeWiSE-RadioExplorer GUI TX packet test panel • Figure 8. STM32CubeWiSE-RadioExplorer GUI payload editor panel • Figure 9. STM32CubeWiSE-RadioExplorer GUI TX packet test and RX packet test panels
21-Nov-2025	3	Updated: • Figure 2. STM32CubeWiSE-RadioExplorer GUI connection panel • Figure 3. STM32CubeWiSE-RadioExplorer GUI system setting and radio setting panel • Figure 5. STM32CubeWiSE-RadioExplorer GUI RSSI test panel • Figure 7. STM32CubeWiSE-RadioExplorer GUI TX packet test panel • Figure 8. STM32CubeWiSE-RadioExplorer GUI payload editor panel • Figure 9. STM32CubeWiSE-RadioExplorer GUI TX packet test and RX packet test panels • Section 2.3.3: Software • Section 5.3.3: Software

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