AN5503

Application note

Guidelines for bringing up on BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series MCUs

Introduction

The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices are high performance, ultralow power wireless systems-on-chip, which support the Bluetooth® Low Energy specifications.

To achieve the maximum performance, some procedures must be carried out before finalizing the application.

This document summarizes the following fundamental steps:

- Application PCB test points
- Power supply and current consumption tests
- Device configuration
- XTAL and LSOSC centering tests
- Output power test
- Packet exchange test
- Sensitivity test
- Power consumption in advertising mode.

Note: The document content is valid for the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices. Any reference to the BlueNRG-LP device and platform is also valid for the BlueNRG-LPS. Any reference to STM32WB09 devices and platforms is also valid for the other STM32WB0 series devices: STM32WB05, STM32WB06, and STM32WB07. Any specific difference is highlighted whenever it is needed.

1 General information

This document applies to the Arm® Cortex® core-based STM32WB0 microcontrollers.

For more information on Bluetooth®, refer to http://www.bluetooth.com.

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

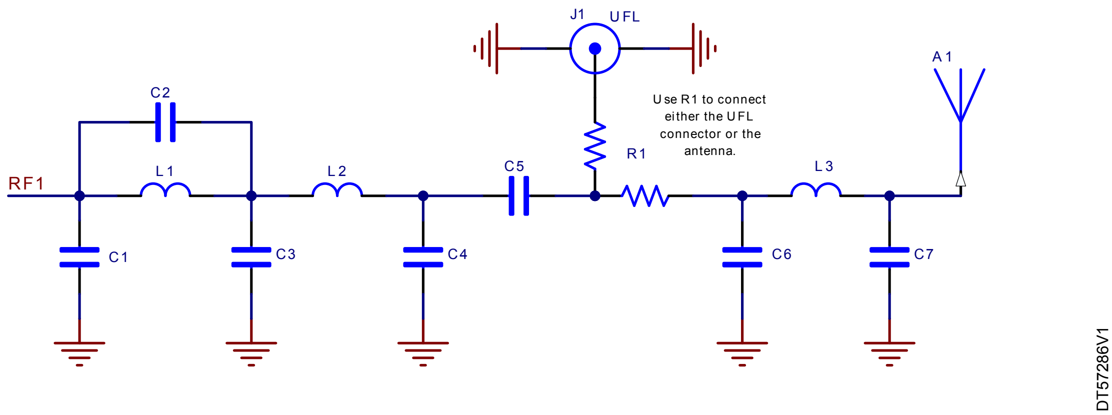
2 Application PCB test points

ST recommends a set of test points to measure the performance of the device on the customer's PCB. According to PCB constraints, it is not always possible to add all test points, therefore some tests cannot be performed.

Table 1. Test points

Test point	Function	Details of the test point
Current consumption	Added to the PCB to measure the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices current consumption	In series with the VDD1,2,3,4, VDDRF, and VDDSD pins
Voltage supply	Added to measure the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices supply voltages	To pins: VCAP, VDDA, VLXSD, VFBSD
RF	If the PCB uses an embedded antenna, like a PCB or a chip antenna, it is recommended to add a UFL connector to allow measurement of the RF performance with a spectrum analyzer	Between the matching network and the embedded antenna (refer to Figure 1. UFL connector)

Figure 1. UFL connector



2.1 DTM test applications

DTM (direct test mode) test application is used as reference software to configure the platform under test. DTM binary file can be built using the DTM test application available on the BlueNRG-LP, BlueNRG-LPS software package (STSW-BNRGLP-DK) in the BLE_Examples/DTM folder. It can be directly loaded on the related STEVAL board using the mass storage capability or the RF-Flasher utility. Based on the test requirements, the user can select:

- DTM UART image
- DTM SPI image.

The prebuilt binary images for the BlueNRG-LP STEVAL-IDB011V1/V2 (DTM UART/SPI mode) are available in the BlueNRG-LP/LPS DK software package in folders: Firmware/BLE_Examples/DTM/STEVAL-IDB011V1.

The prebuilt binary images for the BlueNRG-LPS STEVAL-IDB012V1 (DTM UART/SPI mode) are available in the BlueNRG-LP/LPS DK software package in folders: Firmware/BLE_Examples/DTM/STEVAL-IDB012V1.

In the context of the STM32CubeWB0 SW package, the application equivalent to DTM is called BLE_TransparentMode. It can be built using the related application available on the STM32CubeWB0 software package (STM32WB09: NUCLEO_WB09KE/Applications/BLE/BLE_TransparentMode folder). Only UART mode is supported. Equivalent images for STM32WB05xZ, STM32WB06xC, STM32WB07xC can be also built through related BLE_TransparentMode projects.

3 Power supply test

3.1 Test case specification identifier

SUPPLY_TEST

No specific firmware is needed for this test.

3.2 Test prerequisite

In order to perform this test, it is necessary to add some test points to the platform. Refer to Section 2: Application PCB test points for test pin description.

3.3 Test description

The aim of this test is to ensure that the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices are correctly powered.

3.4 Test setup

3.4.1 Hardware

A multimeter is required for this test.

3.4.2 Software

DTM binary file loaded into the BlueNRG-LP and BlueNRG-LPS devices.

BLE_TransparentMode binary file loaded into the STM32WB0 series device.

Refer to Section 2.1: DTM test applications.

3.5 Test procedure

Power up the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices platforms.

Measure the voltage in: VDD1,2,3,4, VDDRF, VDDSD, VCAP, VDDA, VLXSD, and VFBSD.

3.6 Expected results

The measured pin voltage and current needs to be aligned with the following values if the DC-DC converter ON configuration has been chosen.

Table 2. **Supply test results**

Pin	Expected value
VDD1,2,3,4, VDDRF and VDDSD	1.7 – 3.6 V
VCAP and VDDA	1.2 V
VLXSD	Square wave around 1.2 – 1.95 V
VFBSD	1.2 – 1.95 V

If the DC-DC converter OFF configuration has been chosen, the VLXSD pin is left floating and the VFBSD pin is connected directly to VBAT.

3.7 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.

3.8 Other

Not applicable.

4 Device configuration

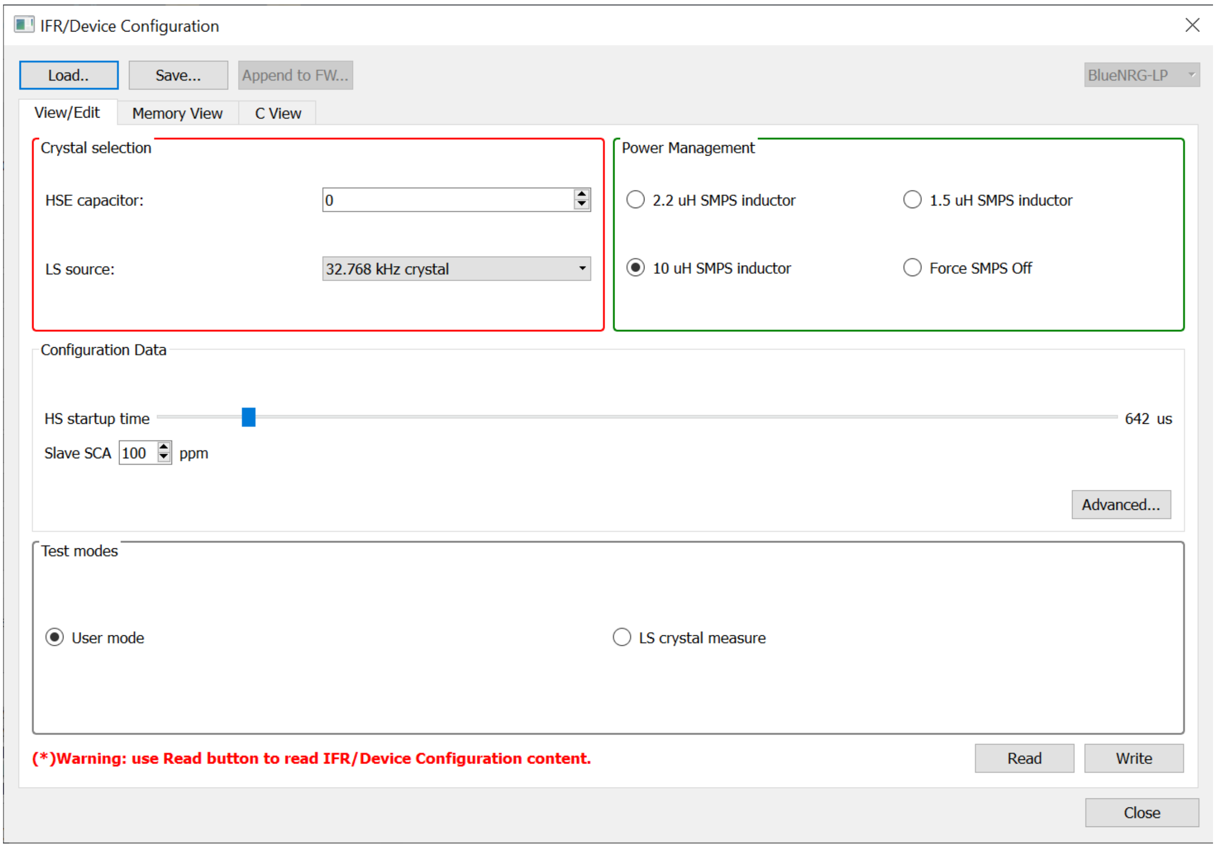
There are some parameters of the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices that must be defined and used during software initialization, before the application board is finalized.

These parameters are:

- Low speed oscillator source (32 kHz or the internal ring oscillator)
- Power management options (SMPS inductor or SMPS off configuration)
- Change HS start-up time parameter from 512 µs to 1953 µs
- Sleep clock accuracy.

When the DTM firmware is used, the device configuration parameters can be set using the BlueNRG GUI PC application available on the BlueNRG GUI SW package (STSW-BNRGUI).

Figure 2. BlueNRG GUI device configuration tool



Note: These BlueNRG GUI configuration features are not supported with the STM32WB0 BLE_TransparentMode applications.

In the context of the STM32WB0 SW package and the BLE_TransparentMode application , the low-speed source (LSE or LSI), high-speed external (HSE) startup value, HSE capacitor tuning value, and LSE drive capability can be defined through the CubeMX tool under the RCC tab.

The SMPS configuration and inductor value must be set through the CFG_HW_SMPS and CFG_HW_SMPS_BOM define configuration options. Refer to `system_stm32wb0x.c/h` files for possible options. The default configuration is SMPS on with a 10 µH SMPS inductor.

5 HS_Startup_Time

The high-speed external clock oscillator (HSE) needs time in order to be ready after system wake-up, upon exit from Deepstop mode. A parameter, referred to as HS_STARTUP_TIME inside the firmware examples, reflects this time. It needs to be tuned in order to let the radio transmit and receive at the programmed instants if the system exits from Deepstop. Higher values are safer, but they can lead to unnecessary extra power consumption since the system wakes up too early in order to give time to the HSE to be ready before transmission or reception. A too short value instead prevents the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices from correctly sending or receiving packets.

5.1 Test case specification identifier

HS_XTAL_startup_TEST.

5.2 Test prerequisite

- A power source at the lowest operating voltage
- One of the following:
  - access to the UART interface OR
  - an oscilloscope and access to VCAP pin and one GPIO (default PB6).

5.3 Test description

The aim of this test is to measure the HSE start-up time in the worst condition. A firmware application measures the HSE start-up time using the internal clock as a reference (assuming the frequency of the HSE is correct, since it is needed to calibrate the internal clock for measurement).

A pulse is also generated on a configurable GPIO (PB6 is the default) when HSE is ready. This is useful in case there is no access to the UART interface or just to double check.

5.4 Test setup

5.4.1 Hardware

A serial terminal connected to the board to receive data from UART. As an alternative, an oscilloscope is required for this test.

5.4.2 Software

RCC_HSEStartupTest firmware application on the STSW-BNRGLP-DK, BlueNRG-LP/BlueNRG-LPS SDK, Projects\Peripheral_Examples\MIX\RCC and Demonstrations\RADIO_TIMER\RADIO_TIMER_HSEStartupTime application in the context of STM32CubeWB0 SW package. This application programs periodic wake-up of the system and it measures the start-up time of the HSE at each wake-up. The current and longer (worst) measure is reported on the UART interface.

5.5 Test procedure

- Load firmware into BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices.
- Power the device at the lowest supported operating voltage: this is the condition in which the HSE needs more time to be ready.
- Run the test at ambient temperature (around 25 °C).

5.6 Expected results

The application outputs on the UART interface information about the measured start-up time.

Increasing the longer reported value by 10% in order to consider variation from 25 °C to 105 °C. Increasing again the value by 30% to have a safe margin, since variation of the crystal parameters like motional inductance and capacitance influence the start-up time.

HS_STARTUP_TIME = measured_value*1.1*1.3.

5.7 Note

The measurement needs to be taken on a sufficient number of boards to know the distribution of this value in the entire set of boards.

5.8 Other

As an alternative, the start-up time can be obtained by measuring time from when the voltage begins to rise on VCAP pin and the time the voltage on the test GPIO is high. The test GPIO can be easily changed (default is PB6).

6 HSOSC centering test

The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices integrate a low-speed frequency oscillator (LSOSC) and a high-speed (32 MHz) frequency oscillator (HSOSC).

The low frequency clock is used in low power mode and can be supplied either by a 32.7 kHz oscillator that uses an external crystal or by an internal ring oscillator, which does not require any external components.

The primary high frequency clock is a 32 MHz crystal oscillator.

The frequency tolerance of the high-speed crystal oscillator must be below ±50 ppm.

The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices, as with all RF systems, are highly dependent on accurate clocks for the correct operation. A deviation in clock frequency directly deviates the radio frequency, and this can degrade RF performance, violate legal requirements or in the worst case lead to a non-functioning system.

For these reasons, the crystal frequency must be centered and this has to be done by choosing the optimum load capacitors for a given circuit and layout. The easiest way to find the correct load capacitance is through the experimentation. The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices make the process of finding the correct capacitor value very easy. In fact, it has an integrated capacitor bank that can be set by software. In this way, no external capacitors are needed, for maximum flexibility, and the cost of external components as well as space on the board are saved.

6.1 Test case specification identifier

HSOSC_center_TEST.

6.2 Test prerequisite

For this test, the UFL connector (see Table 1) is not mandatory.

6.3 Test description

For the reasons previously explained, the crystal frequency must be centered, and the optimum load capacitor values can be found through experimentation. The radio can be set by fixing a constant carrier at a given frequency.

By measuring the output frequency with a spectrum analyzer, the offset can be easily found.

6.4 Test setup

6.4.1 Hardware

A spectrum analyzer is required for this test.

6.4.2 Software

The ST BlueNRG GUI , DTM binary file loaded into the BlueNRG-LP and BlueNRG-LPS devices and BLE_TransparentMode binary file loaded into the STM32WB0 series devices. Refer to Section 2.1: DTM test applications.

6.5 Test procedure

The following procedure is valid for the high-speed oscillator (32 MHz):

Connect the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices board to the spectrum analyzer through an RF cable if it is equipped with UFL connector, otherwise plug a 2.4 GHz antenna into the input port of the instrument.

Power up the selected platform.

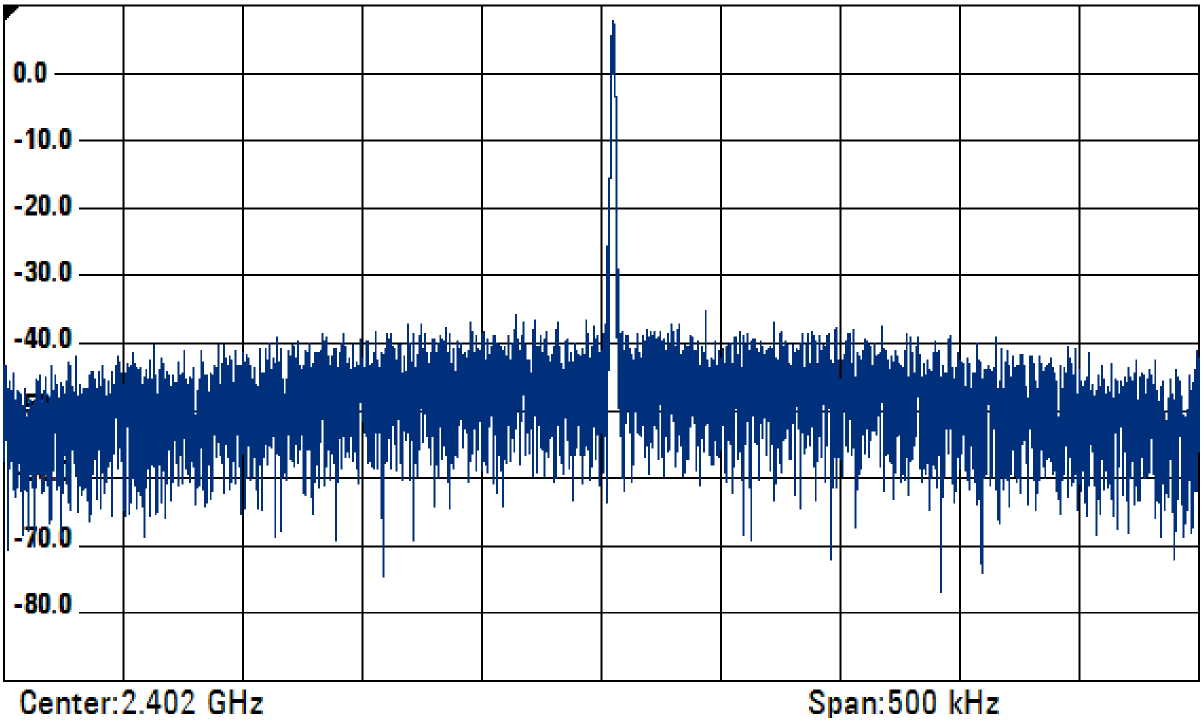
Set the spectrum analyzer to: res BW = 1 kHz, SPAN = 500 kHz (see Figure 3).

Generate a carrier wave tone at Ch0 (freq. 2.402 GHz). A carrier wave can be generated by using the BlueNRG GUI, RF test window, start tone button and selecting TX frequency as 2402 MHz, and channel 0 (a tone can be emitted at f = 2402 + k*2 MHz, with k = 0 to 39).

An alternative approach is to implement and load a simple application that calls the `ACI_HAL_TONE_START` with RF_Channel = 0.

The difference between the desired tone and the measured tone is the frequency offset.

Figure 3. **Frequency tone at Ch0 for the XTAL center test**



6.6 Expected results

The offset limit is:

|Offset| < 50 kHz

If DUT frequency > 2402.05 MHz → increases XTAL caps

If DUT frequency < 2401.95 MHz→ decreases XTAL caps

6.7 Note

Load capacitor value can be increased by choosing a higher value of SWXOTUNE in the RCC_RFSWHSECR register.

In the context of the STSW-BNRGLP-DK DTM application, use CONFIG_HW_HSE_TUNE to set the correct value (for example, CONFIG_HW_HSE_TUNE=32). In the DTM application, the user can also change the value through a device configuration parameter (or force the firmware to use a given value by defining the macro CONFIG_HW_HSE_TUNE; in the context of the STM32CubeWB0 software package the equivalent macro is CFG_HW_RCC_HSE_CAPACITOR_TUNE).

6.8 Other

Not applicable.

7 LSOSC centering test

The LSOSC is used to have a reference time clock. The advantage of using the external 32.768 kHz clock is that it consumes less power than internal RO and it is more accurate (typ. 50 ppm). This test allows its oscillator frequency to be centered, changing the crystal capacitance.

7.1 Test case specification identifier

LSOSC_center_TEST.

7.2 Test prerequisite

For this test, access to PA10 pin is required. Pin can be changed to PA4 if needed.

7.3 Test description

There is a way, using the device configuration tool of the BlueNRG GUI, to put the LSOSC signal to PA10.

By measuring its frequency with an oscilloscope, the frequency offset can easily be measured.

7.4 Test setup

7.4.1 Hardware

An oscilloscope is required for this test.

7.4.2 Software

The ST BlueNRG GUI and, DTM binary file loaded into the BlueNRG-LP and BlueNRG-LPS devices and BLE_TransparentMode binary file loaded into the STM32WB0 series devices. Refer to Section 2.1: DTM test applications.

7.5 Test procedure

Connect an oscilloscope probe to PA10. Power up the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices platform.

Set the scope to capture a consistent number of 32 kHz waveform periods (for example 64 cycles, so set the time base at 200 µs). In this way, the influence of the jitter in the measure is minimized.

In the context of STSW-BNRGLP-DK DTM application, the device configuration tool of the BlueNRG GUI can be used as follow:

1. perform a “read” of the current device configuration
2. tick the check-box “LS crystal measure”
3. perform a “write” operation.

Now a power cycle is required to let the new device configuration be operative.

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

Perform the measurement of the frequency: the difference between the target value (f = 32.768 kHz) and the measured one is the frequency offset Δf.

Note: In the context of STM32CubeWB0 SW package, the 32.768 kHz waveform can be generated and get visible on the oscilloscope screen, by rebuilding the BLE_TransparentMode application with the call to HAL_RCCEx_LSCOConfig(RCC_LSCO2, RCC_LSCOSOURCE_LSE).

7.6 Expected results

If DUT frequency > 32.768 kHz → increases XTAL caps

If DUT frequency < 32.768 kHz → decreases XTAL caps

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

$$ppm = \frac{\Delta f}{f} 10^6 \quad (1)$$

Δf = offset

f = 32.768 kHz

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.

7.7 Note

The total accuracy of the low frequency oscillator must be given to the BLE stack during initialization, through the SleepClockAccuracy parameter (field of BLE_STACK_InitTypeDef).

7.8 Other

Not applicable.

8 Output power test

8.1 Test case specification identifier

OUTPUT_TESTS.

8.2 Test prerequisite

For this test the UFL or SMA connector is mandatory.

8.3 Test description

The aim of this test is verification of the Tx output power level and the step linearity.

8.4 Test setup

8.4.1 Hardware

A spectrum analyzer is required for this test.

8.4.2 Software

The ST BlueNRG GUI, DTM binary file loaded into the BlueNRG-LP and BlueNRG-LPS devices and BLE_TransparentMode binary file loaded into the STM32WB0 series devices. Refer to Section 2.1: DTM test applications.

8.5 Test procedure

Connect the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices boards to the spectrum analyzer through an RF cable. Set the spectrum analyzer to: Res BW = 100 kHz, SPAN = 500 kHz.

Power up the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices platforms.

Generate a carrier wave tone at Ch0 (frequency 2402 MHz) using the BlueNRG GUI, RF test window:

- Check the "high power" check-box to enable "high power mode" (SMPS level at 1.9 V)
- Select power level 31.
- Click on "Start Tone" button.

The same results can be achieved by using the ACI commands:

- ACI_HAL_SET_TX_POWER_LEVEL (En_High_Power = 0x01,PA_Level: 31)
- ACI_HAL_TONE_START (RF_Channel = 0x00, offset = 0x00).

8.6 Expected results

Spectrum analyzer measures a power value of around 8 dBm.

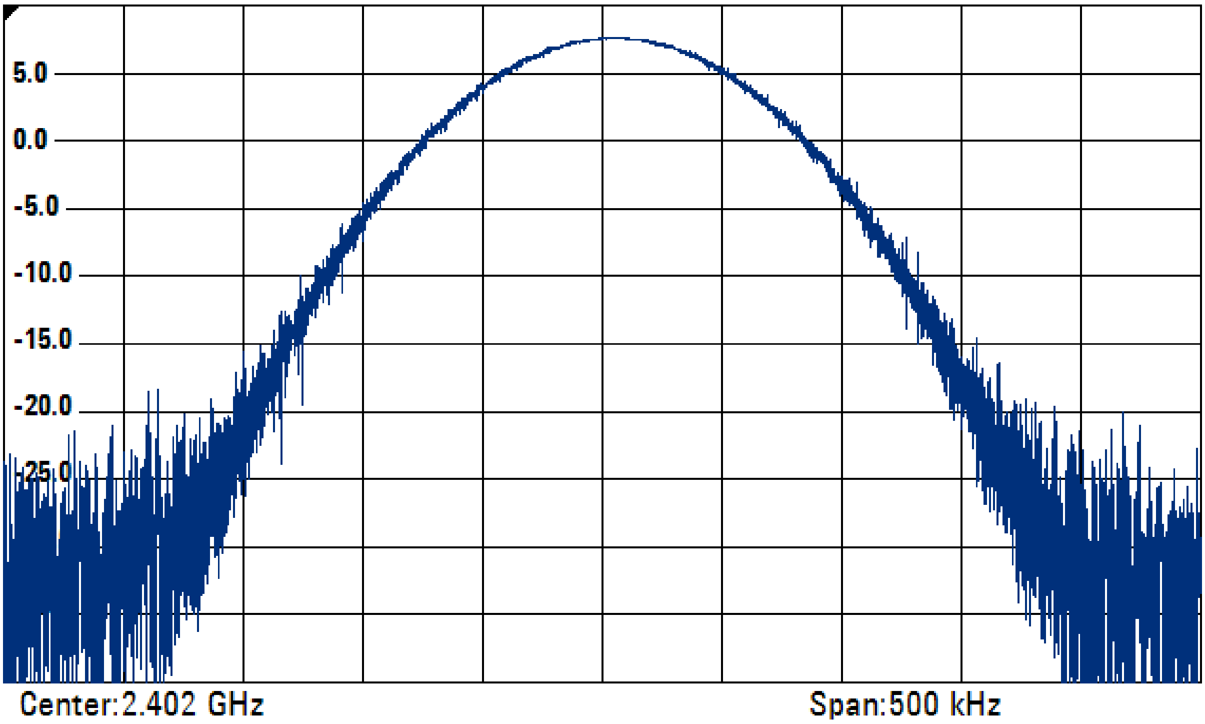
8.7 Note

The results are significantly influenced by the matching network performance. The user can tune it to obtain maximum performance.

8.8 Other

Not applicable.

Figure 4. **Output power measurement in high power mode with PA_level 31**



9 Packet exchange test

9.1 Test case specification identifier

PACKET_TEST.

9.2 Test prerequisite

In order to perform these tests, two BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices boards are used: one for the tester, the second one as the DUT. Tester must be a verified working board.

9.3 Test description

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

9.4 Test setup

9.4.1 Hardware

No instruments required.

9.4.2 Software

Load DTM binary file loaded into the BlueNRG-LP and BlueNRG-LPS devices and BLE_TransparentMode binary file loaded into the STM32WB0 series devices. Refer to Section 2.1: DTM test applications.

9.5 Test procedure

Power up the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices (tester and DUT boards) and ensure that antennas are mounted.

Follow these steps to start packet exchange test and verify that the DUT is able to receive:

In the GUI related to DUT (RX device)

- Go to RF test window, RECEIVER section
- Set Rx frequency
- Click on "Start Receiver" button, to start "Receiver Test".

In the GUI related to tester (TX device)

- Go to RF test window, TRANSMITTER section
- Set Tx power
- Set Tx frequency
- Set length of data to 0x25
- Set packet payload format
- Click on "Start Transmitter" button, to start "Transmitter Test".

In the GUI related to Tester (TX device)

- Click on "Stop Transmitter" button. The number of transmitted packets is displayed
- On #Packet Transmitted field.

In the GUI related to DUT (RX device)

- Click on "Stop Receiver" button. The number of received packets is displayed on the #Packet Received field
- In the PER section, insert the number of transmitted packets from Tx device in the packet transmitted field (read this value from the TRANSMITTER section in the GUI related to the Tx device)
- PER (packet error rate) value is shown in the packet error rate field.

The same results can be achieved by using the ACI commands:

- Start Rx on DUT: HCI_LE_ENHANCED_RECEIVER_TEST
- Make the Tx board send packets: HCI_LE_ENHANCED_TRANSMITTER_TEST, with the length of test data: 0x25

- Stop test on Tx board: HCI_LE_TEST_END
- Send this command in order to determine the number of packets sent by the Tx: ACI_HAL_LE_TX_TEST_PACKET_NUMBER
- Stop test on DUT: HCI_LE_TEST_END
- This returns Y as the number of received packets
- Exchange roles and repeat the same test to verify that DUT is able to transmit.

9.6 Expected results

In a "clean RF environment" (with no interference), the number of packets received over-the-air has to be equal to the number of packets sent by the Tx board.

9.7 Note

Tester can be replaced by any other device with HCI interface.

9.8 Other

Not applicable.

10 Sensitivity test

10.1 Test case specification identifier

SENSITIVITY_TEST.

10.2 Test prerequisite

Two different hardware configurations can be adopted for this test:

1. A signal generator (Agilent E4438C, controlled through a GPIB interface) as Tx and the BlueNRG-1 board (DUT) connected as shown in Figure 1.
2. ST BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices demo kit as Tx device and BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices board (DUT).

10.3 Test description

The aim of this test is to verify the sensitivity level of the DUT board.

10.4 Test setup

10.4.1 Hardware

Tx: Agilent E4438C signal generator or ST BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices demo kit.

Rx: DUT application board to test (see Figure 1).

10.4.2 Software

ST BlueNRG GUI, DTM binary file loaded into the BlueNRG-LP and BlueNRG-LPS devices and BLE_TransparentMode binary file loaded into the STM32WB0 series devices. Refer to Section 2.1: DTM test applications.

10.5 Test procedure

Two procedures can be used.

10.5.1 Signal generator and DUT board

The sensitivity can be evaluated by performing the following steps:

1. Connect the instrument and DUT with an RF cable (with no significant loss)
2. Start Rx on DUT: on the RF test window click on "Start Receiver" button
3. Make the generator send X packets (well-formatted as described in “Direct Test Mode”, vol. 6, part F, and “Host Controller Interface Functional Specification”, vol. 2, part E, in point 3 Section 14: References)
4. Stop test on DUT: on the RF test window click on stop receiver button

On packet received tab there is the number of received packets. PER is 1-Y/X.

If PER is below 0.308 (30.8%), go back to step 2 and decrease the power of the transmitter by one step. If PER goes above 0.308, then the level of power emitted by the equipment in the previous test is the sensitivity of the receiver. The algorithm can be more accurate by reducing the power level step when it is close to the sensitivity level.

The same results can be achieved by directly using the ACI commands:

1. Connect the instrument and DUT with an RF cable (with no significant loss)
2. Start Rx on DUT: HCI_LE_ENHANCED_RECEIVER_TEST
3. Make the generator send X packets (well-formatted as described in “Direct Test Mode”, vol. 6, part F, and “Host Controller Interface Functional Specification”, vol. 2, part E, in point 3 Section 14: References)
4. Stop test on DUT: HCI_LE_TEST_END

This returns Y as the number of received packets. PER is 1-Y/X.

If PER is below 0.308 (30.8%), go back to step b and decrease the power of the transmitter by one step. If PER goes above 0.308, then the level of power emitted by the equipment in the previous test is the sensitivity of the receiver.

The algorithm can be more accurate by reducing the power level step when it is close to the sensitivity level.

10.5.2 ST demo kit and DUT board

In this case, the previous procedure changes in the following way:

1. Connect the RF input/output of the two boards, DUT and ST BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices, by using a variable attenuator
2. In the GUI related to the DUT Rx device
   - Go to RF test window, RECEIVER section
   - Set Rx frequency
   - Click on the "Start Receiver" button, to start "Receiver Test"
3. In the GUI related to the Tx device
   - Go to RF test window, TRANSMITTER section
   - Set Tx power
   - Set Tx frequency
   - Set the length of data to 0x25
   - Set packet payload format
   - Click on the "Start Transmitter" button to start "Transmitter Test"
4. In the GUI related to the Tx device
   - Click on the "Stop Transmitter" button. The number of transmitted packets is displayed on the #Packet Transmitted field.
5. In the GUI related to the DUT Rx device
   - Click on the "Stop Receiver" button. The number of received packets is displayed on the #Packet Received field
6. In the PER section, insert the number of transmitted packets from the Tx device in the packet transmitted field (read this value from TRANSMITTER section in the GUI related to Tx device)
7. PER (packet error rate) value is shown in the packet error rate field

If PER is below 0.308 (30.8%), go back to step 2 and increase the value of attenuation. If PER goes above 0.308, then the level of power received by DUT in the previous test is the sensitivity of the receiver. It is very important to measure correctly or estimate the power received by DUT (for example: by using a tone instead of a modulated signal).

Moreover, to reduce the level of the signal received over-the-air by DUT, the ST demo kit needs to use the minimum output power. Performing the measurements inside an anechoic chamber also gives more accurate results.

The same results can be achieved by using ACI commands:

1. Connect the RF input/output of the two boards, DUT and ST kit, by using a variable attenuator
2. Start Rx on DUT: HCI_LE_ENHANCED_RECEIVER_TEST
3. Make the board send packets: HCI_LE_ENHANCED_TRANSMITTER_TEST, with the length of test data: 0x25
4. Stop test on the board: HCI_LE_TEST_END
5. Send a further command to determine the number of packets sent by the board: ACI_HAL_LE_TX_TEST_PACKET_NUMBER
6. Stop test on DUT: HCI_LE_TEST_END

This returns Y as the number of packets received. PER is 1-Y/X.

If PER is below 0.308 (30.8%), go back to step 2 and increase the value of the attenuation. If PER goes above 0.308, then the level of power received by DUT in the previous test is the sensitivity of the receiver.

10.6 Expected results

The expected value needs to be a few dB from the value reported in the datasheet. If it is not so, the reason can be related to the matching network.

10.7 Note

Since the sensitivity test is very time-consuming, STMicroelectronics can provide a specific software for both hardware configurations in order to implement an automatic procedure.

10.8 Other

Not applicable.

11 Power consumption in advertising mode

11.1 Test case specification identifier

CURRENT_TEST.

11.2 Test prerequisite

In order to perform this test the platform must be provided with the test points in series with VBAT 1, 2, 3 pins (see Table 1).

11.3 Test description

The aim of this test is to verify that BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices current consumption profile during the advertising is aligned with the simulated value (for simulated values use the current consumption estimation tool (STSW-BNRG001) available on www.st.com.

11.4 Test setup

11.4.1 Hardware

Agilent N6705B power analyzer or an oscilloscope.

11.4.2 Software

This test uses an application, which puts the device in advertising mode (power consumption example available on the BlueNRG-LP/BlueNRG-LPS DK development kit/STSW-BNRGLP-DK, on Firmware/BLE_Examples folder). Equivalent application is available on STM32CubeWB0 SW package, Applications\BLE\BLE_PowerConsumption\ folder.

11.5 Test procedure

The power analyzer has to be connected in series to VBAT pins in BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices. If it is not available, a 10 Ohm resistor has to be used to sense the current, connecting two probes to it.

Power up the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices platform and load a firmware so that the device is in advertising mode. Capture the current waveform.

11.6 Expected results

The average current needs to be measured using the power analyzer tool (see Figure 5. Typical current profile during an advertising event).

The measured values are significantly influenced by the device configuration parameters, such as: the HS_Startup_Time and the 32 kHz crystal (external or internal ring oscillator).

Figure 5. Typical current profile during an advertising event

11.7 Note

Not applicable.

11.8 Other

Not applicable.

12 RF tests for certification

Tests described in this application note needs to be used to check the basic functionality of the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices on prototype boards.

Before Bluetooth trademark can be used on the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices, the company must complete the Bluetooth® compliance program; that means the board must be qualified and listed.

Since the BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices are an already qualified product, a board using these devices does not have to re-run all Bluetooth® tests. However, when the devices support is used in a new RF design, the RF-PHY layer must be still tested. To know which tests are to be performed, refer to the current test case reference list (TCRL) and related RF-PHY test specifications on the official Bluetooth® website (http://bluetooth.com/).

Moreover, depending on the country of use, an RF product must be compliant with one or more standards before it can be sold. In particular, Bluetooth® low energy products, which operate in the unlicensed ISM band at 2.4 GHz, must be compliant to:

- FCC part 15.205, 15.209, 15.247 in North America
- ETSI EN 300 328 in Europe
- ARIB STD-T66 in Japan.

Bluetooth® LE tests can be manually performed, but some instruments exist to simplify and automate the testing process.

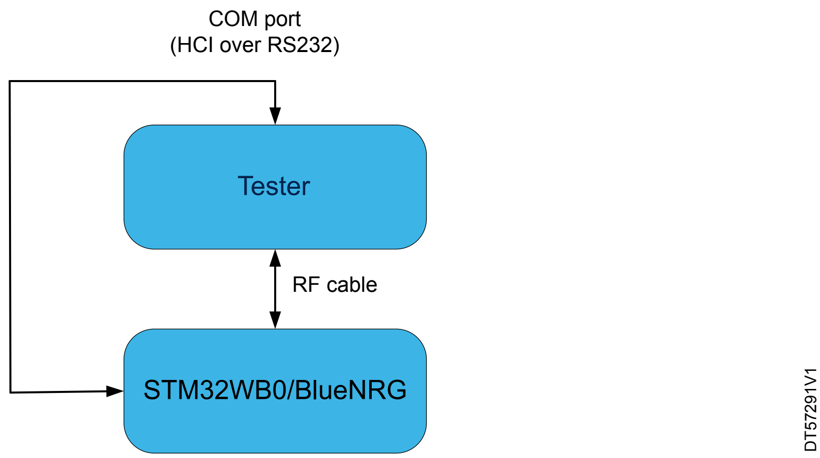
Usually, these instruments operate in two modes:

- Signaling mode
- Non-signaling mode.

12.1 Signaling mode

In this mode, the instrument can autonomously perform the tests. DUT (device under test) must be connected to the instrument with an RF cable. Moreover, DUT has to be connected to one instrument port in order to be controlled by the instrument itself (to start/stop test and receive feedback from DUT). The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices support the direct test mode over HCI, which allows testing low energy PHY layer (see Bluetooth specifications, vol. 6, part F: direct test mode).

Figure 6. Signaling mode RF tests

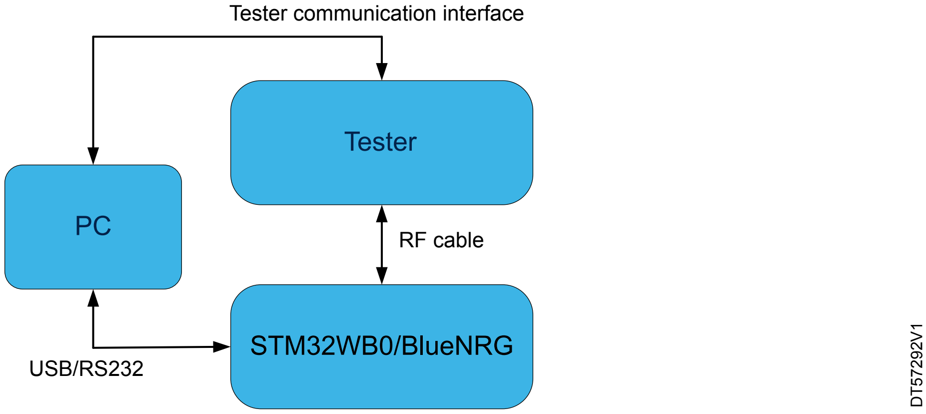


On the test equipment, the serial port for communication with DUT is typically an RS232 interface. The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices come with a UART interface that can be easily made compatible to an RS-232 interface. A level translator is usually needed to adapt the different voltage requirements on the two interfaces.

12.2 Non-signaling mode

In non-signaling mode a third entity (e.g. a PC) controls both DUT and Test instrument at the same time. Typically, the instrument can be controlled by using proprietary commands. The BlueNRG-LP, BlueNRG-LPS devices, and STM32WB0 series devices can use either UART or SPI as the communication interface. The device can be connected to the PC through a serial-to-USB converter.

Figure 7. **Non-signaling mode RF tests**



13 RF tests for board manufacturing

Once the final board has been designed and sent to production, the manufacturer can run some basic tests to be confident that the device works correctly. The minimal set of suggested tests is:

- Output power (see Section 8: Output power test) and crystal frequency centering test (see Section 6: HSOSC centering test)
- Packet exchange test (see Section 9: Packet exchange test).

Some of these tests can also be performed by dedicated instruments, as described in Section 12.1: Signaling mode. In this case, the set of tests to be performed is:

- Output power
- Carrier frequency offset and drift
- Receiver sensitivity.

14 References

Table 3. Document reference

Reference	Document
[1]	BlueNRG-LP datasheet (DS13282)
[2]	BlueNRG-LPS datasheet (DS13819)
[3]	STM32WB05xZ (DS14591)
[4]	STM32WB07xC, STM32WB06xC datasheet (DS14676)
[5]	STM32WB09xE datasheet (DS14210)
[6]	BlueNRG GUI software package (STSW-BNRGUI) user manual (UM2058)
[7]	RF-Flasher utility (STSW-BNRGFLASHER) user manual (UM2406)

Revision history

Table 4. **Revision history**

Date	Version	Changes
27-Jul-2020	1	Initial release.
12-May-2021	2	Updated Section 6 LSOSC centering test.
06-Apr-2022	3	Updated Section Introduction, Section 1.1 DTM test applications, Section 3 Device configuration and Section 13 References. Updated Figure 1. UFL connector. Added the BlueNRG-LPS references throughout the document.
24-Jun-2024	4	Added the STM32WB0 series references throughout the document.
29-Jan-2025	5	Corrected typo errors in: • Section 6: HSOSC centering test • Section 6.5: Test procedure • Section 9.5: Test procedure

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