Guidelines for RF Testing in Apollo-Blue Family

September, 2025

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Work before Testing

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Ready for Tests

- Wire out the VCC, GND, customized UART, SWD interface and RF terminal on EUT board.
- Download DTM firmware (uart_ble_bridge) over J-link tools to make MCU enter Direct Test Mode.
- The J-Flash programming parameters and supported PHYs for Apollo Blue family provided as follows:

MCU Categories	Device Selection	Interface	Speed	Program Start Address	Supported PHYs
Apollo3 Blue Apollo3 Blue Plus	AMA3B1KK-KBR AMA3B2KK-KBR	SWD	1000	0x0000C000	LE 1M PHY
Apollo4 Blue	AMAP42KK-KBR	SWD	1000	0x00018000	LE 1M PHY LE 2M PHY
Apollo510B	AP510NFA-CBR	SWD	1000	0x00410000	LE 1M PHY LE 2M PHY Coded PHY

- Connect customized UART test interface of EUT and USB interface of PC or BLE tester with one USB-to-Serial adapter (driver program must be installed at first).
- Connect antenna port of EUT to tester by using a short RF cable or soldering a pig-tail from on-board test point before conducted testing.

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BLE Conformance Test

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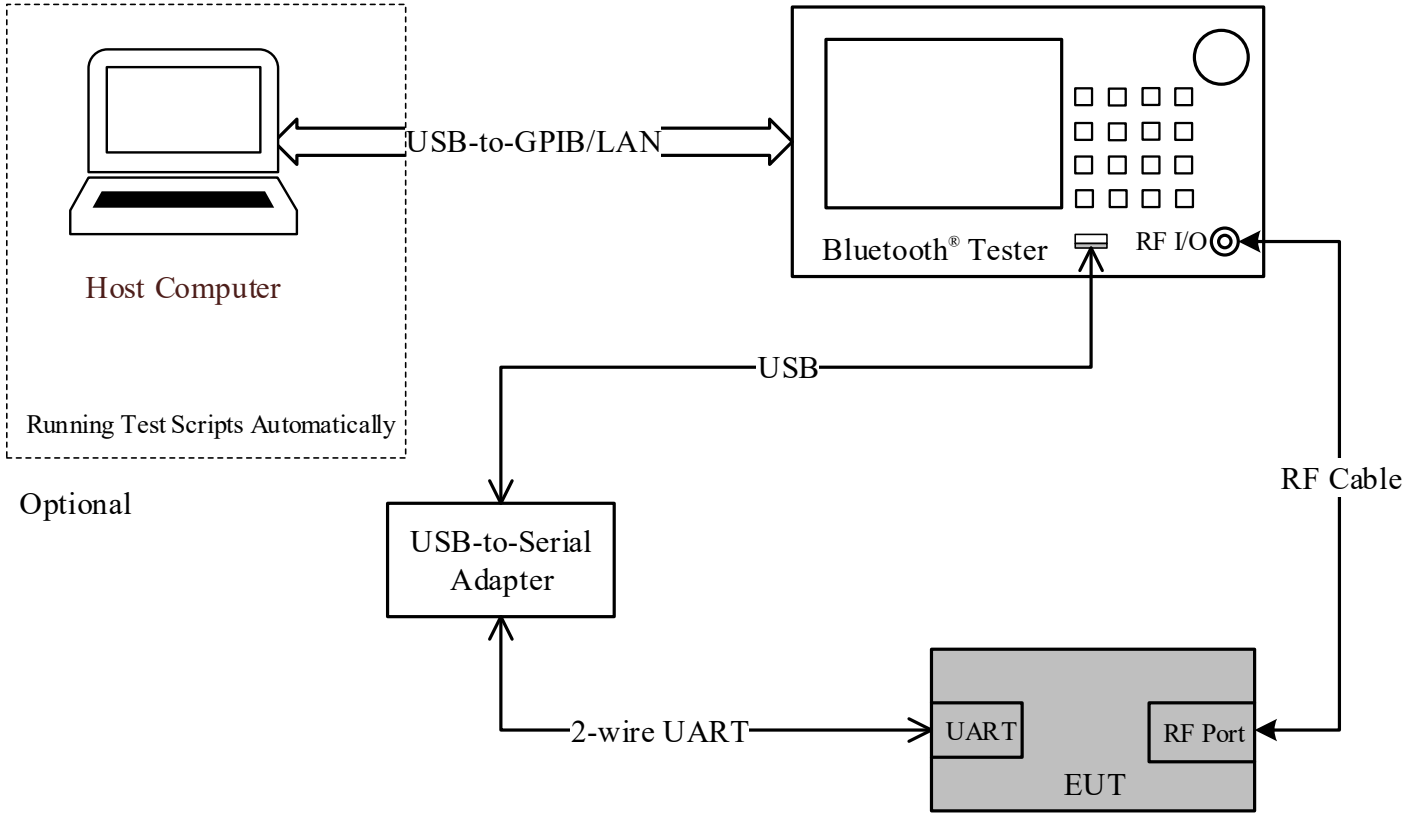
Signaling Test Setup

- There are two main test methods - signaling and non-signaling - and two common models of Bluetooth testers - R&S CMW270/500 and Anritsu MT8852B.
- For Bluetooth signaling test method, RF testing commands are generated by the tester automatically to control EUT and the test setup is shown as follows:



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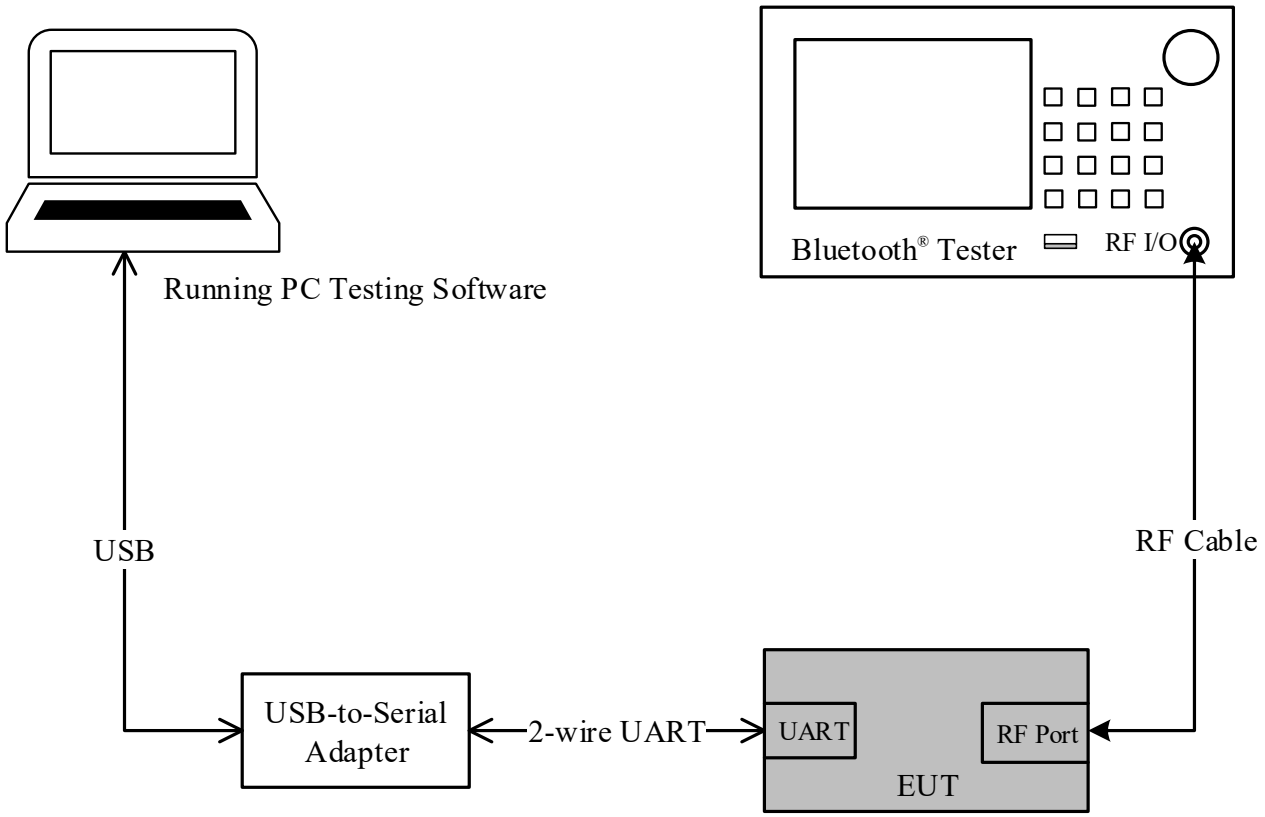
Non-Signaling Test Setup

- For non-signaling test method, RF testing commands are sent by upper PC software like SSCOM tool manually to control EUT and the test setup is shown as follows.
- Among R&S CMW and Anritsu MT8852B, only R&S CMW series testers support non-signaling test method.



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HCI Test Commands for 1M PHY

- For 1M PHY mode, HCI testing commands used in non-signaling test mode are defined as follows or VS commands introduced for specific parts in the following chapters:

Packaged HCI Commands	SSCOM Strings	Description
HCI_RESET	01 03 0C 00	Reset EUT before testing
HCI_LE_TRANSMITTER_TEST	01 1E 20 03 xx 25 00	'00': sending LE test packets with PRBS9 in payload
	01 1E 20 03 xx 25 01	'01': sending LE test packets with repeated '11110000' sequence in payload
	01 1E 20 03 xx 25 02	'02': sending LE test packets with repeated '10101010' sequence in payload
HCI_LE_RECEIVER_TEST	01 1D 20 01 xx	Set EUT in direct RX mode
HCI_LE_TEST_END	01 1F 20 00	End current test and be ready for next one

- 'xx' in all transmitter and receiver testing commands above indicates the channel to be tested (within range: 0x00~0x27), and '0x25' in transmitter tests indicates the payload length is 37 octets typically.
- Note that if each HCI test command processes successfully, the last octet of LE_STATUS packet returned by EUT will be 0x00.

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HCI Test Commands for 2M PHY

- For 2M PHY mode (Apollo4 Blue or later), HCI testing commands used in non-signaling test mode are defined as follows or VS commands introduced for specific parts in the following chapters:

Packaged HCI Commands	SSCOM Strings	Description
HCI_RESET	01 03 0C 00	Same as 1M PHY mode
HCI_LE_TRANSMITTER_TEST	01 34 20 04 xx 25 00 02	'00': sending LE test packets with PRBS9 in payload
	01 34 20 04 xx 25 01 02	'01': sending LE test packets with repeated '11110000' sequence in payload
	01 34 20 04 xx 25 02 02	'02': sending LE test packets with repeated '10101010' sequence in payload
HCI_LE_RECEIVER_TEST	01 33 20 03 xx 02 00	Set EUT in direct RX mode
HCI_LE_TEST_END	01 1F 20 00	Same as 1M PHY mode

- 'xx' in all transmitter and receiver testing commands above indicates the channel to be tested (within range: 0x00~0x27), and '0x25' in transmitter tests indicates the payload length is 37 octets typically.
- Note that if each command processes successfully, the last octet of LE_STATUS packet returned by EUT will be 0x00.

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UART Test Interface

- The UART test Interface characteristics of Bluetooth tester or PC testing software should be set to use the following parameters:
  - Baud rate: 115200
  - Number of data bits: 8
  - Number of stop bits: 1
  - No parity
  - No flow control

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Transmitter Tests (TRM-LE)

No.	Test Case	Requirement	Channels for Testing
1	Output Power	$-20 \le P_{AVG} \le +10$ dBm $P_{PEAK} - P_{AVG} \le 3$ dB	Ch0, 12, 19, 39
2	In-band emissions	$P_{TX} \le -20$ dBm for ($f_{TX} \pm 2$ MHz); $P_{TX} \le -30$ dBm for ($f_{TX} \pm n$ MHz]); where $n \ge 3$	Ch0, 2, 12, 19, 37,39
3	Modulation Characteristics	225 kHz ≤ Δf1avg ≤ 275 kHz (1M PHY) 450 kHz ≤ Δf1avg ≤ 550 kHz (2M PHY) 99.9% Δf2max＞185 kHz (1M PHY) 99.9% Δf2max＞370 kHz (2M PHY) Δf2avg / Δf1avg ≥ 0.8	Ch0, 12, 19, 39
4	Carrier frequency offset and drift	Freq Offset (Accuracy) ≤ ±150 kHz Freq Drift ≤ ±50 kHz Initial frequency drift ≤ ±23 kHz Maximum drift rate ≤ 20kHz/50µs	Ch0, 12, 19, 39

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Receiver Tests (RCV-LE)

No.	Test Case	Requirement	Channels for Testing
1	Receiver sensitivity	PER ≤ 30.8% when input power level = -70 dBm in dirty TX mode	Ch0, 12, 19, 39
2	Maximum input signal level	PER ≤ 30.8% when input power level = -10 dBm	Ch0, 12, 19, 39
3	PER Report Integrity	50% ≤ PER ≤ 65.4% when input power level = -30 dBm and every test packet has an intentionally corrupted CRC value	Ch12, 19
4	Blocking Performance	See RF-PHY.TS.5.1.0 for details	Ch12
5	C/I and Receiver Selectivity Performance	See RF-PHY.TS.5.1.0 for details	Ch0, 2, 12, 19, 37,39
6	Intermodulation Performance	See RF-PHY.TS.5.1.0 for details	Ch0, 12, 19, 39

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Declarations in RCV-LE

- Due to different receiver designs within the Apollo Blue SoCs, the below two values must be declared to the test facility by the manufacturer before applying receiver tests:

No.	Identifier	Channel	Apollo3 Blue	Apollo4 Blue	Apollo510B	Unit
1	In-band image frequency for C/I and receiver selectivity test	Low	-4	-4	3	MHz
		Middle				
		High				
2	Value n for intermodulation test	Low	3 or 5	3 or 5	3	integer
		Middle				
		High				

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Tips for Tester Model Selection

- Generally, R&S CMW series Bluetooth testers, such as CMW270/500, are recommended for R&D use since they can be operated more flexibly.
- Anritsu MT8852B series are more suitable for production tests since they can run testing scripts and generate test results automatically.

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Wireless Regulatory Test

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Overview

- Telecommunication regulatory tests indicate mandatory regional radio type approval where those radio products intend to be sold.
- The primary approval standards include SRRC, FCC and CE corresponding to marketplace in China, North America and Europe, respectively.
- Some test cases in FCC and CE certification require radiated measurement in SAR or FAR similar to EMC tests. In these cases conducted measurement may be used instead for reference.

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Applicable Standards

- All telecommunication regulatory tests shall follow these standards listed as below respectively:

Category	Standard Code	Document Title
SRRC	MIIT regulation [2002]353	微功率（短距离）无线电发射设备技术要求
FCC	47 CFR Part 15 Subpart C	Miscellaneous Wireless Communication Services
	ANSI C63.10-2013	American National Standard for Testing Unlicensed Wireless Devices
CE	ETSI EN 300 328 V2.1.1	Wideband transmission systems; Data transmission equipment operating in the 2.4 GHz ISM band and using wideband modulation techniques
	ETSI EN 300 440 V2.1.1	Short Range Devices (SRD); Radio equipment to be used in the 1 GHz to 40 GHz frequency range
	ETSI EN 301 489-17 V2.1.1	Electromagnetic compatibility and Radio spectrum Matters (ERM); Electro Magnetic Compatibility (EMC) standard for radio equipment

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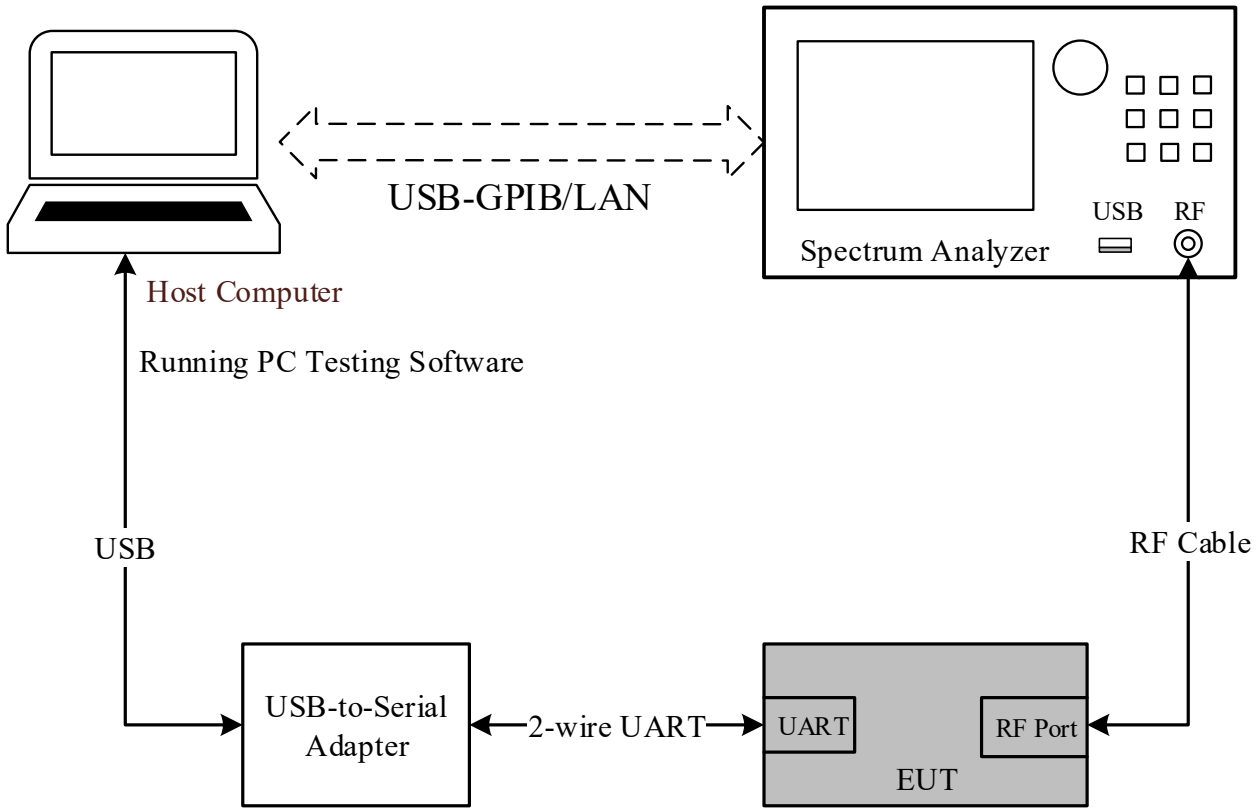
Test Setup

- The regulatory test configuration is similar to the BLE RF-PHY non-signaling test. The only difference is that a spectrum analyzer is used instead of a Bluetooth tester.
- All RF testing commands are sent by a host computer to control EUT. A high-level test setup is shown below:



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RF Test Commands for Apollo510B

- For Apollo510B, RF test commands to be used in regulatory tests are defined as follows:

Packaged HCI Commands	SSCOM Strings	Description
HCI_RESET	01 03 0C 00	Reset EUT before testing
HCI_LE_TRANSMITTER_TEST	01 C1 FC 06 transmitter_test_mode channel test_data_length pkt_payload_type Phy tx_power	**Transmitter test mode** (PM = Packet Mode, CM = Continuously modulated signal): 0x00 = PM (sending packets as in BLE DTM mode). 0x01 = CM - PRBS9 sequence 0x02 = CM - PRBS15 sequence 0x03 = CM - '0000000000000000' sequence 0x04 = CM - '1111111111111111' sequence 0x05 = CM - '0101010101010101' sequence 0x06 = CM - '0011001100110011' sequence 0x07 = CM - '0000111100001111' sequence 0x08 = CM - '0000000011111111' sequence 0x09 - 0xFF - Reserved **Packet payload type** for PM mode (valid only for packet mode): 0x00 = PRBS9 sequence 0x01 = Repeated '11110000' sequence 0x02 = Repeated '10101010' sequence 0x03 = PRBS15 0x04 = Repeated '11111111' sequence 0x05 = Repeated '00000000' sequence 0x06 = Repeated '00001111' sequence 0x07 = Repeated '01010101' sequence 0x08 - 0xFF = Reserved Transmit power level: Range: -127 to +20 Units: dBm
HCI_LE_TRANSMITTER_TEST_END	01 C2 FC 00	End current TX test and be ready for next one

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RF Test Commands for Apollo510B (continue)

Packaged HCI Commands	SSCOM Strings	Description
HCI_LE_RECEIVER_TEST	01 C5 FC 06 channel Phy Sync word (4-byte in little endian)	Set EUT in RX mode. Sync word is 0x29417671
HCI_LE_RECEIVER_TEST_END	01 C6 FC 00	1B status + 2B number of received packets + 2B average RSSI will be responded.

- ***Note:***
  - HCI_LE_TRANSMITTER_TEST examples sending packet in BLE DTM mode, payload type PRBS9 sequence with TX power @0 dBm:
    - 01 C1 FC 06 00 00 25 00 01 00, (2402MHz)
    - 01 C1 FC 06 00 13 25 00 01 00, (2440MHz)
    - 01 C1 FC 06 00 27 25 00 01 00, (2480MHz)

  - HCI_LE_RECEIVER_TEST examples:
    - 01 C5 FC 06 00 01 29 41 76 71, (2402MHz)
    - 01 C5 FC 06 13 01 29 41 76 71, (2440MHz)
    - 01 C5 FC 06 27 01 29 41 76 71, (2480MHz)

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RF Test Commands for Apollo4

- As provided in ANSI C63.10, the EUT should be set to operate in the worst-case transmission situation i.e. continuous transmit mode with 100% duty cycle regardless of the carrier wave or modulated data during testing.
- For Apollo4 Blue, RF testing commands to be used in regulatory tests are defined as shown below. Note the last octet in transmitter test command indicates the CW tone or continuous modulated signal.

Packaged HCI Commands	SSCOM Strings	Description
HCI_RESET	01 03 0C 00	Reset EUT before testing
HCI_LE_TRANSMITTER_TEST	01 1E 20 03 xx 25 10	'10': Set EUT in continuous carrier wave mode at center frequency
	01 1E 20 03 xx 25 11	'11': Set EUT in continuous modulation transmit mode with duty cycle = 100%
HCI_LE_RECEIVER_TEST	01 1D 20 01 xx	Set EUT in direct RX mode
HCI_LE_TEST_END	01 1F 20 00	End current test and be ready for next one

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RF Test Commands for Apollo3

- For Apollo3 Blue, RF testing commands to be used in regulatory tests are defined as as shown below. Note the last octet in transmitter test command indicates the CW tone or continuous modulated signal.

Packaged HCI Commands	SSCOM Strings	Description
HCI_RESET	01 03 0C 00	Reset EUT before testing
HCI_LE_TRANSMITTER_TEST	01 1E 20 03 xx 25 08	'08': Set EUT in continuous carrier wave mode at center frequency
	01 1E 20 03 xx 25 09	'09': Set EUT in continuous modulation transmit mode with duty cycle = 100%
HCI_LE_RECEIVER_TEST	01 1D 20 01 xx	Set EUT in direct RX mode
HCI_LE_TEST_END	01 1F 20 00	End current test and be ready for next one

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SRRC Requirements

No.	Test Items	Requirement	Channel for Testing	EUT Status
1	Peak Output Power	EIRP ≤ 20 dBm	Low/Mid/High	Continuous transmit mode
2	Frequency Tolerance	±20 ppm	Low/Mid/High	Carrier wave transmit mode
3	Frequency Range (Band Edge)	EIRP≤-80 dBm/Hz out of 2.4-2.4835 GHz band	Low/High	Continuous transmit mode
4	Spurious emissions of transmitter	See table on next page	Low/Mid/High	Continuous transmit mode
5	Spurious emissions of receiver	Same as above	Low/Mid/High	Receiver mode

- ***Note:***
  - The frequency tolerance mainly depends on the frequency accuracy of the external HF crystal (32 MHz or 48 MHz). Select the crystal accordingly.

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Limitation of Spurious Emission

Frequency Range	Measurement BW	Detector	Limit
30 - 1000 MHz	100 kHz	Peak	-36 dBm
2.4 – 2.4835 GHz	100 kHz	Peak	-33 dBm
3.4 - 3.53 GHz	1 MHz	Peak	-40 dBm
5.725 - 5.85 GHz	1 MHz	Peak	-40 dBm
Others within 1 - 12.75GHz	1MHz	Peak	-30 dBm

- ***Note:***
  - The frequency range should be set outside 2.5 times the channel bandwidth of the center frequency to be tested.
    - When measuring at 2402 MHz (lowest channel), the lower stop frequency should be set to 2397 MHz and the upper start frequency should be set to 2407 MHz.
    - When measuring at 2480 MHz (highest channel), the upper start frequency should be set to 2483.5 MHz.

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FCC Requirements

No.	Test Items	Requirement	Channel for Testing	EUT Status
1	Output Power	EIRP ≤ 30 dBm	Low/Mid/High	Continuous transmit mode
2	Occupied Bandwidth	6 dB Bandwidth ≥ 500 kHz	Low/Mid/High	Continuous transmit mode
3	Conducted Spurious Emission	-20 dBc (Peak) -30 dBc (Average)	Low/Mid/High	Continuous transmit mode
4	Band Edge (Authorized-band)	-20 dBc relative to desired power	Low/High	Continuous transmit mode
5	Band Edge (Restricted-band)	Compliance with RSE limit (especially at 2483.5 MHz)	Low/High	Continuous transmit mode
6	Power Spectral Density	≤ 8 dBm / 3 kHz	Low/Mid/High	Continuous transmit mode
7	RSE (Radiated Spurious Emission)	See table on next page	Low/Mid/High	Continuous transmit mode

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Limitation of RSE

Frequency Range	RBW	Detector	Distance	Field Strength	Calculated EIRP
30 – 88 MHz	100 kHz	Quasi-Peak	3 m	40 dBuV/m	-55 dBm
88 – 216 MHz				43.5 dBuV/m	-52 dBm
216 – 960 MHz				46 dBuV/m	-49 dBm
960 – 1000 MHz				54 dBuV/m	-41.2 dBm
1 – 18 GHz	1MHz	Average		54 dBuV/m	-41.2 dBm

Note:

- The relationship between field strength [dBuV/m] and EIRP [dBm] is:

  EIRP = E + 20log d –104.8 = Conducted Power + Antenna Gain

  where:

  - EIRP = the equivalent isotropically radiated power, in dBm
  - E = the field strength of the emission at the measurement distance, in dBµV/m
  - d = the measurement distance, in m

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CE Requirements

No.	Test Items	Requirement	Channel for Testing	EUT Status
1	RF Output Power	EIRP ≤ 20 dBm	Low/Mid/High	Continuous transmit mode
2	Power Spectral Density	≤ 10 dBm/MHz	Low/Mid/High	Continuous transmit mode
2	Occupied Channel Bandwidth (similar as band edge)	99% power BW fall within 2.4 – 2.4835 GHz completely	Low/High	Continuous transmit mode
3	Unwanted Emissions in out-of-band domain	-10 dBc at 2399 or 2484.5 MHz -20 dBc at 2398 or 2485.5 MHz	Low/High	Continuous transmit mode
4	Unwanted Emissions in spurious domain	See table on next two pages	Low/High	Continuous transmit mode
5	Receiver Spurious Emissions		Low/High	Receiver mode
6	Receiver Blocking		Low/High	Receiver mode

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Unwanted Emissions in spurious domain

Frequency Range	Maximum Power (dBm)	Measurement BW	Detector
30 – 47 MHz	-36	100 kHz	Peak
47 – 74 MHz	-54		
74 – 87.5 MHz	-36		
87.5 – 118 MHz	-54		
118 – 174 MHz	-36		
174 – 230 MHz	-54		
230 – 470 MHz	-36		
470 – 862 MHz	-54		
862 – 1000 MHz	-36		
1 – 12.75 GHz	-30	1MHz	

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Receiver Measurement

- Receiver Spurious Emissions

Frequency Range	Emission Limits (dBm)	Measurement BW	Detector
30 – 1000 MHz	-57	100 kHz	Peak
1 – 12.75 GHz	-47	1 MHz	

- Receiver Blocking Parameters (2 vector signal generators required)

Wanted signal mean power (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)	PER Limit	Blocking signal type
Pmin + 6 dB	2380	-57	10%	Continuous Wave
	2503.5			
Pmin + 6 dB	2300	-47		
	2583.5			

- Note:
  - Pmin is the minimum level of the wanted signal power (in dBm) at PER less than or equal to 10%.

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Notes

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Attention, Please!

- Proper impedance matching and filtering between chip and antenna are necessary for minimizing mismatch loss and rejecting harmonics.
- If possible, a shielding box is recommended to enclose the EUT to eliminate uncertain interfering signals in the air especially during RX testing.
- The conducted RF path loss (including cable and connector loss) between the EUT and tester should be set appropriately to get more accurate data.
- When preforming RSE tests in anechoic chamber, wiring out from EUT should be avoided in order that leakage power emitting in these leads is eliminated.
- It is recommended that all RF measurement instruments are calibrated annually or more frequently to guarantee measuring accuracy.

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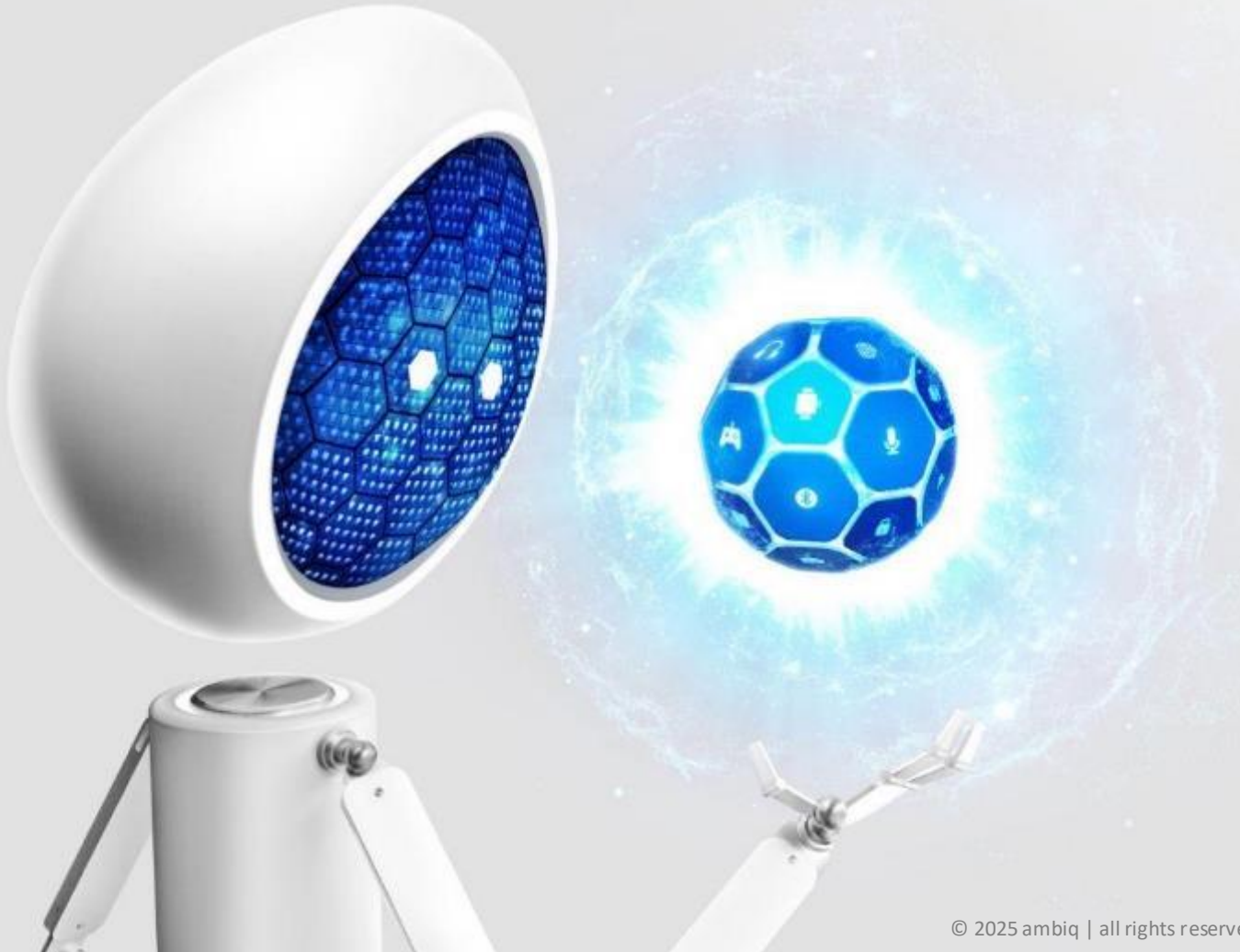

The End

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