LE Radio Physical Layer (RFPHY)

***Bluetooth*® Test Suite**

- **Revision:** RFPHY.TS.p23
- **Revision Date:** 2025-02-18
- **Prepared By:** BTI
- **Published during TCRL:** TCRL.2025-1

Contents

1 Scope

This Bluetooth document contains the Test Suite Structure (TSS) and test cases to test the implementation of the Radio Frequency Physical (RFPHY) layer with the objective to provide a high probability of air interface interoperability between the tested implementation and other manufacturers' Bluetooth devices.

2 References, definitions, and abbreviations

2.1 References

This document incorporates provisions from other publications by dated or undated reference. These references are cited at the appropriate places in the text, and the publications are listed hereinafter. Additional definitions and abbreviations can be found in [1] and [2]. Mathematical conventions used in this document comply with the definitions given in [1].

[1] Test Strategy and Terminology Overview

[2] Bluetooth Specification, Version 4.0 or later, Vol. 6, Part A: Physical Layer Specification

[3] ICS Proforma for RFPHY

[4] Bluetooth Specification, Version 4.0 or later, Vol. 6, Part F: Direct Test Mode

[5] Bluetooth Core IXIT Proforma

[6] Bluetooth Core Specification Addendum 5, Volume 6, Part A: Physical Layer Specification

[7] Bluetooth Specification, Version 5.0 or later, Vol. 6, Part A: Physical Layer Specification

[8] Bluetooth Specification, Version 5.1 or later, Vol. 6, Part A: Physical Layer Specification

[9] Bluetooth Specification, Version 5.1 or later, Vol. 6, Part F: Direct Test Mode

[10] Bluetooth Specification, Version 5.0 or later, Vol. 6, Part B: Link Layer Specification

[11] Bluetooth Specification, Version 6.0 or later, Vol. 6, Part A: Physical Layer Specification

[12] Bluetooth Specification, Version 6.0 or later, Vol. 6, Part F: Direct Test Mode

2.2 Definitions

In this Bluetooth document, the definitions from [1] and [2] apply.

2.3 Acronyms and abbreviations

In this Bluetooth document, the definitions, acronyms, and abbreviations from [1] and [2] apply.

3 Test Suite Structure (TSS)

3.1 Test Strategy

The two primary objectives of the Test Strategy are:

- To ensure interoperability between devices in the marketplace
- To verify that a basic level of system performance is provided by devices in the marketplace

The objectives are met by performing a series of functional and parametric tests over the allowed range of parameter variation.

With these objectives in mind, the creation of the Test Strategy also considers ways to reduce the test execution time required for product qualification.

To avoid qualification test redundancy, telecommunication regulatory motivated tests are not included in the Bluetooth qualification requirements.

3.2 Test groups

The test groups are organized in two levels. The first level defines the protocol groups representing the protocol services. The second level separates the protocol services in functional modules. All tests are Capability tests as defined in the standard ISO subgroups.

3.2.1 Protocol groups

The protocol group identifies the following test purposes:

- Transmitter
- Receiver

4 Test cases (TC)

4.1 Introduction

4.1.1 Test case identification conventions

Test cases are assigned unique identifiers per the conventions in [1]. The convention used here is: **<spec abbreviation>/<IUT role>/**<class>/**<feat>**/<func>/<subfunc>/<cap>/**<xx>-<nn>-<y>**.

Identifier Abbreviation	**Spec Identifier <spec abbreviation>**
RFPHY	Bluetooth Low Energy physical layer specification
Identifier Abbreviation	**Class Identifier <class>**
RCV	Receiver tests
TRM	Transmitter tests
TRM-RCV	Transmitter/Receiver tests
Identifier Abbreviation	**Feature Identifier <feat>**
CS	Channel Sounding
IQC	IQ samples Coherency
IQDR	IQ samples Dynamic Range
PS	Power Stability

Table 4.1: RFPHY TC feature naming conventions

4.1.2 Conformance

When conformance is claimed for a particular specification, all capabilities are to be supported in the specified manner. The mandated tests from this Test Suite depend on the capabilities to which conformance is claimed.

The Bluetooth Qualification Program may employ tests to verify implementation robustness. The level of implementation robustness that is verified varies from one specification to another and may be revised for cause based on interoperability issues found in the market.

Such tests may verify:

- That claimed capabilities may be used in any order and any number of repetitions not excluded by the specification
- That capabilities enabled by the implementations are sustained over durations expected by the use case
- That the implementation gracefully handles any quantity of data expected by the use case
- That in cases where more than one valid interpretation of the specification exists, the implementation complies with at least one interpretation and gracefully handles other interpretations
- That the implementation is immune to attempted security exploits

A single execution of each of the required tests is required to constitute a Pass verdict. However, it is noted that to provide a foundation for interoperability, it is necessary that a qualified implementation consistently and repeatedly pass any of the applicable tests.

In any case, where a member finds an issue with the test plan generated by the Bluetooth SIG qualification tool, with the test case as described in the Test Suite, or with the test system utilized, the member is required to notify the responsible party via an erratum request such that the issue may be addressed.

4.2 Cabled test setup configurations

This section describes the cabled test setups for tests between an IUT and a test system when performing specific groups of tests in this Test Suite.

4.2.1 Test Equipment Setup for AoD Receiver testing

This setup is used to test IQ samples coherency on an IUT that is an AoD Receiver.

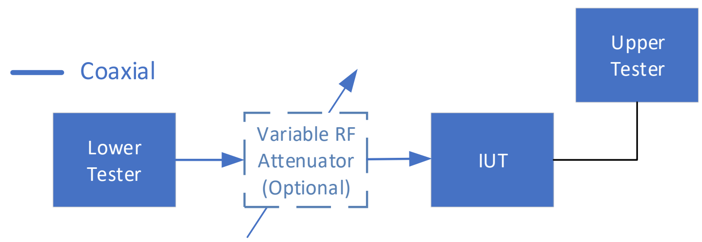

Figure 4.1: Test Equipment Setup for AoD Receiver

4.2.2 Test Equipment Setup for AoA Receiver or AoD Transmitter testing

This setup is used to test IQ samples coherency on an IUT that is an AoD Transmitter or an AoA Receiver.

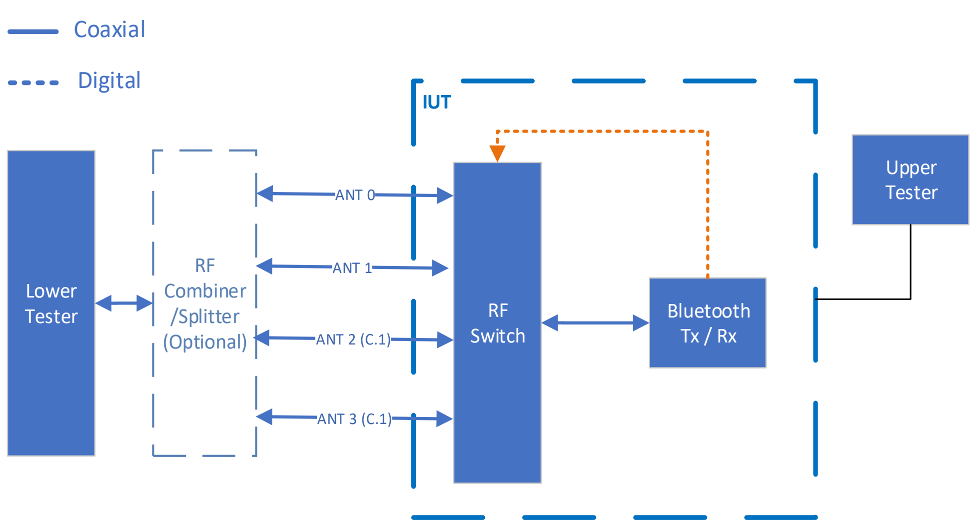

Figure 4.2: Test Equipment Setup for AoA Receiver or AoD Transmitter (C.1 – Mandatory to support if declared, otherwise Excluded)

The IUT provides 2–4 antenna input/output ports, matching the maximum number of antennae supported (TSPX_number_of_antennae) declared in the IXIT [5]. The antenna ports are marked as 0, 1, 2, and 3 in Figure 4.2. If the IUT only supports external antenna switching, an IUT-controlled RF switch component is used.

4.2.3 Test Equipment Setup for Channel Sounding testing

This test setup is used to test Channel Sounding on an IUT.

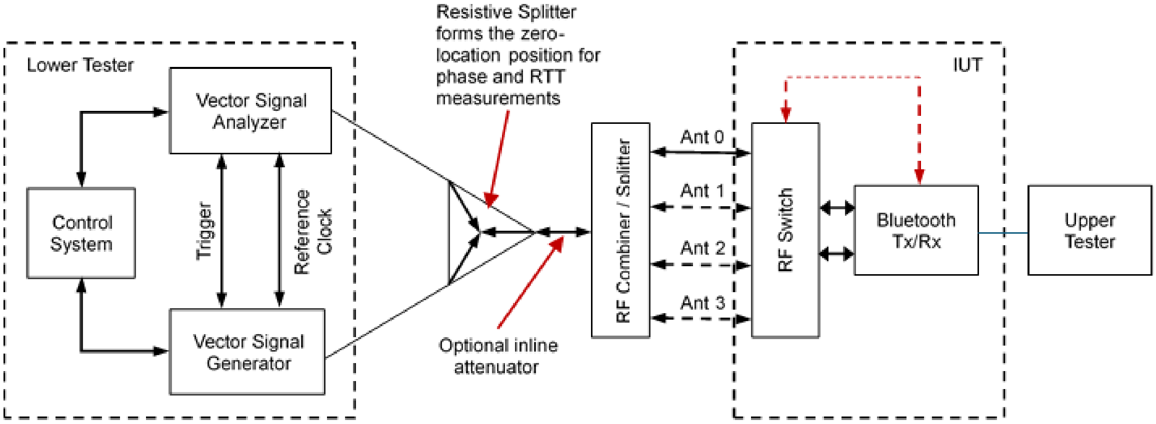

Figure 4.3: Test Equipment Setup for Channel Sounding

The IUT provides 1–4 antenna input/output ports, matching the maximum number of antenna supported (TSPX_number_of_cs_antennae) declared in the IXIT [5]. The antenna ports are marked as 0, 1, 2, and 3, as shown in Figure 4.3.

The optional inline attenuator shown in Figure 4.3 is for use in level adjustment purposes to balance the input signal levels present at the VSA's input RF port. The VSA's input RF port is exposed to both the transmission energy from the VSG and the IUT in 2-way Channel Sounding ranging procedures.

4.3 Common test case conditions and parameters

Unless stated otherwise in individual test cases the following applies throughout this Test Suite:

1. The IUT is connected to the Lower Tester via a 50Ω connector. If there is no antenna interface, a temporary 50Ω interface or a suitable coupling device may be used.
2. The test case is to be performed at normal operating conditions.

The Bluetooth low energy system uses center frequencies 2402 + n*2 MHz, where n = 0,1,2…39. The total number of communication frequencies is 40.

A Bluetooth low energy system supporting Channel Sounding uses 72 RF channels for CS exchanges. These RF channels have center frequencies at 2402 + k*1 MHz, where k is an integer from 2 to 22 and 26 to 76.

The Test Suite uses the direct test mode in all transmit and receive test cases [4]. In direct test mode, hopping is disabled and the IUT's transmit and receive frequencies are set according to the frequencies for testing defined for each test.

4.3.1 Default Frequencies

The default frequencies for testing are as follows:

Modulation	IUT Low	IUT Mid	IUT High
1 Msym/s	2402 MHz (n=0)	2426 MHz (n=12) or 2440 MHz (n=19) at the choice of the IUT	2480 MHz (n=39)
2 Msym/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

4.3.2 Channel Sounding Default Frequencies

The default frequencies (f_O) used for Channel Sounding (populated in the Override Channel[i] channel pattern list) testing are as follows:

Modulation	IUT Low	IUT Mid	IUT High
1 Msym/s	2404 MHz (k=2)	2440 MHz (k=38)	2478 MHz (k=76)
2 Msym/s	2404 MHz (k=2)	2440 MHz (k=38)	2478 MHz (k=76)
2 Msym/s, BT = 2.0	2412 MHz (k=10)	2440 MHz (k=38)	2470 MHz (k=68)

The number of Mode-0 and Main-Mode CS steps per CS sub-event that use the static CS test frequencies is defined in Section 4.3.3.3. The channels specified for test are repeated for as many CS procedures that are required to satisfy the test case criteria.

4.3.3 Common Parameters and Variables

4.3.3.1 Channel Sounding Access Addresses

CS packets containing a CS_SYNC portion (including CS test packets) use a role-dependent static Access Address (CS synchronization word):

- Role = Initiator: ‘10100001111010100100110101101100’ (in transmission order)
- Role = Reflector: ‘00011110011101101000011110000101’ (in transmission order)

Note: CS roles are interchangeable dependent upon the test to be performed between the Tester and the IUT.

4.3.3.2 Channel Sounding Test Command Parameters

This section defines the HCI_LE_CS_Test Command default parameters (see Vol. 4, Part E, Section 7.8.142, “LE CS Test Command”). This command is used to schedule a single CS procedure that consists of one CS subevent used for the CS RFPHY test.

The default values detailed in Table 4.2 are used unless otherwise specified.

Parameter	Value
Main_Mode_Type	0x01 (Mode-1)
Sub_Mode_Type	0xFF (Unused)
Main_Mode_Repetition	0x00 (No repetition)
Mode_0_Steps	0x03 (Maximum)
Role	0x00 (Initiator)
RTT_Type	0x00 (RTT AA Only)
CS_SYNC_PHY	0x01 (LE 1M PHY)
CS_SYNC_Antenna_Selection	0x01 (A1)
Subevent_Len	0x3D08FF
Subevent_Interval	0x0000 (Single sub-event)
Max_Num_Sub_events	0x00 (Ignore)
Transmit_Power_Level	0x7F (Maximum)
T_IP1_Time	Shortest supported by the IUT
T_IP2_Time	Shortest supported by the IUT
T_FCS_Time	Shortest supported by the IUT

Parameter	Value
T_PM_Time	0x28 (40 us)
T_SW_Time	0x00 (0 us)
Tone_Antenna_Config	0x00 (1:1)
Reserved	0x00
DRBG_Nonce	0x0000
Channel_Map_Repetition	0x01 (Single repetition)
Override_Config	0x0129 (Bits 0, 3, 5, and 8 enabled: 0: Channel_Length and Channel[i] 3: T_PM_Tone_Ext 5: Access Address 8: Payload pattern)
Override_Parameters_Length	0x0E
Override_Parameters_Data	0x03 (Channel_Length) 0x02, 0x02, 0x02 (Channel[i]) 0x00 (T_PM_Tone_Ext: No tone extensions) 0x36B25785 (CS_SYNC_AA_Initiator) 0xA1E16E78 (CS_SYNC_AA_Reflector) 0x00 (Payload Pattern, PRBS9)

Table 4.2: LE CS Test Command Default Parameters

For tests requiring a pseudo random full-band frequency sweep, the Override parameters are set as specified in Table 4.3.

Parameter	Value
Override_Config	0x0129 (Bits 0, 3, 5, and 8 enabled)
Override_Parameters_Length	0x53
Override_Parameters_Data	0x48 (Channel_Length) {See Table 4.5} (Channel[i]) 0x00 (T_PM_Tone_Ext) 0x36B25785 (CS_Sync_AA_Initiator) 0xA1E16E78 (CS_Sync_AA_Reflector) 0x00 (Payload Pattern, PRBS9)

Table 4.3: LE CS Test Command Override Parameters for the full-band frequency sweep

For the Step Mode-0, Frequency Verification measurements, the Override parameters are set as specified in Table 4.4.

Parameter	Value
Override_Config	0x0129 (Bits 0, 3, 5, and 8 enabled)
Override_Parameters_Length	0x0E

Parameter	Value
Override_Parameters_Data	0x03 (Channel_Length) {See Table 4.5} (Channel[i]) 0x00 (T_PM_Tone_Ext) 0x36B25785 (CS_Sync_AA_Initiator) 0xA1E16E78 (CS_Sync_AA_Reflector) 0x00 (Payload Pattern, PRBS9)

Table 4.4: LE CS Test Command Override Parameter for Step Mode-0, Frequency Verification test cases

List of channels used in the test pattern are populated via the Channel[i] parameter.

- For the full-band frequency sweep (see Table 4.3) (used in phase measurement accuracy tests) the entire 72 CS channel list as defined in Table 4.5 is utilized.
- For Step Mode-0, Frequency Verification (see Table 4.4), three channels (3 Mode-0, and 1 Main-Mode) are used. These channels are defined as channel[i mod 72] to channel[(i+2) mod 72] in channel list. In the first subevent tested [i] = 0. For each subsequent subevent, the channels used are shifted by [i+1], i.e., the channels used in the second subevent are channel[i+1] to channel[i+3] and so on. The Channel[i] list in Table 4.5 is cycled through for as many times as required to perform the test case. The selected three channels may end at any position in the Channel[i] list.

Parameter	Value
Channel[i]	{ 0x15, 0x0c, 0x0a, 0x1d, 0x05, 0x11, 0x4a, 0x4c, 0x14, 0x41, 0x0b, 0x02, 0x24, 0x3e, 0x13, 0x2c, 0x32, 0x43, 0x1e, 0x2a, 0x2b, 0x06, 0x0e, 0x25, 0x22, 0x1c, 0x03, 0x3d, 0x29, 0x34, 0x45, 0x1a, 0x2d, 0x26, 0x09, 0x36, 0x48, 0x21, 0x04, 0x44, 0x31, 0x3a, 0x28, 0x0d, 0x4b, 0x27, 0x39, 0x16, 0x33, 0x49, 0x3f, 0x46, 0x1f, 0x47, 0x3c, 0x37, 0x42, 0x2f, 0x07, 0x1b, 0x23, 0x10, 0x30, 0x35, 0x12, 0x2e, 0x20, 0x40, 0x08, 0x38, 0x0f, 0x3b }

Table 4.5: LE CS Test Command Channel[i] Override Parameter values

4.3.3.3 Channel Sounding Signal Transmission

This section defines the generic Initiator-Reflector signal exchange used for Channel Sounding RFPHY tests. Tests are performed on a CS sub-event basis. A single CS sub-event is scheduled within each CS procedure utilized, see [12].

Each CS sub-event contains the following CS steps (signal exchanges):

- M Mode-0 CS steps, in the range $1 \leq M \leq 3$ followed by,
- K Main-Mode CS steps, in the range $1 \leq K \leq 72,$

Figure 4.4 outlines the CS step exchanges within a single CS sub-event. T_IPx refers to a CS step mode dependent Initiator-Reflector interlude period:

- T_IP1; Mode-0, and Mode-1 CS signal exchange interlude period.
- T_IP2; Mode-2, and Mode-3 CS signal exchange interlude period.

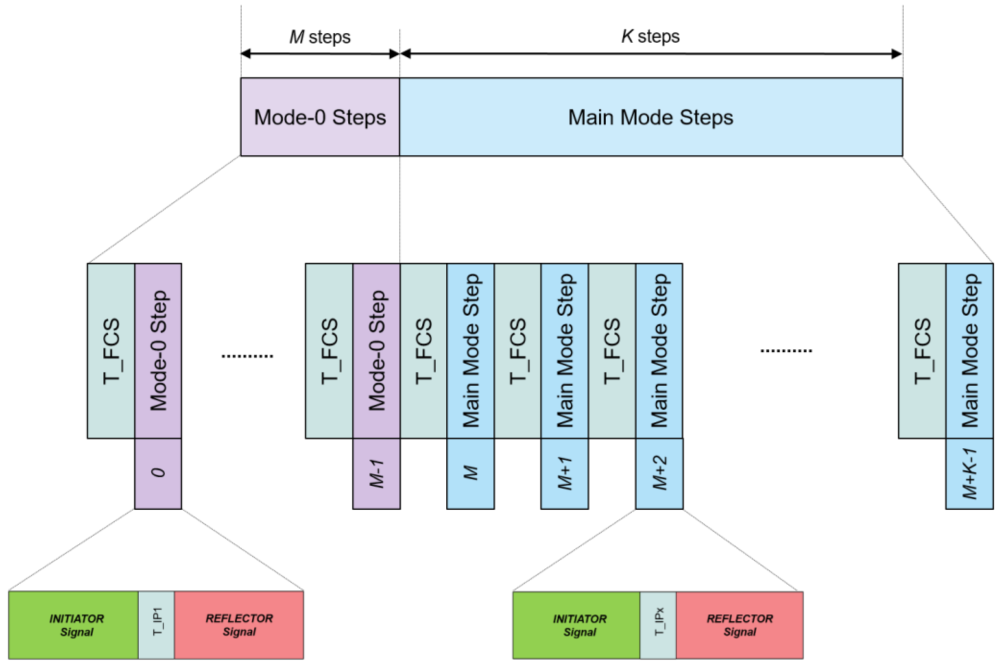

Figure 4.4: Channel Sounding RFPHY test signal transmission overview

4.4 Pass/Fail verdict conventions

Each test case has an Expected Outcome section. The IUT is granted the Pass verdict when all the detailed pass criteria conditions within the Expected Outcome section are met.

The convention in this Test Suite is that, unless there is a specific set of fail conditions outlined in the test case, the IUT fails the test case as soon as one of the pass criteria conditions cannot be met. If this occurs, then the outcome of the test is a Fail verdict.

4.5 Common Packet Contents

4.5.1 Fields and Bits Reserved for Future Use

Unless a specific test states otherwise, all fields within packets and all bits within fields that are described as reserved for future use are set to 0 in packets sent by the Upper and Lower Testers.

4.6 Transmitter tests (TRM)

4.6.1 Output power

- Test Purpose

  Verify the maximum peak and average power emitted from the IUT.

- Reference

  [2] Chapter 3

  [6] Chapter 3

- Initial Condition
  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.

- The values of MAX_TX_LENGTH and MAX_TX_LENGTH_2M (for which the TC is performed) are specified in Section 6.6.
- TSPX_Antenna_Gain is declared by the manufacturer of the IUT in the IXIT [5].
- The IUT is set for a symbol rate as specified in Table 4.6.
- If the IUT supports CTE as specified in Table 4.6, the IUT is set to transmit AoA Constant Tone Extensions.

• Test Case Configuration

Test Case	P_{AVG} Requirements	Symbol Rate	Payload Length
RFPHY/TRM/BV-01-C [Output power, 1 Ms/s]	-20 dBm ≤ P_{AVG} ≤ +10 dBm	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-18-C [Output power, Class 1, 1 Ms/s]	+10 dBm < P_{AVG} ≤ +20 dBm	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-19-C [Output power, 2 Ms/s]	-20 dBm ≤ P_{AVG} ≤ +10 dBm	2 Ms/s	MAX_TX_LENGTH_2M
RFPHY/TRM/BV-20-C [Output power, Class 1, 2 Ms/s]	+10 dBm < P_{AVG} ≤ +20 dBm	2 Ms/s	MAX_TX_LENGTH_2M
RFPHY/TRM/BV-15-C [Output power, With Constant Tone Extension, 1 Ms/s]	-20 dBm ≤ P_{AVG} ≤ +10 dBm	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-21-C [Output power, With Constant Tone Extension, Class1, 1 Ms/s]	+10 dBm < P_{AVG} ≤ +20 dBm	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-22-C [Output power, With Constant Tone Extension, 2 Ms/s]	-20 dBm ≤ P_{AVG} ≤ +10 dBm	2 Ms/s	MAX_TX_LENGTH_2M
RFPHY/TRM/BV-23-C [Output power, With Constant Tone Extension, Class1, 2 Ms/s]	+10 dBm < P_{AVG} ≤ +20 dBm	2 Ms/s	MAX_TX_LENGTH_2M

Table 4.6: Output power test cases

- Test Procedure

1. The IUT transmits LE test packets with PRBS9 payload (Payload Length specified in Table 4.6). See [4] Section 4, “LE Test Packet Definition” for details. If the IUT supports CTE as specified in Table 4.6, then the Constant Tone Extension is TSPX_CTE_len_max * 8 µs.
2. The following settings are used for the Lower Tester:

Center frequency	at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case)
Frequency span	Zero span
Resolution BW	3 MHz
Video BW	3 MHz
Detector	Peak
Mode	Clear/Write
Sweep time	Must cover at least one complete test packet
Trigger	RF (trigger on rising edge)

3. Upon packet transmission, the Lower Tester is triggered to make a sweep over the duration of one packet. The sweep starts at the beginning of the first bit in the preamble.
4. The peak power value, P_{PK}, of the sweep is recorded.
5. The Lower Tester calculates average power P_{AVG} over at least 20%–80% of the burst duration (position of p_0 defines the beginning of the burst; see Section 6.4 Definition of the Position of Bit p0).
6. Steps 2–5 are repeated for the remaining frequencies for testing defined in the test condition section.
7. The antenna gain G (in dBi) is added to the P_{AVG} results (in dBm) to calculate the average equivalent isotropic radiated power $P_{AVG\ EIRP}$.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  <u>Pass verdict</u>

  All measured values fulfill the following conditions:

  $P_{PK} \leq (P_{AVG} + 3\ dB)$

  $P_{AVG\ EIRP} = P_{AVG} + G \leq 100\ mW\ (20\ dBm)\ EIRP$

  P_{AVG} meets the requirements in Table 4.6.

4.6.2 In-band emissions

- Test Purpose

  Verify that the in-band spectral emissions are within limits at normal operating conditions from the IUT.

- Reference

  [2] Chapter 3.2

  [7] Chapter 3.2.2

- Initial Condition
  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_TX_LENGTH and MAX_TX_LENGTH_2M (for which the TC is performed) is specified in Section 6.6.
- Test Case Configuration

Test Case	In-band Emission Requirements	Frequencies To Skip	Symbol Rate	Payload Length
RFPHY/TRM/BV-03-C [In-band emissions, uncoded data at 1 Ms/s]	P_{TX} ≤ -20 dBm for (f_{TX} ± 2 MHz) P_{TX} ≤ -30 dBm for (f_{TX} ± [3 + n] MHz])*	f_{TX} $f_{TX - 1MHz}$, $f_{TX + 1MHz}$	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-08-C [In-band emissions at 2 Ms/s]	P_{TX} ≤ -20 dBm for (f_{TX} ± 4 MHz) P_{TX} ≤ -20 dBm for (f_{TX} ± 5 MHz) P_{TX} ≤ -30 dBm for (f_{TX} ± [6 + n] MHz])*	f_{TX} $f_{TX - 1MHz}$, $f_{TX + 1MHz}$ $f_{TX - 2MHz}$, $f_{TX + 2MHz}$ $f_{TX - 3MHz}$, $f_{TX + 3MHz}$	2 Ms/s	MAX_TX_LENGTH_2M

* where n=0,1,2…

Table 4.7: In-band emissions test cases

- Test Procedure
  1. The IUT is set to receive at the lowest frequency for testing defined in frequencies for testing defined in the test condition section.
  2. The IUT transmits LE test packets with PRBS9 payload (Payload Length specified in Table 4.7). See [4], Section 4, “LE Test Packet Definition” for details.
  3. Set N:=0
  4. The following settings are used for the Lower Tester:

Center frequency	2401 MHz + N MHz
Frequency span	1 MHz
Resolution BW	100 kHz
Video BW	300 kHz
Detector	Average
Mode	Maximum hold
Sweep time	100 ms
Number of sweeps	10

  5. Measure the power levels, P_{TX}_N,i at the following 10 frequencies: (2401 MHz + N MHz) – 450 kHz + i·100 kHz, where i=0…9
  6. Calculate and record PTX = Σ(P_{TX}_N,i)

7. Increase center frequency by 1 MHz; N:=N+1 AND skip to next frequency if the increased frequency is equal to Frequency To Skip specified in Table 4.7.
8. Repeat Steps 4–7 until the center frequency is 2481 MHz
9. Set the IUT transmit frequency (f_{TX}) to:
10. The mid operating frequency defined in the frequencies for testing defined in the test condition section and
11. The high operating frequency defined in the frequencies for testing defined in the test condition section
12. Repeat Steps 3–8 for both frequencies.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  All measured values fulfill the In-band Emission Requirements specified in Table 4.7.

  For each operating frequency, up to three bands of 1 MHz width (as defined in the measurement) can be exempted from the requirements. The excepted values, however, comply with an absolute value of $P_{TX} \leq -20$ dBm.

4.6.3 Modulation characteristics

- Test Purpose

  Verify that the modulation characteristics of the transmitted signal are correct.

- Reference

  [2] Chapter 3.1

  [6] Chapter 3.1, Chapter 3.1.1

- Initial Condition
  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_TX_LENGTH, MAX_TX_LENGTH_2M, and MAX_TX_LENGTH_CODED_S8 (for which the TC is performed) is specified in Section 6.6.

- Test Case Configuration

Test Case	$\Delta f1_{avg}$ Requirements	Symbol Rate	Payload Length
RFPHY/TRM/BV-05-C [Modulation Characteristics, uncoded data at 1 Ms/s]	225 kHz ≤ $\Delta f1_{avg}$ ≤ 275 kHz	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-09-C [Stable Modulation Characteristics, uncoded data at 1 Ms/s]	247.5 kHz ≤ $\Delta f1_{avg}$ ≤ 252.5 kHz	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-10-C [Modulation Characteristics at 2 Ms/s]	450 kHz ≤ $\Delta f1_{avg}$ ≤ 550 kHz	2 Ms/s	MAX_TX_LENGTH_2M

Test Case	$\Delta f1_{avg}$ Requirements	Symbol Rate	Payload Length
RFPHY/TRM/BV-11-C [Stable Modulation Characteristics at 2 Ms/s]	495 kHz $\leq \Delta f1_{avg} \leq$ 505 kHz	2 Ms/s	MAX_TX_LENGTH_2M
RFPHY/TRM/BV-13-C [Modulation Characteristics, LE Coded (S=8)]	225 kHz $\leq \Delta f1_{avg} \leq$ 275 kHz 99.9% of all $\Delta f1_{max}$ frequency values recorded over 10 LE test packets are greater than 185 kHz	1 Ms/s coded S=8	MAX_TX_LENGTH_CODED_S8

Table 4.8: Modulation characteristics test cases

- Test Procedure

1. The IUT is set to transmit at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case).
2. The IUT transmits LE test packets with Payload Length (specified in Table 4.8) octet packet payload. See [4], Section 4, "LE Test Packet Definition", for details.

   For Uncoded 1 Ms/s and 2 Ms/s, the payload consists of a repetitive sequence of $0F_{hex}$ octets (11110000_{bin} in transmission order).

   For LE Coded (S=8), the payload consists of a repetitive sequence of 0xFF octets (binary '11111111' in transmission order). This sequence, once passed through the S=8 encoder, becomes a repetitive sequence of '00111100' symbols. The symbol duration is 1 µs.

3. The following settings are used for the Lower Tester:

Center frequency	lowest frequency for testing as defined in the test condition section
Mode	FM demodulation
Demodulator filter BW	Specified in Section 6.9 (minimum)
Filter passband ripple	Specified in Section 6.9
Trigger	RF (trigger on rising edge)

The following measurement channel filter minimum attenuator characteristics are used:

Frequency (for 1 Ms/s)	Frequency (for 2 Ms/s)	Attenuation
±650 kHz	±1.3 MHz	-3 dB
±1 MHz	±2.0 MHz	-14 dB
±2 MHz	±4.0 MHz	-44 dB

4. The payload is FM demodulated with the settings described in Step 3.

   For Uncoded 1 Ms/s and 2 Ms/s, the measurement starts at the beginning of the fifth bit of the payload (see Figure 4.5 for description). The last four bits in the payload are disregarded (i.e., last bit in the measurement is the fourth bit in the final payload octet).

   For LE Coded (S=8), the measurement starts at the beginning of the 31st symbol in the payload. The last 34 symbols in the payload are disregarded.

5. Each individual bit is to be oversampled at least 32 times. The sequence center frequency; $f1_{ccf}$ is calculated as the average frequency of all samples over each 00001111_{bin} sequence.

6. For the second, third, sixth and seventh bits in each 00001111_{bin} sequence, the absolute value of the frequency offset from $f1_{ccf}$ is recorded as $\Delta f1_{max}$. $\Delta f1_{max}$ is defined as the average deviation for each individual bit. See Figure 4.5 for reference.
7. The average frequency value of all $\Delta f1_{max}$ frequencies in a packet is calculated and recorded as $\Delta f1_{avg}$.
8. For LE Coded (S=8), skip Steps 9–13; S=8 only supports ‘0011’ and ‘1100’ see Section 3.3.2, “Pattern mapper” in [10] for details.
9. The IUT transmits LE test packets with Payload Length (specified in Table 4.8) octet payload consisting of a repetitive sequence of 55_{hex} octets (10101010_{bin} in transmission order). See [4], Section 4, “LE Test Packet Definition” for details.
10. The payload is FM demodulated with the settings described in Step 3. The measurement starts at the beginning of the fifth bit in the payload field. The last four bits in the payload are disregarded (i.e., last bit in the measurement is the fourth bit in the final payload octet).
11. Each individual bit is to be oversampled at least 32 times. The sequence center frequency; f2ccf is calculated as the average frequency of all samples over each 10101010_{bin} sequence.
12. The maximum deviation from the sequence center frequency, $f2_{ccf}$ is recorded as $\Delta f2_{max}$ for each individual bit. See Figure 4.6 for reference.
13. The average frequency value of all $\Delta f2_{max}$ frequencies in a packet is calculated and recorded as $\Delta f2_{avg}$.
14. Steps 2–13 are repeated for a minimum of 10 packets.
15. Steps 2–14 are repeated when the IUT is transmitting at the remaining frequencies defined in the test condition section.

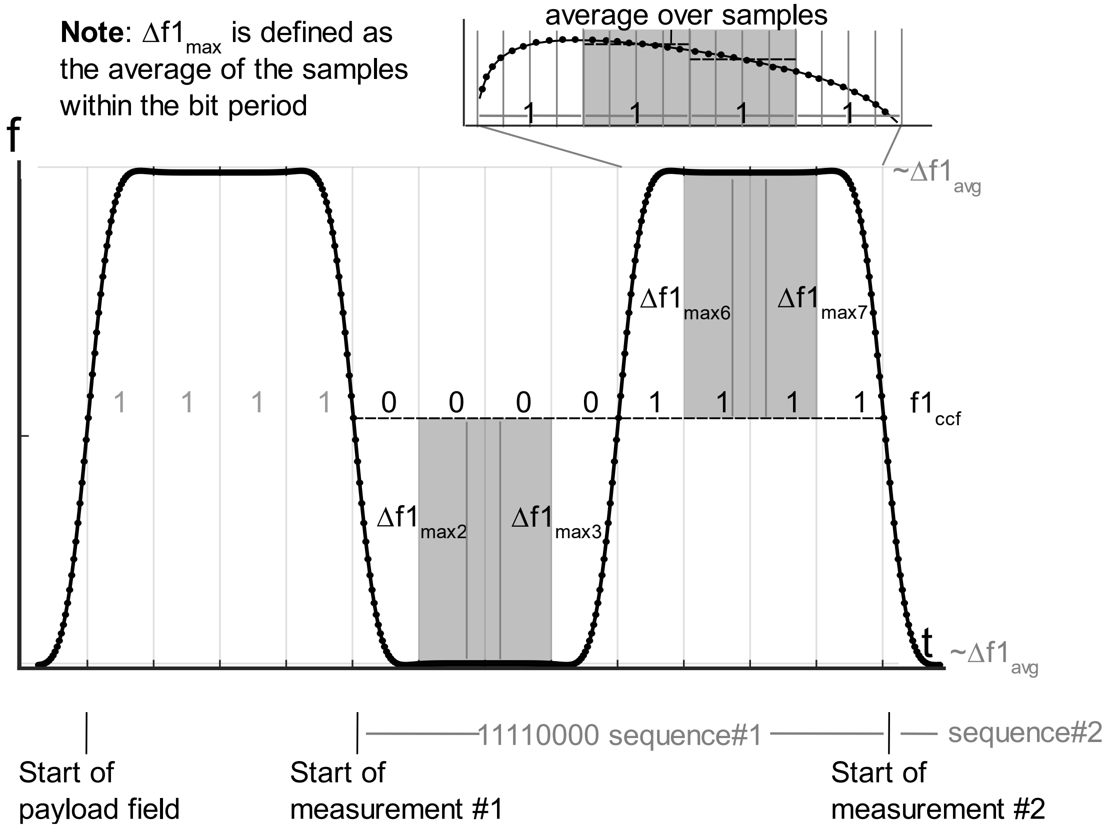

Figure 4.5: Frequency deviation measurement principle for 11110000-payload sequence

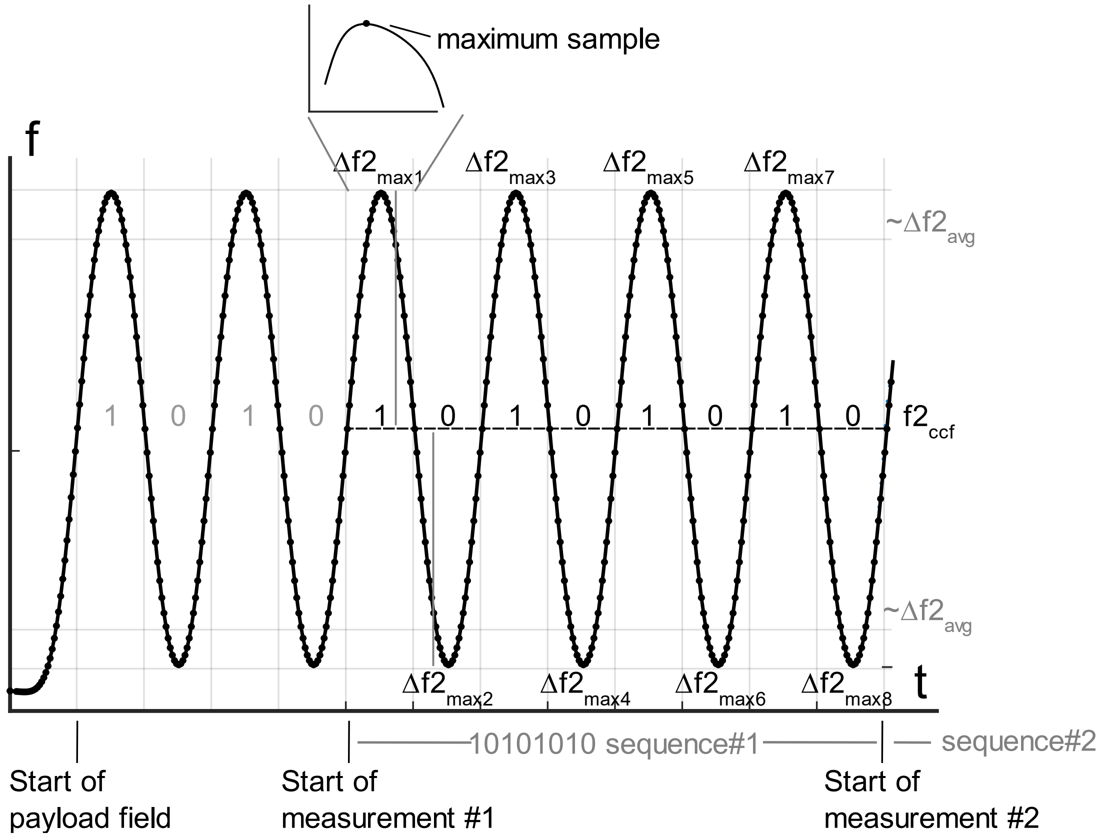

Figure 4.6: Frequency deviation measurement principle for 10101010-payload sequence

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  All measured values fulfill the $\Delta f1_{avg}$ Requirements specified in Table 4.8 at the low, mid, and high frequencies:

  Where $\Delta f2_{max}$ is recorded (all cases except LE Coded, S=8), at least 99.9% of all $\Delta f2_{max}$ frequency values recorded over 10 LE test packets are greater than 185 kHz (for 1 Ms/s) or 370 kHz (for 2 Ms/s).

  Where $\Delta f2_{avg}$ is recorded (all cases except LE Coded, S=8): $\frac{\Delta f2_{avg}}{\Delta f1_{avg}} \geq 0.8$

- Notes

  To compensate for the statistical distribution of individual samples, the decision criteria is applied to 99.9% of the sample values.

4.6.4 Carrier frequency offset and drift

- Test Purpose

  Verify that the carrier frequency offset and carrier drift of the transmitted signal are correct.

- Reference

  [2] Chapter 3.3

  [6] Chapter 3.3

- Initial Condition
  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_TX_LENGTH, MAX_TX_LENGTH_2M, and MAX_TX_LENGTH_CODED_S8 (for which the TC is performed) is specified in Section 6.6.

- Test Case Configuration

Test Case	Drift Requirement Limits	Symbol Rate	Payload Length
RFPHY/TRM/BV-06-C [Carrier frequency offset and drift, uncoded data at 1 Ms/s]	$\lvert f_1 - f_0\rvert \le 23$ kHz $\lvert f_n - f_{n-5}\rvert_{n=6, 7, 8 \ldots k} \le 20$ kHz	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-12-C [Carrier frequency offset and drift at 2 Ms/s]	$\lvert f_1 - f_0\rvert \le 13.3$ kHz $\lvert f_n - f_{n-5}\rvert_{n=6, 7, 8 \ldots k} \le 20$ kHz	2 Ms/s	MAX_TX_LENGTH_2M
RFPHY/TRM/BV-14-C [Carrier frequency offset and drift, LE Coded (S=8)]	$\lvert f_0 - f_3\rvert \le 19.2$ kHz $\lvert f_n - f_{n-3}\rvert_{n=7, 8, 9 \ldots k} \le 19.2$ kHz	1 Ms/s coded S=8	MAX_TX_LENGTH_CODED_S8

Table 4.9: Carrier frequency offset and drift test cases

- Test Procedure
  1. The IUT is set to transmit at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case.
  2. The IUT transmits LE test packets with Payload Length (specified in Table 4.8) octet payload. See [4], Section 4, “LE Test Packet Definition”, for details.

     For Uncoded 1 Ms/s and 2 Ms/s, the payload consists of a repetitive sequence of 55_{hex} octets (10101010_{bin} in transmission order) in the payload.

     For LE Coded (S=8), the payload consists of a repetitive sequence of 0xFF octets (binary ‘11111111’ in transmission order). This sequence, once passed through the S=8 encoder, becomes a repetitive sequence of ‘00111100’ symbols. The symbol duration is 1 µs.

3. The following settings are used for the Lower Tester:

Center frequency	lowest frequency for testing defined in the test condition section
Mode	FM demodulation
Demodulator filter BW	Specified in Section 6.9 (minimum)
Filter passband ripple	Specified in Section 6.9
Trigger	RF (trigger on rising edge)

The following measurement channel filter minimum attenuator characteristics are used:

Frequency (for 1 Ms/s)	Frequency (for 2 Ms/s)	Attenuation
±650 kHz	±1.3 MHz	-3 dB
±1 MHz	±2.0 MHz	-14 dB
±2 MHz	±4.0 MHz	-44 dB

The packet is FM demodulated with the settings described in Step 3. The measurement is to be performed at the start of the preamble field in the transmitted packet.

For Uncoded 1 Ms/s, the Lower Tester integrates the frequency of the FM demodulated signal from the center of the first preamble bit to the center of the first bit following the 8th preamble bit, 8 bits in total. See Figure 4.7 for reference.

For 2 Ms/s, the Lower Tester integrates the frequency of the FM demodulated signal from the center of the first preamble bit to the center of the first bit following the 16th preamble bit, 16 bits in total.

For LE Coded (S=8), the Lower Tester integrates the frequency of the FM demodulated signal in groups of 16 symbols. The first symbol in the integration group corresponds to the third symbol of the preamble (first 1 of the ‘11110000’… sequence). The last 14 symbols of the preamble are disregarded.

4. The integral sum in Step 4 is considered to be the initial carrier frequency of the IUT, and is recorded as f_0 for Uncoded 1 Ms/s and 2 Ms/s and f_0, f_1, f_2, and f_3 for LE Coded (2 Ms/s).
5. Throughout the payload of the packet:

For Uncoded 1 Ms/s, the Lower Tester integrates the frequency of the FM demodulated signal in 10-bit intervals, starting at the second bit in the payload.

For 2 Ms/s, the Lower Tester integrates the frequency of the FM demodulated signal in 20-bit intervals, starting at the second bit in the payload.

For LE Coded (S=8), the Lower Tester integrates the frequency of the FM demodulated signals in 16-symbol intervals, starting at the 27th symbol in the PDU payload and until the (8*MAX_TX_LENGTH_CODED_S8)th symbol. The last 16-symbol sequence should not overlap the CRC field at the end of the packet.

The measurement is repeated until the end of the payload duration. The last bit interval (10-bit for Uncoded 1 Ms/s, 20-bit for 2 Ms/s) should not overlap the CRC-field at the end of the packet. See Figure 4.8 and Figure 4.10 for reference. The integral sums are recorded as f_n, where n is an integer from 1 to k (for Uncoded 1 Ms/s and 2 Ms/s) and 5 to k (for LE Coded S=8). f_k represents the last integral sum before the start of the CRC field in the packet.

6. Steps 2–6 are repeated for a minimum of 10 packets.
7. Steps 2–7 are repeated when the IUT is transmitting at the remaining frequencies defined in the test condition section.

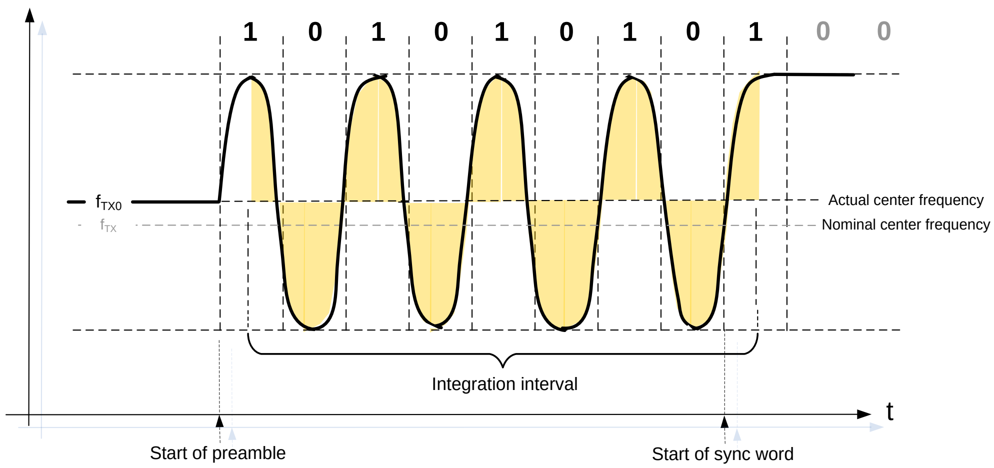

Figure 4.7: Initial frequency offset (f_0) measurement principle

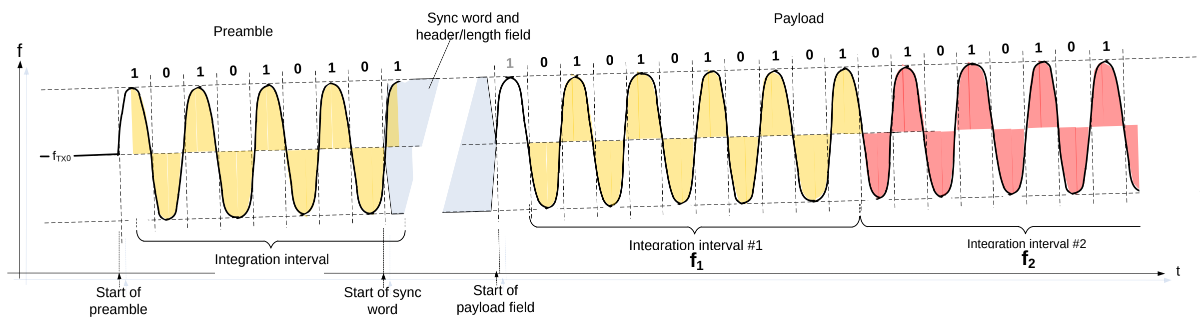

Figure 4.8: Frequency drift measurement principle

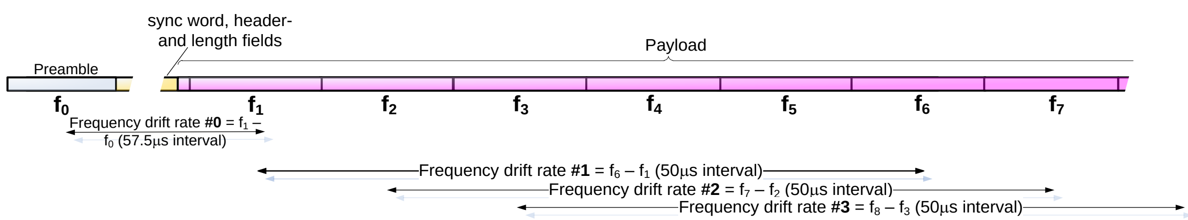

Figure 4.9: Frequency drift rate measurement principle

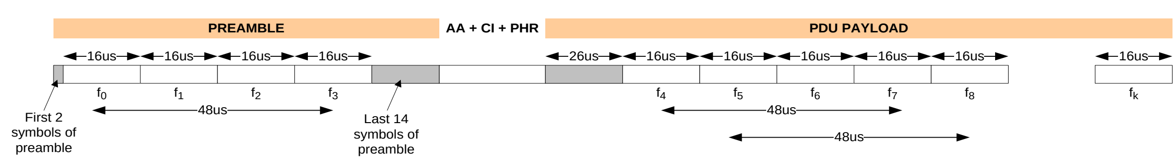

Figure 4.10: Frequency drift rate measurement principle for S=8

- Test Condition

Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  For Uncoded 1 Ms/s and 2 Ms/s, the maximum drift rate is 20 kHz/50 µs, anywhere in the packet. The maximum drift rate applies to the difference between any two bit groups (10-bit for Uncoded 1 Ms/s, 20-bit for 2 Ms/s) separated by 50 µs within the payload field of the packet transmitted by the IUT. The requirement also applies to the frequency difference between the initial frequency measurement f_0 and the first payload frequency measurement f_1. See Figure 4.9 for reference.

  For LE Coded (S=8), the maximum drift rate is 19.2 kHz/48 µs, anywhere in the packet. The maximum drift rate applies to the difference between any two groups of 16 symbols separated by 48 µs within the payload field of the packet transmitted by the IUT. The requirement also applies to the frequency difference between the initial frequency measurement f_0 and f_3 within the preamble. See Figure 4.10 for reference.

  All measured values fulfill the following conditions at the low, mid and high frequencies.

  <u>Pass verdict</u>

  $f_{TX} – 150\text{ kHz} \le f_n \le f_{TX} + 150\text{ kHz}$

  where f_{TX} is the nominal transmit frequency and n=0,1,2,3…k

  $|f_0 – f_n| \le 50\text{ kHz}$

  where n=2,3,4…k

  and Drift Requirement Limits specified in Table 4.9.

  In all of the above pass verdict requirements, f_k is the last frequency measurement before the CRC field.

4.6.5 Carrier frequency offset and drift, Constant Tone Extension

- Test Purpose

  Verify that the carrier frequency offset and carrier drift of the transmitted Constant Tone Extension portion in a transmitted signal with uncoded data is within specified limits at normal operating conditions.

- Reference

  [8] Chapter 3.3

- Initial Condition

  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The values of MAX_TX_LENGTH, MAX_TX_LENGTH_2M, and TSPX_CTE_len_max (for which the TC is performed) are specified in Section 6.6.
  - The IUT is set to transmit AoA Constant Tone Extensions.

- Test Case Configuration

Test Case	Drift Requirement Limits	Symbol Rate	Payload Length
RFPHY/TRM/BV-16-C [Carrier frequency offset and drift, uncoded data at 1 Ms/s, Constant Tone Extension]	$\lvert f_{s1} - f_p \rvert \leq 19.2$ kHz $\lvert f_{si} - f_0 \rvert_{i=1,2,3,4\ldots k} \leq 50$ kHz $\lvert f_{si} - f_{si\text{-}3} \rvert_{i=4\ldots k} \leq 19.2$ kHz	1 Ms/s	MAX_TX_LENGTH
RFPHY/TRM/BV-17-C [Carrier frequency offset and drift at 2 Ms/s, Constant Tone Extension]	$\lvert f_{s1} - f_p \rvert \leq 13.6$ kHz $\lvert f_{si} - f_0 \rvert_{i=1,2,3,4\ldots k} \leq 50$ kHz $\lvert f_{si} - f_{si\text{-}3} \rvert_{i=4\ldots k} \leq 19.2$ kHz	2 Ms/s	MAX_TX_LENGTH_2M

Table 4.10: Carrier frequency offset and drift, Constant Tone Extension test cases

- Test Procedure

1. The IUT is set to transmit at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case).
2. The IUT transmits LE test packets with Payload Length (specified in Table 4.10) octet payload consisting of a repetitive sequence of 0Fhex octets (11110000bin in transmission order) in the payload and with TSPX_CTE_len_max * 8 µs Constant Tone Extension. See [9] Section 4, "LE Test Packet Definition" for details.
3. The following settings are used for the Lower Tester:

Center frequency	lowest frequency for testing as defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case)
Mode	FM demodulation
Demodulator filter BW	Specified in Section 6.9 (minimum)
Filter passband ripple	Specified in Section 6.9
Trigger	RF (trigger on rising edge)

The following measurement channel filter minimum attenuator characteristics are used:

Frequency (for 1Ms/s)	Frequency (for 2Ms/s)	Attenuation
±650 kHz	±1.3 MHz	-3 dB
±1 MHz	±2.0 MHz	-14 dB
±2 MHz	±4.0 MHz	-44 dB

4. The payload is FM demodulated with the settings described in Step 3. The average frequency deviation measurement starts at the beginning of the fifth bit of the payload (see Figure 4.11 for description). The last four bits in the payload are disregarded (i.e., last bit in the measurement is the fourth bit in the final payload octet).
5. Each individual bit is to be oversampled at least 32 times. The sequence center frequency; f1ccf is calculated as the average frequency of all samples over each 00001111_{bin} sequence.
6. For the second, third, sixth, and seventh bits in each 00001111bin sequence, the absolute value of the frequency offset from $f1_{ccf}$ is recorded as $\Delta f1_{max}$. $\Delta f1_{max}$ is defined as the average deviation for each individual bit. See Figure 4.11 for reference.
7. The average frequency value of all $\Delta f1_{max}$ frequencies in a packet is calculated and recorded as $\Delta f1_{avg}$.
8. The initial frequency offset measurement f0 is to be performed at the start of the preamble field in the transmitted packet.

For Uncoded 1 Ms/s, the Lower Tester integrates the frequency of the FM demodulated signal from the center of the first preamble bit to the center of the first bit following the 8th preamble bit, 8 bits in total. See Figure 4.12 for reference.

For 2 Ms/s, the Lower Tester integrates the frequency of the FM demodulated signal from the center of the first preamble bit to the center of the first bit following the 16th preamble bit, 16 bits in total.

9. The integral sum in Step 8 is considered to be the initial carrier frequency of the IUT, and is recorded as f0.
10. The average center frequency measurement fp is to be performed starting at the (n+1)th bit of the payload and

    For Uncoded 1 Ms/s, covering 16 bits, where n = (MAX_TX_LENGTH * 8) - 20.

    For 2 Ms/s, covering 32 bits, where n = (MAX_TX_LENGTH_2M * 8) – 36.

    The first n bits and the last 4 bits are not used for this measurement. See Figure 4.13 and Figure 4.14 for reference.

11. The average frequency deviation measurement $f3_{maxi}$ and carrier frequency offset measurement f_{si} within the Constant Tone Extension are to be performed starting at the first bit of the reference period within the Constant Tone Extension covering 16 µs units. The first 4 µs of the Constant Tone Extension are not used for the measurement. For bursts with odd number of Constant Tone Extension units, the last 4 µs of the Constant Tone Extension portion are not used. For bursts with even number of Constant Tone Extension units, the last 12 µs of the Constant Tone Extension portion are not used for the measurement. f_{si} is recorded as $f3_{maxi} - \Delta f1_{avg}$. See Figure 4.15 for reference.
12. Steps 2–11 are repeated for a minimum of 10 packets.
13. Steps 2–12 are repeated when the IUT is transmitting at the remaining frequencies defined in the test condition section.

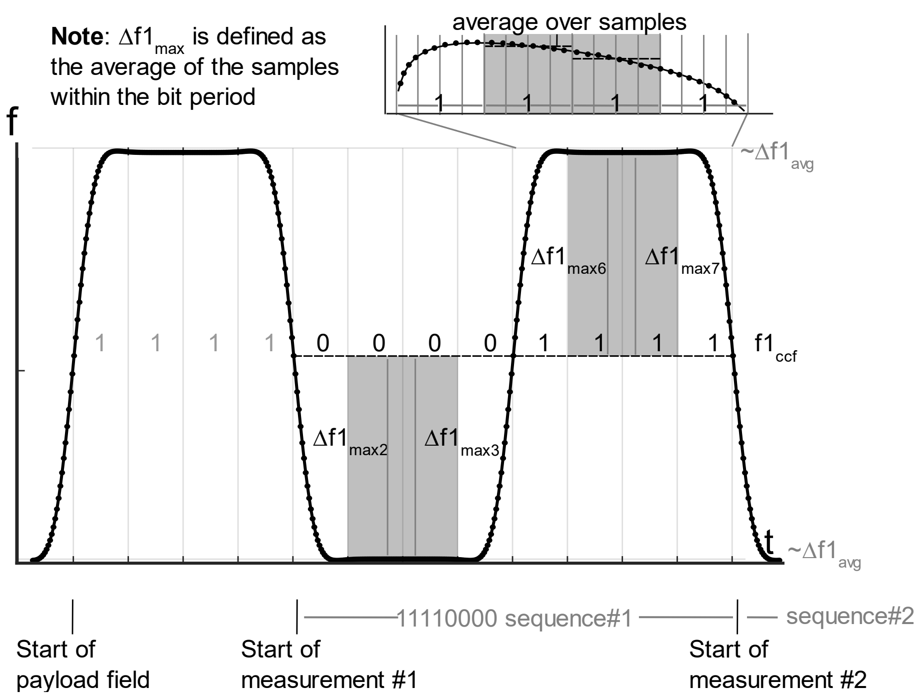

Figure 4.11: Frequency deviation measurement principle for 11110000-payload sequence

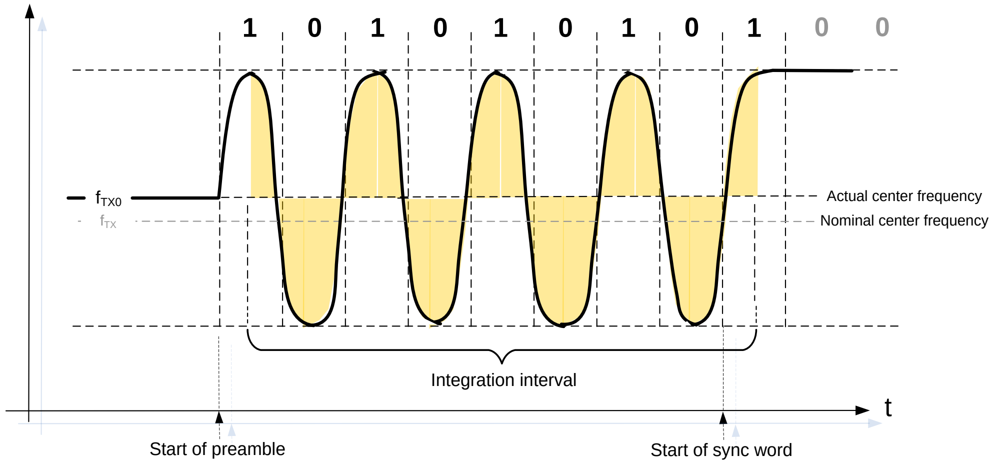

Figure 4.12: Initial carrier frequency (f_0) measurement principle for 1 Ms/s

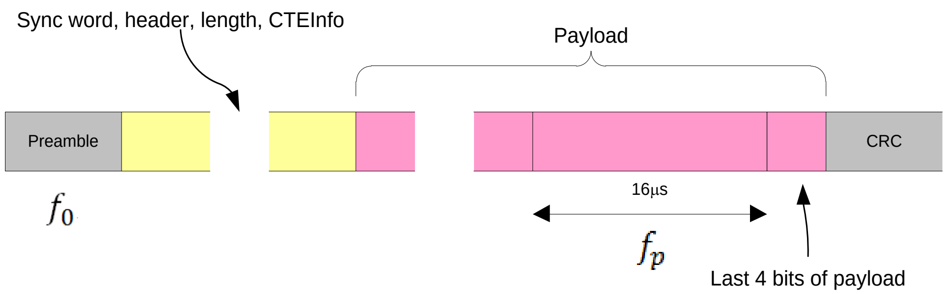

Figure 4.13: Average center frequency measurement (f_p) measurement location

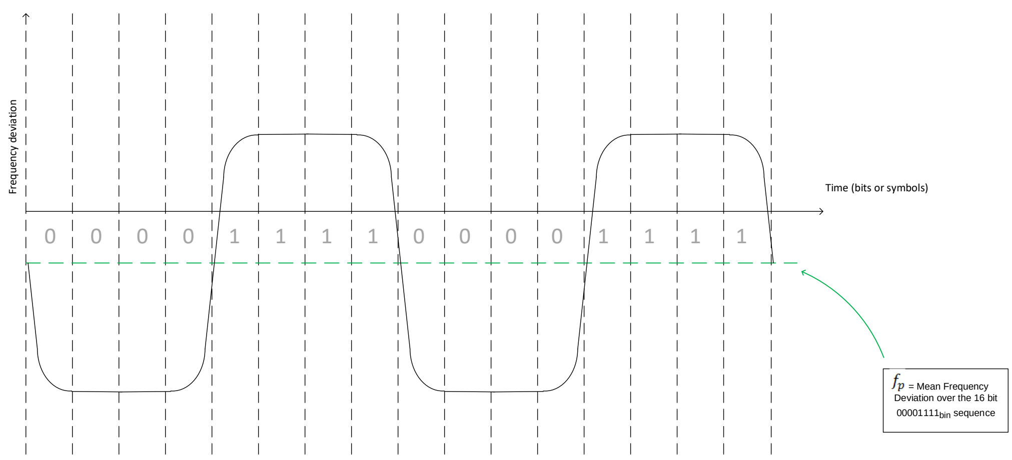

Figure 4.14: Average center frequency measurement (f_p) principle

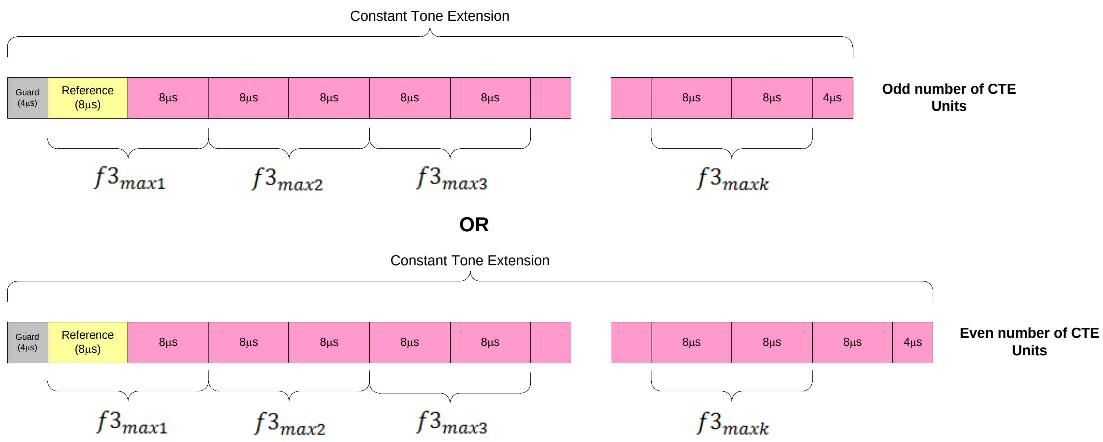

Figure 4.15: Average frequency deviation measurement principle

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  f_{TX} – 150 kHz ≤ f_{si} ≤ f_{TX} + 150 kHz

  where f_{TX} is the nominal transmit frequency and i=1,2,3…k

  f_{TX} – 150 kHz ≤ f_0 ≤ f_{TX} + 150 kHz

  and Drift Requirement Limits specified in Table 4.10.

4.6.6 Tx Power Stability, AoD Transmitter

- Test Purpose

  Verify that the AoD transmit signal has settled at the beginning of the reference period and the transmit slots, and remains stable within the reference period and transmit slots, respectively.

- Reference

  [8] Section 5

  [9] Section 4.1

- Initial Condition
  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The values of TSPX_CTE_len_max (for which the TC is performed) are specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.21.

- Test Case Configuration

Test Case	PHY	Slot Duration
RFPHY/TRM/PS/BV-01-C [Tx Power Stability, AoD Transmitter at 1 Ms/s with 2 µs Switching Slot]	1 Ms/s	2 µs
RFPHY/TRM/PS/BV-02-C [Tx Power Stability, AoD Transmitter at 1 Ms/s with 1 µs Switching Slot]	1 Ms/s	1 µs
RFPHY/TRM/PS/BV-03-C [Tx Power Stability, AoD Transmitter at 2 Ms/s with 2 µs Switching Slot]	2 Ms/s	2 µs
RFPHY/TRM/PS/BV-04-C [Tx Power Stability, AoD Transmitter at 2 Ms/s with 1 µs Switching Slot]	2 Ms/s	1 µs

Table 4.11: Tx Power Stability, AoD Transmitter test cases

- Test Procedure

1. The IUT transmits LE test packets with no payload and with TSPX_CTE_len_max * 8 µs Constant Tone Extension with switching slots as specified in Table 4.11. See [9], Section 4, “LE Test Packet Definition” for details.
2. The following settings are used for the Lower Tester:

Center Frequency	at the lowest frequency for testing defined in the test condition section
Frequency Span	Zero Span
Resolution BW	3 MHz
Video BW	3 MHz
Detector	Average

3. The RF power of the CTE is measured with the settings described in Step 2.
4. The Lower Tester records $P_{REF,AVE}$, as the average power during the reference period, measured from the beginning of the first symbol of the reference period to the end of the last symbol within the reference period.
5. The Lower Tester records $P_{REF,DEV}$ as the maximum absolute deviation between any one sample of the output power taken during the reference period relative to $P_{REF,AVE}$, recorded in Step 4.
6. For each transmit slot, n, Lower Tester records $P_{n,AVE}$ as the average power within the slot, where n is an integer from 1 to k, where k is the number of transmit slots within the packet.
7. For each transmit slot, n, Lower Tester records $P_{n,DEV}$ as the as the maximum absolute deviation between any one sample of the output power within the transmit slot relative to average power within the slot, $P_{N,AVE}$, recorded in Step 6.
8. Steps 3–7 are repeated when the IUT is transmitting at the remaining frequencies defined in the test condition section.

- Test Condition

The IUT and the Lower Tester are set up according to the cabled testing setup described in Section 4.8 and Common test case conditions and parameters defined in Section 4.3 apply.

Frequencies for Testing:

Role	PHY	IUT Low	IUT Mid	IUT High
All	1 Ms/s	2402 MHz (n=0)	2440 MHz (n=19)	2480 MHz (n=39)
All	2 Ms/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

- Expected Outcome

  The maximum deviation of the signal power within the reference period is not more than 25% of the average signal power measured within the reference period.

  The maximum deviation of the signal power within a TX slot is not more than 25% of the average signal power measured within that TX slot.

  All measured values fulfill the following conditions at the low, mid, and high frequencies.

  Pass verdict

  For each frequency, the following conditions are satisfied:

  - $P_{REF,DEV}$ / $P_{REF,AVE}$ < 0.25
  - $P_{n,DEV}$ / $P_{n,AVE}$ < 0.25 for n=1,2,3,…,k

4.6.7 Antenna switching integrity, AoD Transmitter

- Test Purpose

  Verify that the antenna switching occurs during the switching slots of the Constant Tone Extension for an AoD transmit signal.

- Reference

  [8] Section 5

  [9] Section 4.1

- Initial Condition

  - The IUT is set to direct TX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The values of TSPX_CTE_len_max (for which the TC is performed) are specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.12.

- Test Case Configuration

Test Case	PHY	Slot Duration
RFPHY/TRM/ASI/BV-05-C [Antenna switching integrity, AoD Transmitter at 1 Ms/s with 2 µs Switching Slot]	1 Ms/s	2 µs
RFPHY/TRM/ASI/BV-06-C [Antenna switching integrity, AoD Transmitter at 1 Ms/s with 1 µs Switching Slot]	1 Ms/s	1 µs
RFPHY/TRM/ASI/BV-07-C [Antenna switching integrity, AoD Transmitter at 2 Ms/s with 2 µs Switching Slot]	2 Ms/s	2 µs
RFPHY/TRM/ASI/BV-08-C [Antenna switching integrity, AoD Transmitter at 2 Ms/s with 1 µs Switching Slot]	2 Ms/s	1 µs

Table 4.12: Antenna switching integrity, AoD Transmitter test cases

- Test Procedure

  1. The IUT transmits LE test packets with no payload and with TSPX_CTE_len_max * 8 µs Constant Tone Extension with switching slots as specified in Table 4.12. See [9], Section 4, “LE Test Packet Definition” for details.
  2. The following settings are used for the Lower Tester:

Center Frequency	at the lowest frequency for testing defined in the test condition section
Frequency Span	Zero Span
Resolution BW	3 MHz
Video BW	3 MHz
Detector	Average

  3. All non-reference antenna ports are disconnected and terminated.
  4. The Lower Tester records the average output power during nth Tx slot, where n = 1 to k (Nof Tx slots in the packet), $P_{n,AVE,OFF}$.
  5. Connect the Xth non reference antenna port, where X = 1 .. number of non-reference antennae. All other non-reference antennae are disconnected and terminated.
  6. The Lower Tester records the average output power during the nth Tx slot, where n = 1 to k (Nof Tx slots in the packet), $P_{n,X,AVE,ON}$.
  7. Repeat Steps 5–6 for all non-reference antennae.

- Test Condition

  The IUT and Lower Tester are set up according to the cabled testing setup described in Section 4.8 and Common test case conditions and parameters defined in Section 4.3 apply.

  Frequencies for Testing:

Role	PHY	IUT Low	IUT Mid	IUT High
All	1 Ms/s	2402 MHz (n=0)	2440 MHz (n=19)	2480 MHz (n=39)
All	2 Ms/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

- Expected Outcome

  The average signal power measured when an antenna port is connected is at least 10 dB greater than the average signal power measured when the antenna port is disconnected in the transmit slots corresponding to the antenna.

  All measured values fulfill the following conditions at the low, mid and high frequencies.

  Pass verdict

  For each frequency, the following conditions are satisfied:

  - $P_{m,X,AVE,ON} - P_{m,AVE,OFF} \geq 10$ dB,

    where m corresponds to the Tx slot corresponding to the antenna X transmission, and

    X = 1 .. Number of non-reference antenna

4.6.8 CS Stable Phase

- Test Purpose

  Verify that the IUT’s carrier phase remains stable for the period of T_PM_MEAS, where T_PM_MEAS is the maximum duration of a CS_Tone used for measurement.

- Reference

  [11] Section 3.4

- Initial Condition

  - Roles are non-configurable; the IUT is fixed in the Initiator role.
  - A static Access Address (CS Sync Word) is used for the duration of the test, see Section 4.3.3.1.
  - A fixed 1:1 antenna configuration is used in the Test Equipment Setup, see Section 4.2.3.
  - The IUT's transmitter is set to maximum output power.
  - The transmit frequency for the entire CS subevent is fixed at f_O, see Section 4.3.2.

Within the Main-Mode period, only a single IUT transmission occurs as described in Figure 4.16. This is a special test scenario whereby the Lower Tester (in the Reflector role), may choose not to respond to the IUT's transmission, see [12] Section 2.4 for details.

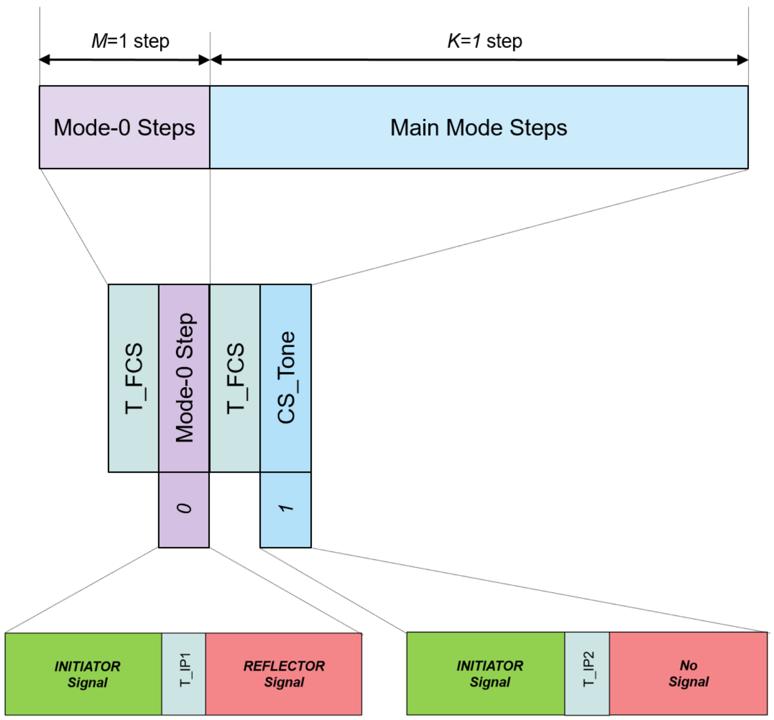

Figure 4.16: Stable Phase test signal transmission overview

The IUT transmits a CS_Tone of duration 652 μs (T_PM) as shown in Figure 4.17. T_PM_MEAS (of duration 650 us) is defined as the Stable Phase Evaluation Window, the period in which the Lower Tester samples the CS_Tone as described in Figure 4.17.

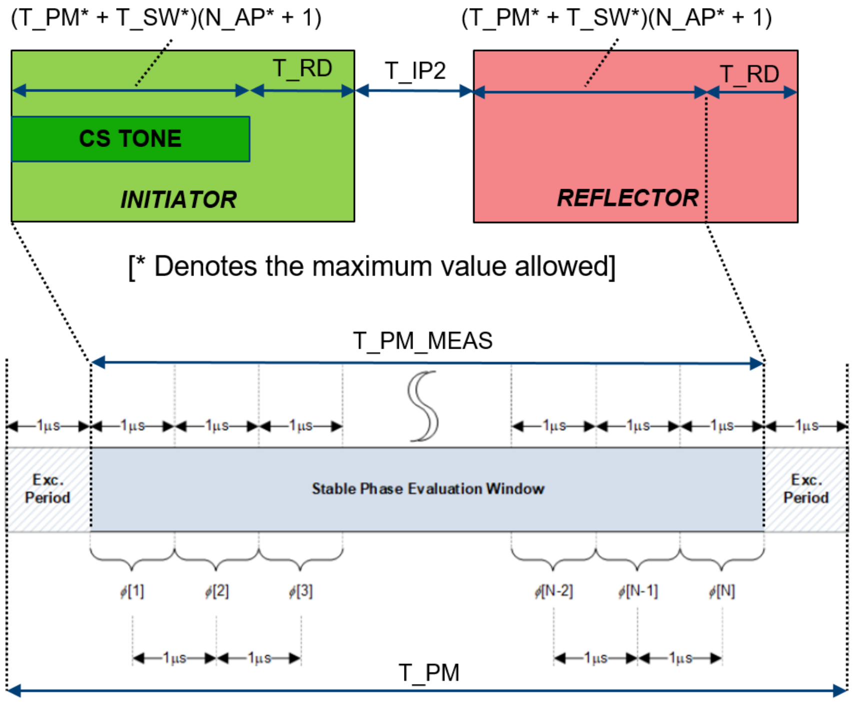

Figure 4.17: Stable Phase measurement overview

- Test Case Configuration

Test Case	PHY	Main Mode Type
RFPHY/TRM/CS/BV-01-C [Stable Phase, 1 Ms/s, CS_Tone]	1 Ms/s	CS_Tone
RFPHY/TRM/CS/BV-02-C [Stable Phase, 2 Ms/s, CS_Tone]	2 Ms/s	CS_Tone

Table 4.13: CS Stable Phase test cases

- Test Procedure

1. The Upper Tester commands the IUT to enable the Channel Sounding procedure using the Override_Config bit number 10 parameter enabled (Stable Phase test).
2. The Lower Tester uses the PHY test filter characteristics as defined in Section 6.9.
3. The IUT sends a Mode-0 transmission to the Lower Tester. The Lower Tester responds with a Mode-0 transmission.
4. The IUT sends a CS_Tone transmission. The Lower Tester synchronizes to the previous Mode-0 CS_SYNC (CS_SYNC_0_I) transmission, measuring the CS_Tone sent by the IUT following a period of T_RD+T_IP2+T_SY+T_GD+T_FM+T_RD+T_FCS+1 μs, where 1 μs accounts for exclusion period (see Figure 4.17).
5. The CS_Tone is down converted and sampled at 1 μs intervals during the period of T_PM_MEAS.
6. The zero mean, detrended phase $\phi_{zmd}[n]$ is calculated (see [11] Chapter 3.4, Stable Phase).

7. Steps 1–6 are repeated to obtain at least 10,000 absolute values of $\phi_{zmd}[n]$.
   This will require $\left\lceil\frac{10{,}000}{650}\right\rceil$ CS sub-events, where $\lceil x \rceil = ceiling(x)$.
8. Steps 1–7 are repeated for the remaining frequencies as defined in Section 4.3.2.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply. The default frequencies are defined in Section 4.3.2.

- Expected Outcome

  Pass verdict

  95% of at least 10,000 absolute values of $\phi_{zmd}[n]$ are $\leq 20°$.

4.6.9 CS Modulation Characteristics, 2 Ms/s, BT = 2.0

- Test Purpose

  Verify that the modulation characteristics of the transmitted signal are correct when transmitting data at 2 Ms/s, BT = 2.0.

- Reference

  [11] Section 3.1

- Initial Condition
  - The Lower Tester is configured as the Reflector and the IUT as the Initiator.
  - A static Access Address (CS Sync Word) is used for the duration of the test, see Section 4.3.3.1.
  - A fixed 1:1 antenna configuration is used in the Test Equipment Setup, see Section 4.2.3.
  - The IUT's transmitter is set to maximum output power.
  - The IUT is configured to transmit a fixed sequence of M Mode-0 CS steps, where M is the minimum number of Mode-0 steps the IUT supports.
  - The transmit frequency for the entire CS subevent is fixed at f_0 (see Section 4.3.2).

- Test Case Configuration

TCID	PHY	Main Mode Type
RFPHY/TRM/CS/BV-03-C [Modulation Characteristics, 2 Ms/s, BT = 2.0, Mode-1]	2 Ms/s, BT = 2.0	Mode-1
RFPHY/TRM/CS/BV-04-C [Modulation Characteristics, 2 Ms/s, BT = 2.0, Mode-3]	2 Ms/s, BT = 2.0	Mode-3

Table 4.14: CS Modulation Characteristics, 2 Ms/s, BT = 2.0 test cases

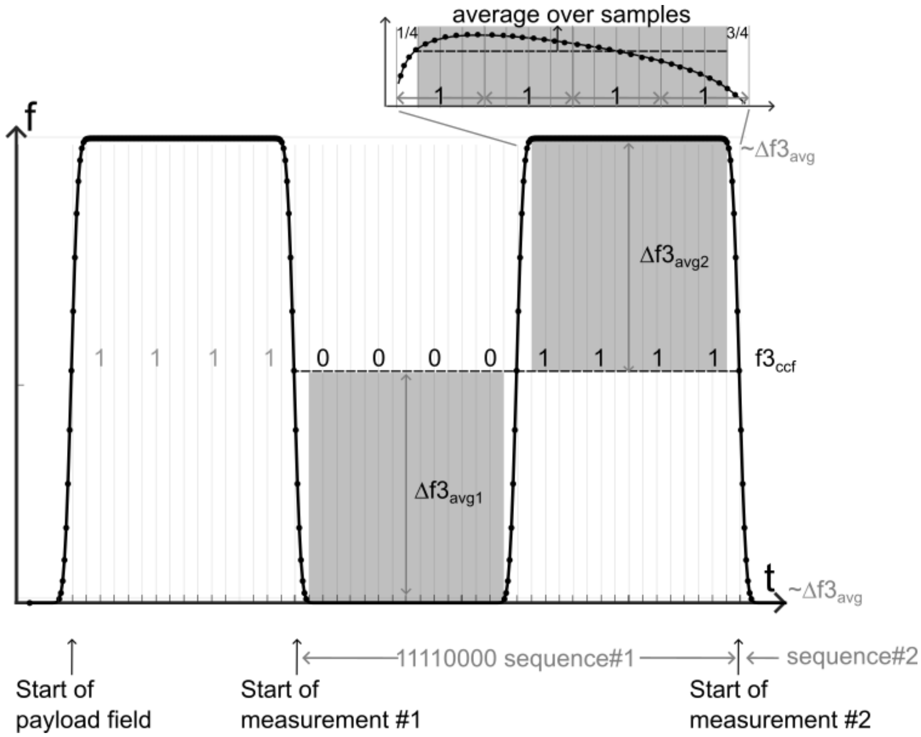

Figure 4.18: CS 2Ms/s BT = 2.0 frequency deviation measurement principle for 11110000-payload sequence

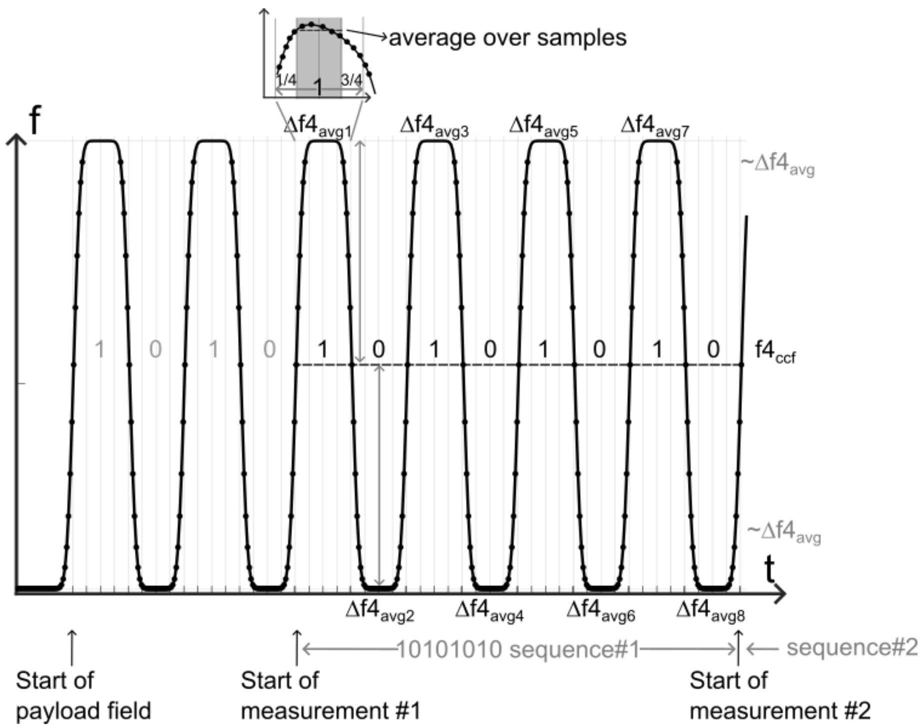

Figure 4.19: CS 2Ms/s BT = 2.0 frequency deviation measurement principle for 10101010-payload sequence

- Test Procedure
  1. The Upper Tester commands the IUT to enable the Channel Sounding procedure with:
     - Role set to Initiator
     - Test command Override_Config bit 8 set enabling the CS_SYNC_Payload_Pattern parameter
     - CS_SYNC_Payload_Pattern set to 0x01, the value for repeated 11110000_{bin} sequence (in transmission order)
     - Mode-0 CS Steps set to M steps, where $M = 3$
     - Main Mode CS steps set to $1 \le K \le 72$
     - Lowest frequency for testing as defined in Section 4.3.2
     - Other parameters as specified in Section 4.3.3
  2. The Lower Tester uses the 2 Ms/s, BT = 2.0 PHY test filter characteristics as defined in Section 6.9.
  3. The IUT sends a Mode-0 transmission to the Lower Tester.
  4. The Lower Tester responds with a Mode-0 transmission.
  5. Main-Mode CS steps are exchanged between the Lower Tester and the IUT.
  6. The wanted signal packet payload is FM demodulated with the settings described in Step 2. The measurement starts at the beginning of the fifth bit of the payload (see Figure 4.18 for description). The last four bits in the payload are disregarded (i.e., the last bit in the measurement is the fourth bit in the 16th octet).
  7. Each individual bit is to be oversampled at least 32 times. The sequence center frequency $f3_{ccf}$ is calculated as the average frequency of all samples over each 11110000_{bin} sequence.
  8. Starting at ¾ of the first bit and ending after ¼ of the fourth bit, and starting at ¾ of the fifth bit and ending after ¼ of the eighth bit in each 11110000_{bin} sequence, the absolute value of the frequency offset from $f3_{ccf}$ is recorded as $\Delta f3_{max}$. $\Delta f3_{max}$ and is defined as the average deviation for each individual bit. See Figure 4.18 for reference.
  9. The average frequency value of all $\Delta f3_{max}$ frequencies in a packet is calculated and recorded as $\Delta f3_{avg}$.
  10. The IUT transmits LE CS test packets of maximal length with payload pattern set to a repetitive 1010101010_{bin} sequence.
  11. The payload is FM demodulated with the settings described in Step 2. The measurement starts at the beginning of the fifth bit in the payload field. The last four bits in the payload are disregarded (i.e., last bit in the measurement is the fourth bit in the final payload octet).
  12. Each individual bit is oversampled at least 32 times. The sequence center frequency $f4_{ccf}$ is calculated as the average frequency of all samples over each 1010101010_{bin} sequence.
  13. The average deviation measured from ¼ to ¾ of each bit from the sequence center frequency $f4_{ccf}$ is recorded as $\Delta f4_{avg}$ for each individual bit. See Figure 4.19 for reference.
  14. Main-Mode steps are measured to obtain a total number of $K = 52$ CS steps.
      This will require $\left\lceil \frac{52}{K} \right\rceil$ CS sub-events, where $\lceil x \rceil = ceiling(x)$.
  15. Repeat Steps 1–14 for the remaining frequencies as defined in Section 4.3.2.

- Expected Outcome

  Pass verdict

  All measured values must fulfill the following conditions at the test frequencies defined in Section 4.3.2:

  - $450\ kHz \le \Delta f3avg \le 550\ kHz$

At least 99.7% of all $\Delta f4avg$ frequency values recorded over 52 LE CS test packets must be greater than 420 kHz.

- $\frac{\Delta f4avg}{\Delta f3avg} \geq 0.95$

4.6.10 CS TX Output SNR Control

- Test Purpose

  Verify that the configured SNR output for an IUT's transmitted signal is within limits.

- Reference

  [11] Section 3.1.3

- Initial Condition

  - The Lower Tester is configured as the Reflector and the IUT as the Initiator.
  - A static Access Address (CS Sync Word) is used for the duration of the test, see Section 4.3.3.1.
  - A fixed 1:1 antenna configuration is used in the Test Equipment Setup, see Section 4.2.3.
  - The IUT's transmitter is set to maximum output power.
  - The IUT is configured to the lowest supported SNR (SNRmin) output level index (SOI).
  - The IUT is configured to transmit a fixed sequence of M Mode-0 CS steps, where M is the minimum number of Mode-0 steps the IUT supports.
  - The transmit frequency for the entire CS subevent is fixed at f_0 (see Section 4.3.2).

- Test Case Configuration

TCID	PHY	Main Mode Type
RFPHY/TRM/CS/BV-05-C [TX SNR Output Control, 1 Ms/s, Mode-1]	1 Ms/s	Mode-1
RFPHY/TRM/CS/BV-06-C [TX SNR Output Control, 1 Ms/s, Mode-3]	1 Ms/s	Mode-3
RFPHY/TRM/CS/BV-07-C [TX SNR Output Control, 2 Ms/s, Mode-1]	2 Ms/s	Mode-1
RFPHY/TRM/CS/BV-08-C [TX SNR Output Control, 2 Ms/s, Mode-3]	2 Ms/s	Mode-3
RFPHY/TRM/CS/BV-09-C [TX SNR Output Control, 2 Ms/s, Mode-1, BT = 2.0]	2 Ms/s, BT = 2.0	Mode-1
RFPHY/TRM/CS/BV-10-C [TX SNR Output Control, 2 Ms/s, Mode-3, BT = 2.0]	2 Ms/s, BT = 2.0	Mode-3

Table 4.15: CS TX Output SNR Control test cases

- Test Procedure

  1. The Upper Tester commands the IUT to enable the Channel Sounding procedure with:
     - Role set to Initiator
     - RTT_Type set to the value of $0x00$ (RTT AA Only)
     - Mode-0 CS Steps set to M steps, where $M = 1$
     - Main Mode CS steps set to $1 \le K \le 72$
     - Lowest frequency for testing as defined in Section 4.3.2
     - Other parameters as specified in Section 4.3.3
  2. The Lower Tester uses the PHY test filter characteristics as defined in Section 6.9.
  3. The IUT sends a Mode-0 transmission to the Lower Tester.
  4. The Lower Tester responds with a Mode-0 transmission.
  5. Main-Mode CS steps as defined in Table 4.15 are exchanged between the Lower Tester and the IUT.
  6. The Lower Tester down converts and measures the CS_SYNC portion sent by the IUT continuously over time within step k (see [11] Section 3.1.1) for each Main-Mode packet received with the filter characteristics as defined in Section 6.9. The IUT's transmitter SNR is then computed per CS Main-Mode step to provide a value of $SNR_{TX}(k)$.
  7. For each CS Main-Mode step, a value of $SNR_{TX}^{error}(k)$ is calculated as $\left|SNR_{TX}^{desired} - SNR_{TX}(k)\right|$, where $SNR_{TX}^{desired}$ is the configured SNR output value at the IUT.
  8. Steps 1–7 are repeated to obtain at least 10,000 values of $SNR_{TX}^{error}(k)$. This will require $\left\lceil\frac{10{,}000}{K}\right\rceil$ CS sub-events, where $\lceil x \rceil = ceiling(x)$.
  9. Repeat Steps 1–8 for the remaining frequencies as defined in Section 4.3.2.
  10. Repeat Steps 1–9 for the remaining supported output level indexes (SOI).

- Expected Outcome

  Pass verdict

  The measured SNR output control error values must fulfill the following condition:

  - $SNR_{TX}^{error}(k) \le 3\ dB$

  The standard deviation of the randomness of the added error satisfies:

  - $std\left(SNR_{TX}^{error}(k)\right) \ge 0.25\ dB$

  for 95% of at least 10,000 CS steps.

4.7 Receiver tests (RCV)

4.7.1 Receiver sensitivity

- Test Purpose

  Verify that the receiver sensitivity is within limits for non-ideal signals at normal operating conditions when receiving a signal. For stable modulation tests, the receiver is set to assume the transmitter has a stable modulation index. The non-ideal signals used in this test are within the specification limits but deviate from the ideal case.

- Reference

  [2] Chapter 4.1

  [6] Chapter 4.1

- Initial Condition
  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The Lower Tester's transmit power is chosen such that the input power to the IUT receiver is as specified in Table 4.9.
  - The value of MAX_RX_LENGTH, MAX_RX_LENGTH_2M, MAX_RX_LENGTH_CODED_S2, and MAX_RX_LENGTH_CODED_S8 (for which the TC is performed) is specified in Section 6.6.
  - The IUT is set to assume the transmitter has a standard modulation index or stable modulation index (specified in Table 4.16).
- Test Case Configuration

Test Case	Modulation	Input Power	Symbol Rate	Payload Length
RFPHY/RCV/BV-01-C [Receiver sensitivity, uncoded data at 1 Ms/s]	Standard	-70 dBm	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-08-C [Receiver sensitivity at 2 Ms/s]	Standard	-70 dBm	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-14-C [Receiver Sensitivity, uncoded data at 1 Ms/s, Stable Modulation Index]	Stable	-70 dBm	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-20-C [Receiver sensitivity at 2 Ms/s, Stable Modulation Index]	Stable	-70 dBm	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-26-C [Receiver sensitivity, LE Coded (S=2)]	Standard	-75 dBm	1 Ms/s coded S=2	MAX_RX_LENGTH_CODED_S2
RFPHY/RCV/BV-27-C [Receiver sensitivity, LE Coded (S=8)]	Standard	-82 dBm	1 Ms/s coded S=8	MAX_RX_LENGTH_CODED_S8
RFPHY/RCV/BV-32-C [Receiver sensitivity, LE Coded (S=2), Stable Modulation Index]	Stable	-75 dBm	1 Ms/s coded S=2	MAX_RX_LENGTH_CODED_S2
RFPHY/RCV/BV-33-C [Receiver sensitivity, LE Coded (S=8), Stable Modulation Index]	Stable	-82 dBm	1 Ms/s coded S=8	MAX_RX_LENGTH_CODED_S8

Table 4.16: Receiver sensitivity test cases

- Test Procedure

1. The IUT is set to receive at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case).
2. The Lower Tester transmits LE test packets with PRBS9 payload with Payload Length (specified in Table 4.16). See [4], Section 4, "LE Test Packet Definition" for details.
3. The signal characteristics of the modulated signal transmitted by the Lower Tester are to be changed over time. The signal parameter sets to be used are described in Table 4.17. All other parameters are as defined in Section 6.1.
4. The Lower Tester transmits the first 50 packets using the first parameter set; the next 50 packets are transmitted using the second parameter set etc. Upon completion of the last parameter set, the sequence is repeated. The PER is measured according to Section 6.3.
5. Steps 2–4 are repeated when the IUT is receiving at the remaining frequencies defined in the test condition section.

Test Run	Carrier Frequency Offset	Modulation Index		Symbol Timing Error
		Standard Modulation	Stable Modulation	
1	100 kHz	0.45	0.495	-50 ppm
2	19 kHz	0.48	0.498	-50 ppm
3	-3 kHz	0.46	0.496	+50 ppm
4	1 kHz	0.52	0.502	+50 ppm
5	52 kHz	0.53	0.503	+50 ppm
6	0 kHz	0.54	0.504	-50 ppm
7	-56 kHz	0.47	0.497	-50 ppm
8	97 kHz	0.5	0.500	-50 ppm
9	-25 kHz	0.45	0.495	-50 ppm
10	-100 kHz	0.55	0.505	+50 ppm

Table 4.17: Transmitter parameter settings for PER test

In addition to fixed frequency offset, frequency drift over time is added to the signal characteristics. This is implemented by adding a low frequency modulation to the signal. The modulating signal is sinusoidal with deviation of 50 kHz and a modulation frequency of 1250 Hz. The modulating signal is synchronized with the packets so that packets start alternately at 0° and 180° of the modulating signal. See Figure 4.20 for reference.

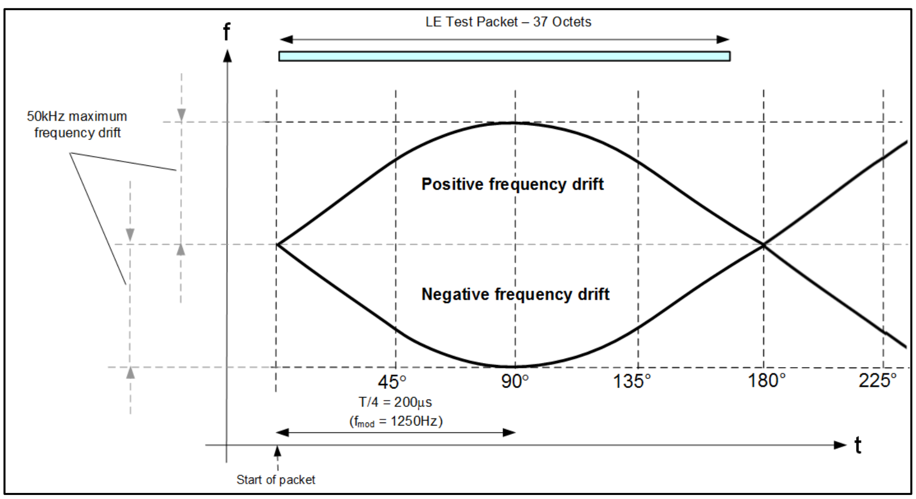

Figure 4.20: Dirty transmitter frequency drift emulation principle

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  All measured values fulfill the following condition:

  PER better than **30.8%** for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is 37 bytes.

PER better than the value calculated according to the formula specified in Section 6.3.1 for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is greater than 37 bytes.

4.7.2 C/I and Receiver Selectivity Performance

- Test Purpose

  Verify the receiver's performance in the presence of co-/adjacent channel interference. For stable modulation tests, the receiver is set to assume the transmitter has a stable modulation index. The receiver mirror image rejection performance is also verified in this test.

- Reference

  [2] Chapter 4.2

  [6] Chapter 4.2

- Initial Condition

  - Refer to Figure 4.21 for test setup principle.
  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The image frequency (f_{image} for 1 Ms/s or $f_{image-2M}$ for 2 Ms/s) of the receiver relative to the receiver frequency is declared by the equipment manufacturer as an IXIT value.
  - The value of MAX_RX_LENGTH, MAX_RX_LENGTH_2M, MAX_RX_LENGTH_CODED_S2, and MAX_RX_LENGTH_CODED_S8 (for which the TC is performed) is specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.18.
  - The IUT is set to assume the transmitter has a standard modulation index or stable modulation index (specified in Table 4.18).

- Test Case Configuration

Test Case	Modulation	Input Power	Symbol Rate	Payload Length
RFPHY/RCV/BV-03-C [C/I and Receiver Selectivity Performance, uncoded data at 1 Ms/s]	Standard	-67 dBm	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-09-C [C/I and Receiver Selectivity Performance at 2 Ms/s]	Standard	-67 dBm	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-15-C [C/I and Receiver Selectivity Performance, uncoded data at 1 Ms/s, Stable Modulation Index]	Stable	-67 dBm	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-21-C [C/I and Receiver Selectivity Performance at 2 Ms/s, Stable Modulation Index]	Stable	-67 dBm	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-28-C [C/I and Receiver Selectivity Performance, LE Coded (S=2)]	Standard	-72 dBm	1 Ms/s coded S=2	MAX_RX_LENGTH_CODED_S2
RFPHY/RCV/BV-29-C [C/I and Receiver Selectivity Performance, LE Coded (S=8)]	Standard	-79 dBm	1 Ms/s coded S=8	MAX_RX_LENGTH_CODED_S8

Test Case	Modulation	Input Power	Symbol Rate	Payload Length
RFPHY/RCV/BV-34-C [C/I and Receiver Selectivity Performance, LE Coded (S=2), Stable Modulation Index]	Stable	-72 dBm	1 Ms/s coded S=2	MAX_RX_LENGTH_CODED_S2
RFPHY/RCV/BV-35-C [C/I and Receiver Selectivity Performance, LE Coded (S=8), Stable Modulation Index]	Stable	-79 dBm	1 Ms/s coded S=8	MAX_RX_LENGTH_CODED_S8

Table 4.18: C/I and receiver selectivity performance test cases

- Test Procedure

1. The IUT is set to receive at the low operating frequency listed in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case).
2. Two test signals are fed to the IUT input port:

   Wanted signal:

   Packets transmitted at the receiving frequency (f_{RX}) with Payload Length (specified in Table 4.18) octet PRBS9 payload at a Symbol Rate specified in Table 4.18. Refer to Section 6.1 and [4], Section 4 for details. Signal level of the wanted signal at the IUT input port is Input Power (specified in Table 4.18).

   Interference signal:

   Continuous modulated carrier at 2400 MHz, modulated with PRBS15 data at a Symbol Rate specified in Table 4.18. Refer to Section 6.1 and [4], Section 4 for details. Signal level of the interference signal at the IUT input port and frequency relative to the receiving frequency is as defined in Table 4.19.

3. The Lower Tester's transmit power is chosen such that the input power to the IUT receiver is as listed in Table 4.19.
4. For 1 Ms/s, Steps 2–3 are repeated for interference frequencies 2400 MHz+N·MHz where N=1,2,3…83.

   For 2 Ms/s, Steps 2–3 are repeated for interference frequencies 2400MHz+2N MHz where N=1,2,3…41.

5. The PER is measured according to Section 6.3.
6. Steps 2–5 are repeated when the IUT is receiving at the mid- and high operation frequencies listed in the test condition section.

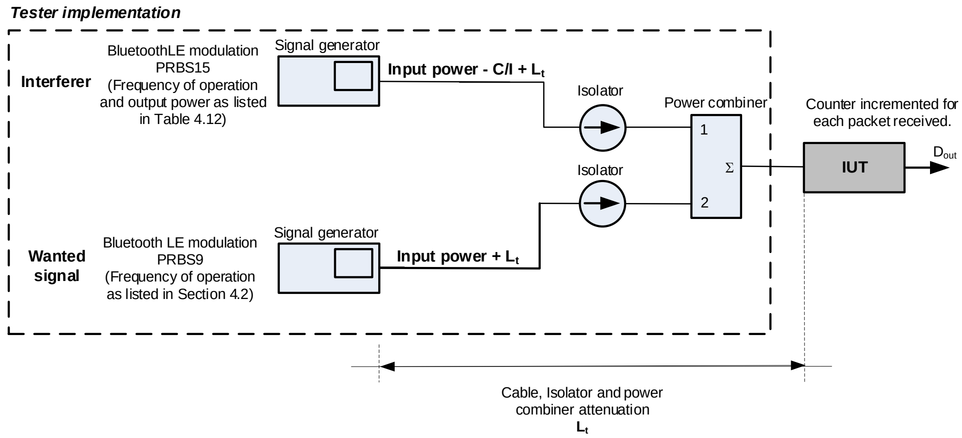

Figure 4.21: C/I and receiver selectivity test setup

Interference signal frequency[1]	$f_{interference}$		Interferer signal level at IUT input port (dBm)			Wanted signal level relative to interference signal level (C/I requirement) (dB)		
	1Ms/s and LE Coded	2Ms/s	Uncoded	S=2	S=8	Uncoded	S=2	S=8
Co-channel	f_{RX}	f_{RX}	-88	-89	-91	21	17	12
Adjacent channel	$f_{RX} \pm 1$ MHz	$f_{RX} \pm 2$ MHz	-82	-83	-85	15	11	6
Adjacent channel	$f_{RX} \pm 2$ MHz	$f_{RX} \pm 4$ MHz	-50	-51	-53	-17	-21	-26
Adjacent channel	$f_{RX} \pm (3+n)$ MHz [n=0,1,2…]	$f_{RX} \pm (6+2n)$ MHz [n=0,1,2…]	-40	-41	-43	-27	-31	-36
Image frequency	f_{image}	$f_{image-2M}$	-58	-59	-61	-9	-13	-18
Adjacent channel to image frequency	$f_{image} \pm 1$ MHz	$f_{image-2M} \pm 2$ MHz	-52	-53	-55	-15	-19	-24

Table 4.19: C/I and receiver selectivity test parameter settings

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  All measured values fulfill the following condition:

  PER better than **30.8%** for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is 37 bytes.

  PER better than the value calculated according to the formula specified in Section 6.3.1 for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is greater than 37 bytes.

[1] If two frequencies defined in Table 4.19 refer to the same physical channel, the less stringent requirement applies.

For each individual measurement the C/I requirement may be relaxed for a maximum of five interference frequency settings. The C/I-performance is in this case be equal to, or better than -17 dB (Interference level at least 17 dB higher than wanted signal level). This relaxation applies to the following measurements:

- Adjacent channel ± 2 MHz (for 1 Ms/s) or ± 4 MHz (for 2 Ms/s)
- Adjacent channel ± (3+n) MHz (for 1 Ms/s) or ± (6+2n) MHz (for 2 Ms/s) [n=0,1,2…]

4.7.3 Blocking Performance

- Test Purpose

  Verify that the receiver performs satisfactorily in the presence of interference sources operating outside the 2400 MHz – 2483.5 MHz band.

- Reference

  [2] Chapter 4.3

  [6] Chapter 4.3

- Initial Condition
  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_RX_LENGTH and MAX_RX_LENGTH_2M (for which the TC is performed) is specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.20.
  - The IUT is set to assume the transmitter has a standard modulation index or stable modulation index (specified in Table 4.20).

- Test Case Configuration

Test Case	Modulation	Symbol Rate	Payload Length
RFPHY/RCV/BV-04-C [Blocking Performance, uncoded data at 1 Ms/s]	Standard	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-10-C [Blocking performance at 2 Ms/s]	Standard	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-16-C [Blocking Performance, uncoded data at 1 Ms/s, Stable Modulation Index]	Stable	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-22-C [Blocking performance at 2 Ms/s, Stable Modulation Index]	Stable	2 Ms/s	MAX_RX_LENGTH_2M

Table 4.20: Blocking performance test cases

- Test Procedure

  1. Two test signals are fed to the IUT input port:

     Wanted signal:

     Modulated carrier, packets transmitted at the mid operating frequency listed in the frequencies for testing (listed in the test condition section of this test case) with PRBS9 payload with Payload Length (specified in Table 4.20). See Section 6.1 and [4], Section 4 for details. Signal level of the wanted signal at the IUT input port is as defined in Table 4.21.

     Blocking signal:

     Sinusoidal, un-modulated carrier transmitted at a blocker frequency of $f_{blocker}$ = 30 MHz. Signal level of the blocker signal at the IUT input port is as defined in Table 4.21.

  2. The PER is measured according to Section 6.3. If the PER exceeds the minimum requirement, the frequency is recorded as f_{bf_1}.
  3. Repeat Steps 1 and 2 for 30 MHz ≤ $f_{blocker}$ ≤ 12.75 GHz with the measurement frequency resolution defined in Table 4.21.
  4. $f_{blocker\ n+1}$ = $f_{blocker\_n}$ + measurement frequency resolution (n=0,1,2…)
  5. The PER measurement is repeated for all recorded frequencies in Step 4 but with -50 dBm blocker level at the IUT input ports. If the PER exceeds the minimum requirement, the frequency is recorded as f_{bf_2}.

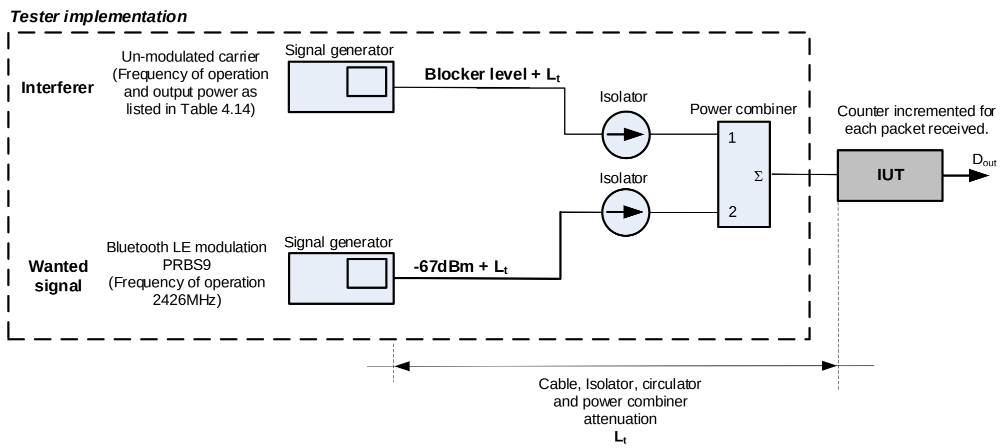

Figure 4.22: Blocking performance test setup

Interference signal frequency	Wanted signal level at IUT input port	Blocking signal level at IUT input port	Measurement frequency resolution
30 – 2000 MHz	-67 dBm	-30 dBm	10 MHz
2003 – 2399 MHz	-67 dBm	-35 dBm	3 MHz
2484 – 2997 MHz	-67 dBm	-35 dBm	3 MHz
3000 MHz – 12.75 GHz	-67 dBm	-30 dBm	25 MHz

Table 4.21: Out-of-band blocking performance and measurement parameters

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

Frequencies for Testing:

Role	IUT Low	IUT Mid	IUT High
All		2426 MHz (n=12)	

- Expected Outcome

  Pass verdict

  All measured values fulfill the following condition:

  PER better than **30.8%** for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is 37 bytes.

  PER better than the value calculated according to the formula specified in Section 6.3.1 for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is greater than 37 bytes.

  The number of f_{bf_1} frequencies recorded in Step 2 do not exceed 10, and the number of f_{bf_2} frequencies recorded in Step 5 do not exceed 3.

4.7.4 Intermodulation Performance

- Test Purpose

  Verify that the receiver intermodulation performance is satisfactory.

- Reference

  [2] Chapter 4.4

  [6] Chapter 4.4

- Initial Condition
  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_RX_LENGTH and MAX_RX_LENGTH_2M (for which the TC is performed) is specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.22.
  - The IUT is set to assume the transmitter has a standard modulation index or stable modulation index (specified in Table 4.22).

- Test Case Configuration

Test Case	Modulation	Symbol Rate	Payload Length
RFPHY/RCV/BV-05-C [Intermodulation Performance, uncoded data at 1 Ms/s]	Standard	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-11-C [Intermodulation performance at 2 Ms/s]	Standard	2 Ms/s	MAX_RX_LENGTH_2M

Test Case	Modulation	Symbol Rate	Payload Length
RFPHY/RCV/BV-17-C [Intermodulation Performance, uncoded data at 1 Ms/s, Stable Modulation Index]	Stable	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-23-C [Intermodulation performance at 2 Ms/s, Stable Modulation Index]	Stable	2 Ms/s	MAX_RX_LENGTH_2M

Table 4.22: Intermodulation performance test cases

- Test Procedure

1. The IUT is set to receive at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case). Three test signals are fed to the IUT input port:

   Wanted signal:

   Modulated carrier, packets transmitted at the receiving frequency (f_{RX}) with octet PRBS9 payload with Payload Length (specified in Table 4.22). Refer to Section 6.1 and [4], Section 4 for details. Signal level of the wanted signal at the IUT input port is -64 dBm.

   Interference signal #1:

   Sinusoidal, un-modulated carrier transmitted at an interferer frequency of f_1. Signal level of the interferer signal at the IUT input port is -50 dBm.

   Interference signal #2:

   Continuous modulated carrier at frequency f_2, modulated with PRBS15 data at a symbol rate as specified in Table 4.22. See Section 6.1 and [4], Section 4 for details. Signal level of the interferer signal at the IUT input port is -50 dBm. The frequency relation between the wanted signal and the interferers is as follows:

   $f_{RX} = 2 \times f_1 - f_2$ and $|f_2 - f_1| = n \times 1$ MHz for 1 Ms/s symbol rate

   $f_{RX} = 2 \times f_1 - f_2$ and $|f_2 - f_1| = n \times 2$ MHz for 2 Ms/s symbol rate

   where n=3, 4, or 5

   Once the frequency configuration is chosen, the PER is measured with the interferers both below *and* above the receive frequency, covering both cases implied by $|f_2 - f_1|$, i.e., the PER is measured twice for each receive frequency.

   Figure 4.24 shows the frequency combination alternatives for the intermodulation test.

2. The Lower Tester's transmit power is chosen such that the input power to the IUT receiver is as listed in Step 1. Figure 4.23 illustrates the test setup principle.
3. The PER is measured according to Section 6.3.
4. Steps 2 and 3 are repeated when the IUT is receiving at the remaining frequencies defined in the test condition section.

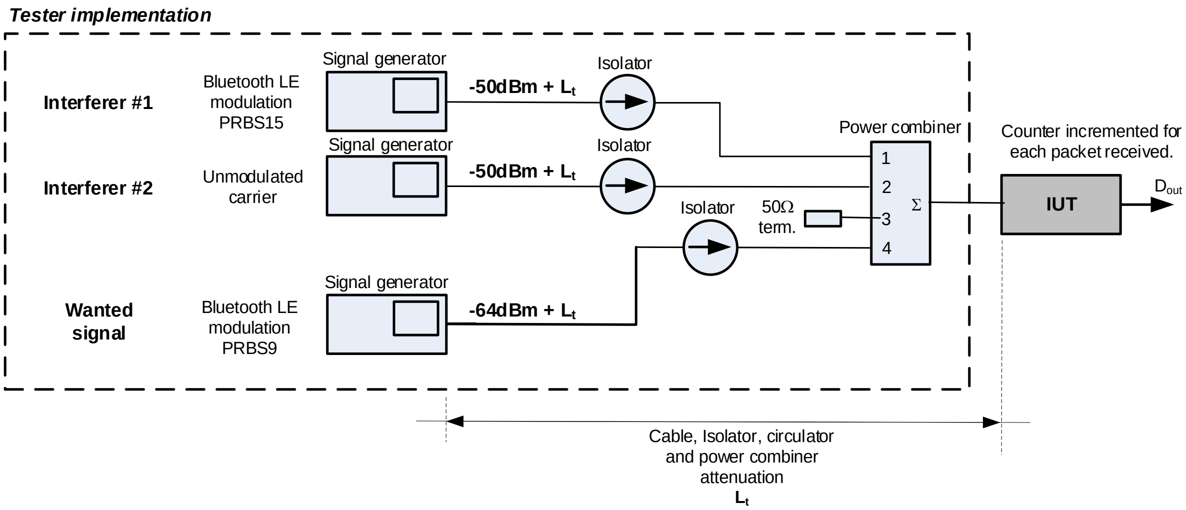

Figure 4.23: Test setup for intermodulation test

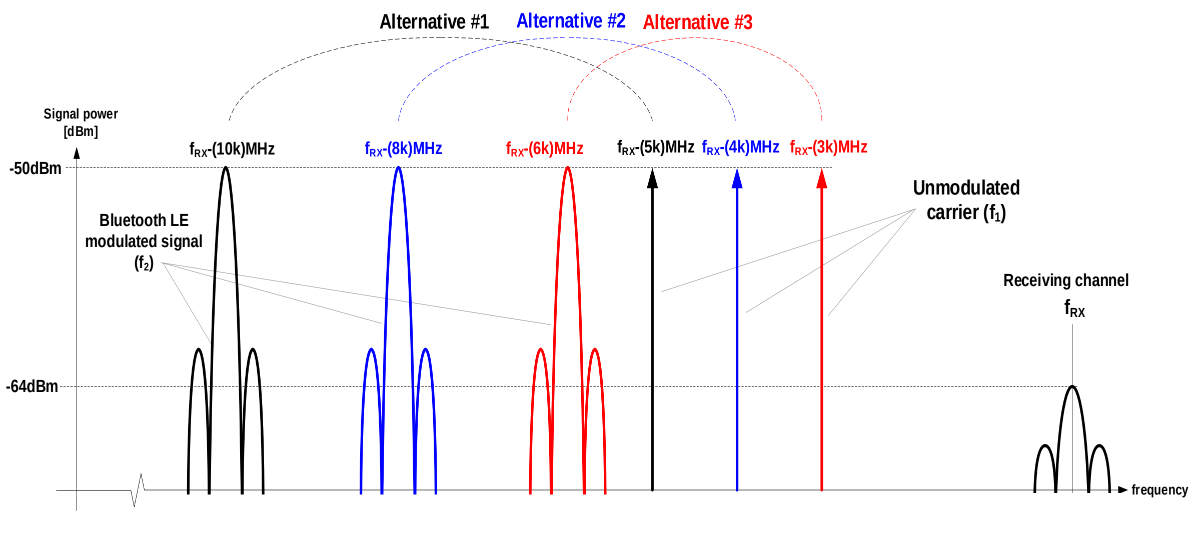

Figure 4.24: Test signal allocation alternatives in the frequency domain at symbol rate k (in Ms/s). Note: figure shows only frequencies below f_0.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  The measured values fulfill the following condition:

  PER better than **30.8%** for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is 37 bytes.

  PER better than the value calculated according to the formula specified in Section 6.3.1 for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is greater than 37 bytes.

  The value of n (for which the TC is performed) is declared by the manufacturer in the IXIT table [3].

4.7.5 Maximum input signal level

- Test Purpose

  Verify that the receiver is able to demodulate a wanted signal at high signal input levels.

- Reference

  [2] Chapter 4.5

  [6] Chapter 4.5

- Initial Condition

  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_RX_LENGTH and MAX_RX_LENGTH_2M (for which the TC is performed) is specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.23.
  - The IUT is set to assume the transmitter has a standard modulation index or stable modulation index (specified in Table 4.23).

- Test Case Configuration

Test Case	Modulation	Symbol Rate	Payload Length
RFPHY/RCV/BV-06-C [Maximum input signal level, uncoded data at 1 Ms/s]	Standard	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-12-C [Maximum input signal level at 2 Ms/s]	Standard	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-18-C [Maximum input signal level, uncoded data at 1 Ms/s, Stable Modulation Index]	Stable	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-24-C [Maximum input signal level at 2 Ms/s, Stable Modulation Index]	Stable	2 Ms/s	MAX_RX_LENGTH_2M

Table 4.23: Maximum input signal level test cases

- Test Procedure

  1. The IUT is set to receive at the lowest frequency for testing defined in the frequencies for testing applicable to the IUT (listed in the test condition section of this test case).
  2. The Lower Tester transmits packets with octet PRBS9 payload with Payload Length (specified in Table 4.23). Refer to Section 6.1, “Reference Signal Definition” and [4], Section 4 for details. The signal level at the IUT input port is -10 dBm.
  3. The PER is measured according to Section 6.3.
  4. Steps 1–3 are repeated when the IUT is receiving at the remaining frequencies defined in the test condition section.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected outcome

  Pass verdict

  All measured values fulfill the following condition:

  PER better than **30.8%** for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is 37 bytes.

  PER better than the value calculated according to the formula specified in Section 6.3.1 for a minimum of **1500** packets transmitted by the Lower Tester if the IUT's Payload Length is greater than 37 bytes.

4.7.6 PER report integrity

- Test Purpose

  Verify that the IUT PER report mechanism reports the correct number of received packets to the Lower Tester.

- Reference

  Section 6.3

  [2] Chapter 2.3

  [6] Chapter 2.3

- Initial Condition

  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The value of MAX_RX_LENGTH, MAX_RX_LENGTH_2M, MAX_RX_LENGTH_CODED_S2, and MAX_RX_LENGTH_CODED_S8 (for which the TC is performed) is specified in Section 6.6.
  - The IUT is set for a symbol rate as specified in Table 4.24.
  - The IUT is set to assume the transmitter has a standard modulation index or stable modulation index (specified in Table 4.24).

- Test Case Configuration

Test Case	Modulation	Symbol Rate	Payload Length
RFPHY/RCV/BV-07-C [PER Report Integrity, uncoded data at 1 Ms/s]	Standard	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-13-C [PER Report Integrity at 2 Ms/s]	Standard	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-19-C [PER Report Integrity, uncoded data at 1 Ms/s, Stable Modulation Index]	Stable	1 Ms/s	MAX_RX_LENGTH
RFPHY/RCV/BV-25-C [PER Report Integrity at 2 Ms/s, Stable Modulation Index]	Stable	2 Ms/s	MAX_RX_LENGTH_2M
RFPHY/RCV/BV-30-C [PER Report Integrity, LE Coded (S=2)]	Standard	1 Ms/s coded S=2	MAX_RX_LENGTH_CODED_S2
RFPHY/RCV/BV-31-C [PER Report Integrity, LE Coded (S=8)]	Standard	1 Ms/s coded S=8	MAX_RX_LENGTH_CODED_S8
RFPHY/RCV/BV-36-C [PER Report Integrity, LE Coded (S=2), Stable Modulation Index]	Stable	1 Ms/s coded S=2	MAX_RX_LENGTH_CODED_S2
RFPHY/RCV/BV-37-C [PER Report Integrity, LE Coded (S=8), Stable Modulation Index]	Stable	1 Ms/s coded S=8	MAX_RX_LENGTH_CODED_S8

Table 4.24: PER Report Integrity test cases

- Test Procedure

  1. The IUT is set to receive at the middle frequency for testing defined in the test condition section.
  2. The Lower Tester transmits packets with octet PRBS9 payload with Payload Length (specified in Table 4.24). Refer to Section 6.1 and [4], Section 4 for details.
  3. The total number of packets transmitted by the Lower Tester is an even random number in the interval [100 ≤ RND ≤ 1500].
  4. Every alternating packet transmitted by the Lower Tester has an intentionally corrupted CRC value.
  5. The signal level at the IUT input port is -30 dBm.
  6. The PER is measured according to Section 6.3.
  7. Steps 1–4 are repeated two times (i.e., three PER measurements in total).

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

  Frequencies for Testing:

Role	IUT Low	IUT Mid	IUT High
All		2440 MHz (n=19)	

- Expected Outcome

  Pass verdict

  All measured values fulfill the following condition:

  50% ≤ PER ≤ (50 + P/2)% for each individual measurement (where P is the appropriate PER value taken from Table 6.2).

4.7.7 IQ Samples Coherency, AoD Receiver

- Test Purpose

  This test group is for generic use and contains four test cases to verify that the measured relative phase values derived from the I and Q values sampled on an IUT AoD Receiver from a Constant Tone Extension are within specified limits.

- Reference

  [8] Section 5

  [9] Section 4.1.7

- Initial Condition

  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The Lower Tester’s transmit power is chosen such that the input power to the IUT receiver is -67 dBm. The Lower Tester does not change its transmit power during the Constant Tone Extension (except during the guard period and the switch slots).
  - The IUT is set to assume the transmitter has a standard modulation index.
  - The IUT is set for a symbol rate as specified in Table 4.25.
  - The rate at which the IUT generates IQ reports (TSPX_IQ_Report_Rate) is defined in the IXIT [5].

- Test Case Configuration

Test Case	PHY	CTE Type (Slot Duration)
RFPHY/RCV/IQC/BV-01-C [IQ Samples Coherency, AoD Receiver at 1 Ms/s with 2 µs Slot]	1 Ms/s	(0x02) 2 µs
RFPHY/RCV/IQC/BV-02-C [IQ Samples Coherency, AoD Receiver at 1 Ms/s with 1 µs Slot]	1 Ms/s	(0x01) 1 µs
RFPHY/RCV/IQC/BV-03-C [IQ Samples Coherency, AoD Receiver at 2 Ms/s with 2 µs Slot]	2 Ms/s	(0x02) 2 µs
RFPHY/RCV/IQC/BV-04-C [IQ Samples Coherency, AoD Receiver at 2 Ms/s with 1 µs Slot]	2 Ms/s	(0x01) 1 µs

Table 4.25: IQ Samples Coherency, AoD Receiver test cases

- Test Procedure

1. The Upper Tester commands the IUT to receive test packets at the lowest frequency for testing as defined in the frequencies for testing (listed in the test condition section of this test case), with expected CTE length of 20 and expected CTE type as specified in Table 4.25.
2. The Lower Tester transmits LE test packets with no PDU payload and with 20 * 8 µs Constant Tone Extension. Antenna switching is executed for each Constant Tone Extension with slot durations as specified in Table 4.25, length of switching pattern and switching pattern set as described in Section 5.2.3 [8] with the number of antenna elements set to 4. See [9] Section 4, “LE Test Packet Definition” for details.
3. The Upper Tester expects to receive HCI_LE_Connectionless_IQ_Report events at the rate specified by TSPX_IQ_Report_Rate and calculates the relative phase and reference phase deviation values for each non-reference antenna, as described in Section 5.2.1 [8].
4. The Lower Tester transmits LE test packets until it reaches the maximum number of packets defined in Section 6.7 or until the RP(m) and RPD sets each contain at least 2,000 values.
5. Repeat Steps 1–4 until the IUT has received on all the remaining frequencies defined in the test condition section.

- Test Condition

The IUT and Lower Tester are set up according to the cabled testing setup described in Section 4.8 and Common test case conditions and parameters defined in Section 4.3 apply.

Frequencies for Testing:

Role	PHY	IUT Low	IUT Mid	IUT High
All	1 Ms/s	2402 MHz (n=0)	2440 MHz (n=19)	2480 MHz (n=39)
All	2 Ms/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

- Expected Outcome

<u>Pass verdict</u>

For each frequency tested, RP(m) and RPD sets contain at least 2,000 valid values each.

For each frequency tested, the IUT meets the requirements from Section 5.2.2 [8].

The presence of invalid IQ samples does not constitute a failure.

4.7.8 IQ Samples Coherency, AoA Receiver

- Test Purpose

  This test group is for generic use and contains two test cases to verify that the measured relative phase values derived from the I and Q values sampled on an IUT AoA Receiver from a Constant Tone Extension are within specified limits.

- Reference

  [8] Section 5

  [9] Section 4.1.7

- Initial Condition
  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The Lower Tester's transmit power is chosen such that the input power to the IUT receiver is -67 dBm. The Lower Tester does not change its transmit power during the Constant Tone Extension (except during the guard period and the switch slots).
  - The IUT is set to assume the transmitter has a standard modulation index.
  - The IUT is set for a symbol rate as specified in Table 4.26.
  - The maximum number of antennae supported by the IUT (TSPX_number_of_antennae) is defined in the IXIT [5].
  - The rate at which the IUT generates IQ reports (TSPX_IQ_Report_Rate) is defined in the IXIT [5].

- Test Case Configuration

Test Case	PHY
RFPHY/RCV/IQC/BV-05-C [IQ Samples Coherency, AoA Receiver at 1 Ms/s with 2 µs Slot]	1 Ms/s
RFPHY/RCV/IQC/BV-06-C [IQ Samples Coherency, AoA Receiver at 2 Ms/s with 2 µs Slot]	2 Ms/s

Table 4.26: IQ Samples Coherency, AoA Receiver test cases

- Test Procedure
  1. The Upper Tester commands the IUT to receive test packets at the lowest frequency for testing as defined in the frequencies for testing (listed in the test condition section of this test case), with expected CTE length of 20, CTE type of 0x00 (AoA CTE), slot durations of 2 µs, length of switching pattern and the switching pattern set as described in Section 5.2.3 [8] with the number of antenna elements set to the minimum value between 4 and TSPX_number_of_antennae.
  2. The Lower Tester transmits LE test packets with no PDU payload and with 20 * 8 µs Constant Tone Extension. See [9] Section 4, "LE Test Packet Definition" for details.
  3. The Upper Tester expects to receive HCI_LE_Connectionless_IQ_Report events at the rate specified by TSPX_IQ_Report_Rate and calculates the relative phase and reference phase deviation values for each non-reference antenna, as described in Section 5.2.1 [8].
  4. The Lower Tester transmits LE test packets until it reaches the maximum number of packets defined in Section 6.7 or until the RP(m) and RPD sets each contain at least 2,000 values.
  5. Repeat Steps 1–4 until the IUT has received on all the remaining frequencies defined in the test condition section.

- Test Condition

  The IUT and Lower Tester are set up according to the cabled testing setup described in Section 4.8 and Common test case conditions and parameters defined in Section 4.3 apply.

  Frequencies for Testing:

Role	PHY	IUT Low	IUT Mid	IUT High
All	1 Ms/s	2402 MHz (n=0)	2440 MHz (n=19)	2480 MHz (n=39)
All	2 Ms/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

- Expected Outcome

  Pass verdict

  For each frequency tested, RP(m) and RPD sets contain at least 2,000 valid values each.

  For each frequency tested, the IUT meets the requirements from Section 5.2.2 [8].

  The presence of invalid IQ samples does not constitute a failure.

4.7.9 IQ Samples Dynamic Range, AoD Receiver

- Test Purpose

  This test group is for generic use and contains four test cases to verify that the I and Q values sampled on receiving an AoD Constant Tone Extension from a peer device have specified values when varying the dynamic range of the Constant Tone Extension and marks any invalid samples as invalid.

- Reference

  [8] Section 5

  [9] Section 4.1.7

- Initial Condition
  - The IUT is set to direct RX mode. Dewhitening is turned off.
  - The IUT is set to assume the transmitter has a standard modulation index.
  - The IUT is set for a symbol rate as specified in Table 4.27.
  - Frequency hopping off, fixed frequency.
  - The rate at which the IUT generates IQ reports (TSPX_IQ_Report_Rate) is defined in the IXIT [5].

- Test Case Configuration

Test Case	PHY	CTE Type (Slot Duration)
RFPHY/RCV/IQDR/BV-07-C [IQ Samples Dynamic Range, AoD Receiver at 1 Ms/s with 2 µs Slot]	1 Ms/s	(0x02) 2 µs
RFPHY/RCV/IQDR/BV-08-C [IQ Samples Dynamic Range, AoD Receiver at 1 Ms/s with 1 µs Slot]	1 Ms/s	(0x01) 1 µs
RFPHY/RCV/IQDR/BV-09-C [IQ Samples Dynamic Range, AoD Receiver at 2 Ms/s with 2 µs Slot]	2 Ms/s	(0x02) 2 µs
RFPHY/RCV/IQDR/BV-10-C [IQ Samples Dynamic Range, AoD Receiver at 2 Ms/s with 1 µs Slot]	2 Ms/s	(0x01) 1 µs

Table 4.27: IQ Samples Dynamic Range, AoD Receiver test cases

- Test Procedure

  1. The Upper Tester commands the IUT to receive test packets at the lowest frequency for testing as defined in the frequencies for testing (listed in the test condition section of this test case), with expected CTE length of 20 and expected CTE type as specified in Table 4.27.
  2. The Lower Tester transmits LE test packets with no PDU payload and with 20 * 8 μs Constant Tone Extension. The Lower Tester applies an attenuation on the line while sending the Preamble, preamble, synchronization word, LE test packet PDU, and CRC, such that the input power to the IUT receiver is set to the value described in Table 4.28 for antenna index 0. Antenna switching is executed for each Constant Tone Extension with slot durations as specified in Table 4.27, length of switching pattern and the switching pattern set as described in Section 5.2.3 [8] with the number of antenna elements set to 4. See [9] Section 4, "LE Test Packet Definition" for details.
  3. The Lower Tester controls a variable attenuator that applies an additional attenuation on the line while sending the Constant Tone Extension, such that the input power to the IUT receiver is set to the value described in Table 4.28 for each antenna index.
  4. The Upper Tester expects to receive HCI_LE_Connectionless_IQ_Report events at the rate specified by TSPX_IQ_Report_Rate and calculates amplitude $A = \text{sqrt}(I^2 + Q^2)$ for each valid sample that was not taken during the reference period.
  5. The Lower Tester transmits LE test packets until it reaches the maximum number of packets defined in Section 6.7 or until the IUT reports at least 2,000 valid IQ sample pairs per antenna, except for antenna index 1.
  6. Repeat Steps 1–5 until the IUT has received on all the remaining frequencies defined in the test condition section.

Antenna Index	Input Power (dBm)
0	-52
1	-49
2	-57
3	-62

Table 4.28: Input Power values for each antenna index

- Test Condition

  The IUT and Lower Tester are set up according to the cabled testing setup described in Section 4.8 and Common test case conditions and parameters defined in Section 4.3 apply.

  Frequencies for Testing:

Role	PHY	IUT Low	IUT Mid	IUT High
All	1 Ms/s	2402 MHz (n=0)	2440 MHz (n=19)	2480 MHz (n=39)
All	2 Ms/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

- Expected Outcome

  <u>Pass verdict</u>

  For each frequency tested, the mean of amplitudes measured for each Lower Tester antenna index 'i' from Table 4.28 follows the equation:

  $$A\text{mean}_{\text{ANT3}} < A\text{mean}_{\text{ANT2}} < A\text{mean}_{\text{ANT0}} < A\text{mean}_{\text{ANT1}}$$

Should there be no valid samples in the non-reference antenna 1, due to saturation, then the Pass verdict is:

$A_{mean_{ANT3}} < A_{mean_{ANT2}} < A_{mean_{ANT0}}$

For each frequency tested, the IUT reports at least 2,000 valid IQ sample pairs per antenna, except for antenna index 1, to the Upper Tester.

The presence of invalid I or Q samples does not constitute a failure.

4.7.10 IQ Samples Dynamic Range, AoA Receiver

- Test Purpose

  This test group is for generic use and contains two test cases to verify that the I and Q values sampled on receiving an AoA Constant Tone Extension from a peer device have specified values when varying the dynamic range of the Constant Tone Extension and marks any invalid samples as invalid.

- Reference

  [8] Section 5

  [9] Section 4.1.7

- Initial Condition

  - The IUT is set to direct RX mode at maximum output power. Whitening is turned off.
  - Frequency hopping off, fixed frequency.
  - The IUT is set to assume the transmitter has a standard modulation index.
  - The IUT is set for a symbol rate as specified in Table 4.29.
  - The maximum number of antennae supported by the IUT (TSPX_number_of_antennae) and the rate at which the IUT generates IQ reports (TSPX_Report_Rate) are defined in the IXIT [5].

- Test Case Configuration

Test Case	PHY
RFPHY/RCV/IQDR/BV-11-C [IQ Samples Dynamic Range, AoA Receiver at 1 Ms/s with 2 µs Slot]	1 Ms/s
RFPHY/RCV/IQDR/BV-12-C [IQ Samples Dynamic Range, AoA Receiver at 2 Ms/s with 2 µs Slot]	2 Ms/s

Table 4.29: IQ Samples Dynamic Range, AoA Receiver test cases

- Test Procedure

  1. The Upper Tester commands the IUT to receive test packets at the lowest frequency for testing as defined in the frequencies for testing (listed in the test condition section of this test case), with expected CTE length of 20, CTE type of 0x00 (AoA CTE), slot durations of 0x02 (2 µs), length of switching pattern and the switching pattern set as described in Section 5.2.3 [8] with the number of antenna elements set to the minimum value between 4 and TSPX_number_of_antennae.
  2. The Lower Tester transmits LE test packets with no PDU payload and with 20 * 8 µs Constant Tone Extension. The Lower Tester applies an attenuation on the line while sending the preamble, synchronization word, LE test packet PDU, and CRC, such that the input power to the IUT receiver is set to the value described in Table 4.30 for antenna index 0. See [9] Section 4, “LE Test Packet Definition” for details.

3. The Lower Tester controls a variable attenuator that applies an additional attenuation on the line while sending the Constant Tone Extension, such that the input power to the IUT receiver is set to the value described in Table 4.30 for each antenna index.
4. The Upper Tester expects to receive HCI_LE_Connectionless_IQ_Report events at the rate specified by TSPX_IQ_Report_Rate and calculates the amplitude A = sqrt(I^2 + Q^2) for each valid sample that was not taken during the reference period.
5. The Lower Tester transmits LE test packets until it reaches the maximum number of packets defined in Section 6.7 or until the IUT reports at least 2,000 valid IQ sample pairs per antenna, except for antenna index 1.
6. Repeat Steps 1–5 until the IUT has received on all the remaining frequencies defined in the test condition section.

Antenna Index	Input Power (dBm)
0	-52
1	-49
2	-57
3	-62

Table 4.30: Input Power values for each antenna index

- Test Condition

The IUT and Lower Tester are set up according to the cabled testing setup described in Section 4.8 and Common test case conditions and parameters defined in Section 4.3 apply.

Frequencies for Testing:

Role	PHY	IUT Low	IUT Mid	IUT High
All	1 Ms/s	2402 MHz (n=0)	2440 MHz (n=19)	2480 MHz (n=39)
All	2 Ms/s	2404 MHz (n=1)	2440 MHz (n=19)	2478 MHz (n=38)

- Expected Outcome

Pass verdict

For each frequency tested, the mean of amplitudes measured for each antenna index ‘i’ from Table 4.30 follows the equation:

$$A\text{mean}_{ANT3} < A\text{mean}_{ANT2} < A\text{mean}_{ANT0} < A\text{mean}_{ANT1}$$

Should there be no valid samples in the non-reference antenna 1, due to saturation, then the Pass verdict is:

$$A\text{mean}_{ANT3} < A\text{mean}_{ANT2} < A\text{mean}_{ANT0}$$

For each frequency tested, the IUT reports at least 2,000 valid IQ sample pairs per antenna, except for antenna index 1, to the Upper Tester.

The presence of invalid IQ samples does not constitute a failure.

4.8 Transmitter/Receiver tests (TRM-RCV)

4.8.1 CS Step Mode-0, Frequency Verification

- Test Purpose

  Verify that the IUT's Fractional Frequency Offset (FFO), and expected transmitted frequencies for Mode-0 transmissions are within limits.

- Reference

  [11] Section 3.5.1

- Initial Condition

  - The Lower Tester is configured as the Initiator and the IUT as the Reflector.
  - A static Access Address (CS Sync Word) is used for the duration of the test, see Section 4.3.3.1.
  - A fixed 1:1 antenna configuration is used in the Test Equipment Setup, see Section 4.2.3.
  - The IUT's transmitter is set to maximum output power.
  - The IUT is configured to transmit a fixed sequence of M Mode-0 CS steps, where M is the maximum number of Mode-0 steps the IUT supports.
  - The IUT transmitter is configured to transmit a single Main-Mode CS step. This Main-Mode CS step is Mode-1.
  - The test frequencies used are swept across all available CS channels in a pseudo random manner, as defined in Section 4.3.3.2 (Table 4.5).

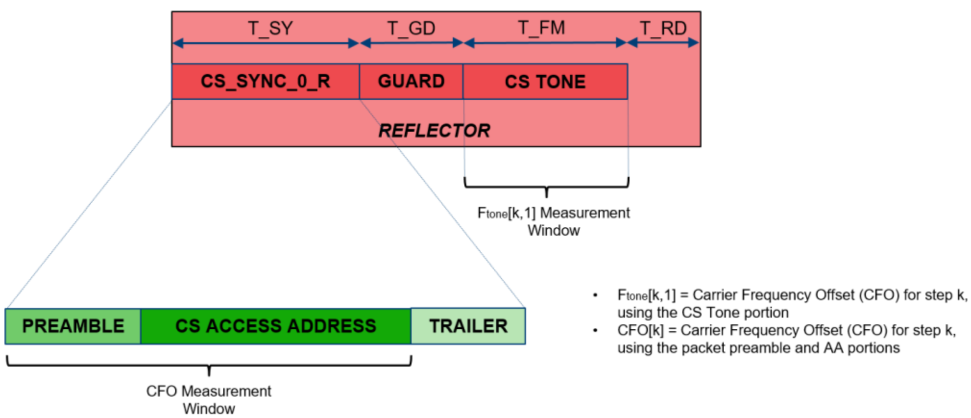

Figure 4.25: Step Mode-0, Reflector signal CFO measurement windows

- Test Case Configuration

TCID	**PHY**	**Main Mode Type**
RFPHY/TRM-RCV/CS/BV-01-C [Step Mode-0, Frequency Verification, 1 Ms/s]	1 Ms/s	Mode-1
RFPHY/TRM-RCV/CS/BV-02-C [Step Mode-0, Frequency Verification, 2 Ms/s]	2 Ms/s	Mode-1
RFPHY/TRM-RCV/CS/BV-03-C [Step Mode-0, Frequency Verification, 2 Ms/s, BT = 2.0]	2 Ms/s, BT = 2.0	Mode-1

Table 4.31: CS Step Mode-0, Frequency Verification test cases

- Test Procedure
  1. The Upper Tester commands the IUT to enable the Channel Sounding procedure with:
     - Role set to Reflector
     - Mode-0 CS steps set to of $M = 3$ steps
     - Main Mode type set to Mode-1
     - Main Mode CS steps set to $K = 1$
     - Other parameters as specified in Section 4.3.3
  2. The Lower Tester sends a Mode-0 transmission to the IUT.
  3. The IUT responds with a Mode-0 transmission, which includes the CS_Tone.
  4. The Lower Tester uses the PHY test filter characteristics as defined in Section 6.9.
  5. The Lower Tester integrates the FM demodulated signal starting at the center of the first preamble bit to the center of the first bit following the last access address bit, and uses this to calculate the center frequency of the packet $f_{pkt}[k]$.
  6. For each step $k = 1..M$, the Lower Tester measures the average frequency of the CS Tone and records this as $F_{tone}[k,1]$.
  7. Calculate the Fractional Frequency Offset (FFO) for each CS step k, $FFO[k] = 10^6.\frac{F_{tone}[k,1]-f_0[k](1+10^{-6}\ FAE[k])}{f_0[k](1+10^{-6}\ FAE[k])}$, where $k = 1..M$, $f_0[k]$ is nominal carrier frequency of the CS Channel for step k, $FAE[k]$ is fractional frequency offset actuation error for the CS channel used in step k of the IUT.
  8. Repeat Steps 2–7 for all M Mode-0 CS steps within the CS sub-event.
  9. The Lower Tester sends a Main Mode transmission.
  10. The IUT responds with a Main Mode transmission.
  11. Repeat Steps 1–10 to obtain a total of 1,000 Mode-0 CS steps.
  12. Steps 1–11 are repeated for the PHYs specified in Table 4.31.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  <u>Pass verdict</u>

  For every sub-event measured:

- $|FFO[k]| \leq 50\ \mathrm{ppm}$, where $k = 1..M$
- $|FFO[k] - FFO[1]| \leq 1\ \mathrm{ppm}$, where $k = 2..M$

For all sub-events measured:

- $95\% \text{ of all recorded } \left|F_{tone} - f_{pkt}(k)\right| < 20\ kHz, \text{where } k = 2, \dots, M$

4.8.2 CS Step Main Mode, Frequency Verification

- Test Purpose

  Verify that the average frequency of each of the IUT's Main Mode transmissions within the CS sub-event are aligned with the initial FFO measurement.

- Reference

  [11] Section 3.5.2, 4.5

- Initial Condition
  - The Lower Tester is configured as the Initiator and the IUT as the Reflector.
  - A static Access Address (CS Sync Word) is used for the duration of the test, see Section 4.3.3.1.
  - The maximum value of N_AP supported by the IUT is used in the Test Equipment Setup, see Section 4.2.3.
  - The IUT's transmitter is set to maximum output power.
  - The IUT is configured to transmit a fixed sequence of M Mode-0 CS steps, where M is the maximum number of Mode-0 steps the IUT supports.
  - Tone extension is set to disabled.
  - The transmit frequency for the entire CS subevent is fixed at f_0, (Section 4.3.2).

- Test Case Configuration

TCID	PHY	Main Mode Type
RFPHY/TRM-RCV/CS/BV-04-C [Step Main Mode, Frequency Verification, 1 Ms/s, Mode-1]	1 Ms/s	Mode-1
RFPHY/TRM-RCV/CS/BV-05-C [Step Main Mode, Frequency Verification, 1 Ms/s, Mode-2]	1 Ms/s	Mode-2
RFPHY/TRM-RCV/CS/BV-06-C [Step Main Mode, Frequency Verification, 1 Ms/s, Mode-3]	1 Ms/s	Mode-3
RFPHY/TRM-RCV/CS/BV-07-C [Step Main Mode, Frequency Verification, 2 Ms/s, Mode-1]	2 Ms/s	Mode-1
RFPHY/TRM-RCV/CS/BV-08-C [Step Main Mode, Frequency Verification, 2 Ms/s, Mode-3]	2 Ms/s	Mode-3
RFPHY/TRM-RCV/CS/BV-09-C [Step Main Mode, Frequency Verification, 2 Ms/s, BT = 2.0, Mode-1]	2 Ms/s, BT = 2.0	Mode-1
RFPHY/TRM-RCV/CS/BV-10-C [Step Main Mode, Frequency Verification, 2 Ms/s, BT = 2.0, Mode-3]	2 Ms/s, BT = 2.0	Mode-3

Table 4.32: CS Step Main Mode, Frequency Verification test cases

- Test Procedure

  1. The Upper Tester commands the IUT to enable the Channel Sounding procedure with:
     - Role set to Reflector
     - Mode-0 CS Steps set to of M = 3 steps, where M is the maximum number of Mode-0 steps the IUT supports
     - Main Mode CS steps set to $1 \leq K \leq 72$
     - Lowest frequency for testing as defined in Section 4.3.2
     - Other parameters as specified in Section 4.3.3
  2. The IUT sends a Mode-0 transmission to the Lower Tester.
  3. The Lower Tester responds with a Mode-0 transmission.
  4. The FFO of first Mode-0 transmission, $FFO[1]$, is measured according to Section 4.8.1. For each CS sub-event used in the measurement, $FFO_E = FFO[1]$.
  5. For each CS step, calculate the expected carrier frequency $f_E[k] = f_0\,[k](1 + 10^{-6}\,FFO_E\,)$.
  6. Perform alternative 6a, 6b, or 6c depending on the Main Mode type and PHY specified in Table 4.32.

     Alternative 6a [Mode-1]:

     6a.1 The Lower Tester sends a Mode-1 transmission (CS_SYNC_1) to the IUT.

     6a.2 The IUT replies with a Mode-1 transmission (CS_SYNC_1) to the Lower Tester.

     6a.3 The Lower Tester integrates the FM demodulated signal of the IUT's CS_SYNC_1 packet starting from the center of the first preamble bit to the center of the first bit following the last access address bit. The Lower Tester uses this to calculate the center frequency of the packet $f_{pkt}[k]$, see Figure 4.26.

     6a.4 Repeat Steps 6a.1–6a.3 for all Mode-1 transmissions within the CS sub-event.

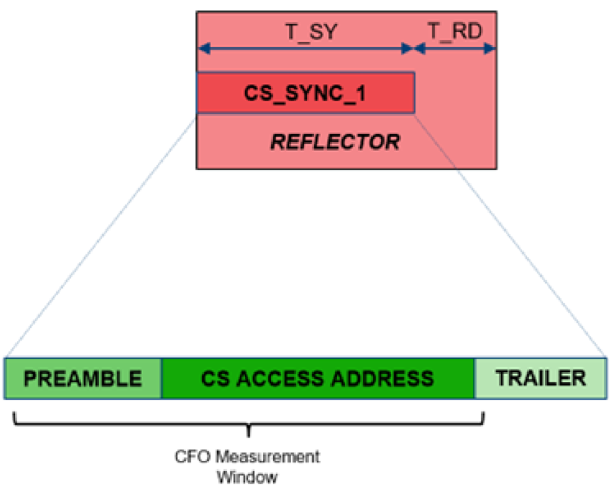

Figure 4.26: Step Main Mode-1, Reflector signal CFO measurement window

     Alternative 6b [Mode-2]:

     6b.1 The Lower Tester sends a Mode-2 transmission (CS_Tone) to the IUT.

     6b.2 The IUT replies with a Mode-2 transmission (CS_Tone) to the Lower Tester.

     6b.3 The Lower Tester performs $f_{tone}[k,p]$ measurements on the CS_Tone packet portion for duration T_PM per antenna, on Step k, and antenna path p, see Figure 4.27. Refer to [11] Volume 6, Part H: Section 4.5 'Timing of Steps'.

     6b.4 Repeat Steps 6b.1–6b.3 for all Mode-2 transmissions within the CS sub-event.

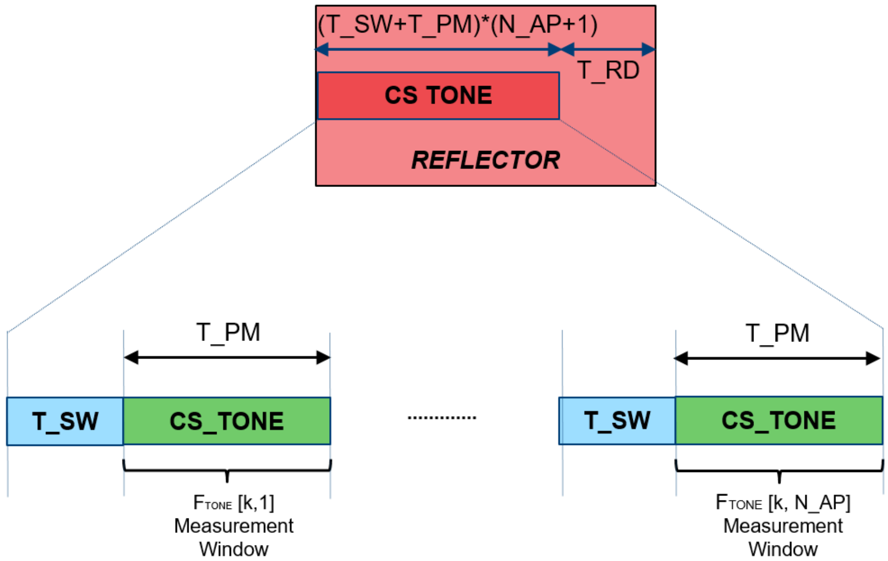

Figure 4.27: Step Main Mode-2, Reflector signal CS tone measurement window

Alternative 6c [Mode-3]:

6c.1 The Lower Tester sends a Mode-3 transmission (CS_SYNC_3 + CS_Tone) to the IUT.

6c.2 The IUT replies with a Mode-3 transmission (CS_Tone + CS_SYNC_3) to the Lower Tester.

6c.3 The Lower Tester performs $f_{tone}[k,p]$ measurements on the CS_Tone packet portion for duration T_PM per antenna, on Step k, and antenna path p. In addition, the Lower Tester integrates the FM demodulated signal of the IUT's CS_SYNC_3 packet starting from the center of the first preamble bit to the center of the first bit following the last access address bit and uses this to calculate the center frequency of the packet $f_{pkt}[k]$, see Figure 4.28. Refer to [11] Volume 6, Part H: Section 4.5 'Timing of Steps'.

6c.4 Repeat Steps 6c.1–6c.3 for all Mode-3 transmissions within the CS sub-event.

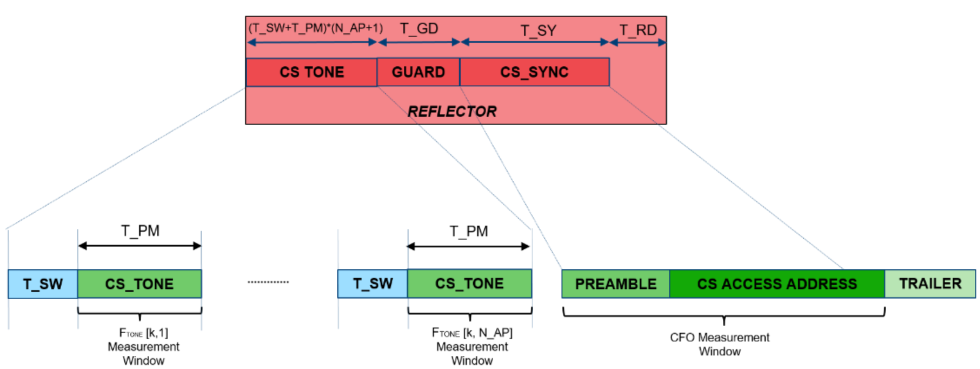

Figure 4.28: Step Main Mode-3, Reflector signal CFO and Ftone measurement windows

7. Repeat Steps 1–6 to obtain a total of 1,000 Main-Mode CS steps.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  Pass verdict

  For every CS sub-event measured, in the case of:

  - Mode-1 and Mode-3 CS steps:
    - $95\%\ of\ all\ measurements{:}\ \left|f_E[k] - f_{pkt}[k]\right| < 20\ \text{kHz}$
  - Mode-2 and Mode-3 CS steps:
    - $95\%\ of\ all\ measurements{:}\ |f_E[k] - f_{tone}[k,p]| < 10\ \text{kHz}$

4.8.3 CS Phase Measurement Accuracy

- Test Purpose

  Verify that the IUT's phase measurement accuracy is within acceptable limits during the phase measurement period for CS tone exchanges.

- Reference

  [11] Section 6.1, 6.2, 6.4

- Initial Condition

  - The Lower Tester is configured as the Initiator and the IUT as the Reflector.
  - A static Access Address (CS Sync Word) is used for the duration of the test, see Section 4.3.3.1.
  - The IUT's transmitter is set to maximum output power.
  - The number of CS antennae (N_AP) in the IUT is defined by the TSPX_number_of_cs_antennae IXIT value.
  - The maximum supported CS antenna path is defined by the TSPX_cs_max_antenna_path IXIT value.
  - The value of N_AP is defined in Table 4.33 based on the Role and Antenna Configuration in Table 4.34.

Role	**Antenna Configuration**	**N_AP**
Reflector	N_AP:1	TSPX_cs_max_antenna_path
Reflector	1:N_AP	TSPX_number_of_cs_antennae
Reflector	2:2	4
Initiator	1:N_AP	TSPX_cs_max_antenna_path
Initiator	N_AP:1	TSPX_number_of_cs_antennae
Initiator	2:2	4

Table 4.33: Antenna Configuration

  - The Lower Tester is configured to transmit a fixed sequence of M Mode-0 CS steps, where M is the minimum number of Mode-0 steps the IUT supports.
  - The Lower Tester's transmit power is adjusted such that the input power to the IUT receiver is $-70\ dBm$.

- The test frequencies used are swept across all available CS channels in a pseudo random manner, as defined in Section 4.3.3.2.
- The FFO of the Lower Tester, as applied to the RF frequencies and the symbol and link layer timing, is set to 50 ppm. This value is initialized to 0 ppm for the first pass of the test procedure.
- The electrical length from the center point of the resistive splitter through to the IUT's antenna connector is predetermined (measured) at each RF channel center frequency. The value of this parameter is used as an offset (to calibrate out the test up) for every RF channel tested during the measurement procedure. This step relocates the test setups reference plane shown in Figure 4.3 (as being at the center of the resistive splitter) to the antenna connector of the IUT.

- Test Case Configuration

TCID	PHY/Role	Main Mode Type	Antenna Configuration
RFPHY/TRM-RCV/CS/BV-11-C [Phase Measurement Accuracy, 1 Ms/s, Mode-2, Reflector, N_AP:1]	1 Ms/s Reflector	Mode-2	N_AP:1
RFPHY/TRM-RCV/CS/BV-19-C [Phase Measurement Accuracy, 1 Ms/s, Mode-2, Reflector, 1:N_AP]	1 Ms/s Reflector	Mode-2	1:N_AP
RFPHY/TRM-RCV/CS/BV-20-C [Phase Measurement Accuracy, 1 Ms/s, Mode-2, Reflector, 2:2]	1 Ms/s Reflector	Mode-2	2:2
RFPHY/TRM-RCV/CS/BV-12-C [Phase Measurement Accuracy, 1 Ms/s, Mode-3, Reflector, N_AP:1]	1 Ms/s Reflector	Mode-3	N_AP:1
RFPHY/TRM-RCV/CS/BV-21-C [Phase Measurement Accuracy, 1 Ms/s, Mode-3, Reflector, 1:N_AP]	1 Ms/s Reflector	Mode-3	1:N_AP
RFPHY/TRM-RCV/CS/BV-22-C [Phase Measurement Accuracy, 1 Ms/s, Mode-3, Reflector, 2:2]	1 Ms/s Reflector	Mode-3	2:2
RFPHY/TRM-RCV/CS/BV-13-C [Phase Measurement Accuracy, 2 Ms/s, Mode-3, Reflector, N_AP:1]	2 Ms/s Reflector	Mode-3	N_AP:1
RFPHY/TRM-RCV/CS/BV-23-C [Phase Measurement Accuracy, 2 Ms/s, Mode-3, Reflector, 1:N_AP]	2 Ms/s Reflector	Mode-3	1:N_AP
RFPHY/TRM-RCV/CS/BV-24-C [Phase Measurement Accuracy, 2 Ms/s, Mode-3, Reflector, 2:2]	2 Ms/s Reflector	Mode-3	2:2
RFPHY/TRM-RCV/CS/BV-14-C [Phase Measurement Accuracy, 2 Ms/s, BT = 2.0, Mode-3, Reflector, N_AP:1]	2 Ms/s, BT = 2.0 Reflector	Mode-3	N_AP:1
RFPHY/TRM-RCV/CS/BV-25-C [Phase Measurement Accuracy, 2 Ms/s, BT = 2.0, Mode-3, Reflector, 1:N_AP]	2 Ms/s, BT = 2.0 Reflector	Mode-3	1:N_AP
RFPHY/TRM-RCV/CS/BV-26-C [Phase Measurement Accuracy, 2 Ms/s, BT = 2.0, Mode-3, Reflector, 2:2]	2 Ms/s, BT = 2.0 Reflector	Mode-3	2:2

TCID	PHY/Role	Main Mode Type	Antenna Configuration
RFPHY/TRM-RCV/CS/BV-15-C [Phase Measurement Accuracy, 1 Ms/s, Mode-2, Initiator, N_AP:1]	1 Ms/s Initiator	Mode-2	N_AP:1
RFPHY/TRM-RCV/CS/BV-27-C [Phase Measurement Accuracy, 1 Ms/s, Mode-2, Initiator, 1:N_AP]	1 Ms/s Initiator	Mode-2	1:N_AP
RFPHY/TRM-RCV/CS/BV-28-C [Phase Measurement Accuracy, 1 Ms/s, Mode-2, Initiator, 2:2]	1 Ms/s Initiator	Mode-2	2:2
RFPHY/TRM-RCV/CS/BV-16-C [Phase Measurement Accuracy, 1 Ms/s, Mode-3, Initiator, N_AP:1]	1 Ms/s Initiator	Mode-3	N_AP:1
RFPHY/TRM-RCV/CS/BV-29-C [Phase Measurement Accuracy, 1 Ms/s, Mode-3, Initiator, 1:N_AP]	1 Ms/s Initiator	Mode-3	1:N_AP
RFPHY/TRM-RCV/CS/BV-30-C [Phase Measurement Accuracy, 1 Ms/s, Mode-3, Initiator, 2:2]	1 Ms/s Initiator	Mode-3	2:2
RFPHY/TRM-RCV/CS/BV-17-C [Phase Measurement Accuracy, 2 Ms/s, Mode-3, Initiator, N_AP:1]	2 Ms/s Initiator	Mode-3	N_AP:1
RFPHY/TRM-RCV/CS/BV-31-C [Phase Measurement Accuracy, 2 Ms/s, Mode-3, Initiator, 1:N_AP]	2 Ms/s Initiator	Mode-3	1:N_AP
RFPHY/TRM-RCV/CS/BV-32-C [Phase Measurement Accuracy, 2 Ms/s, Mode-3, Initiator, 2:2]	2 Ms/s Initiator	Mode-3	2:2
RFPHY/TRM-RCV/CS/BV-18-C [Phase Measurement Accuracy, 2 Ms/s, BT = 2.0, Mode-3, Initiator, N_AP:1]	2 Ms/s, BT = 2.0 Initiator	Mode-3	N_AP:1
RFPHY/TRM-RCV/CS/BV-33-C [Phase Measurement Accuracy, 2 Ms/s, BT = 2.0, Mode-3, Initiator, 1:N_AP]	2 Ms/s, BT = 2.0 Initiator	Mode-3	1:N_AP
RFPHY/TRM-RCV/CS/BV-34-C [Phase Measurement Accuracy, 2 Ms/s, BT = 2.0, Mode-3, Initiator, 2:2]	2 Ms/s, BT = 2.0 Initiator	Mode-3	2:2

Table 4.34: CS Phase Measurement Accuracy test cases

- Test Procedure

1. The Upper Tester commands the IUT to enable the Channel Sounding procedure with:
   - Role set as specified in Table 4.3
   - Mode-0 CS Steps set to $M = 1$ step
   - Main Mode CS steps K set to 72 (all available CS channels)
   - Other parameters as specified in Section 4.3.3
2. The Lower Tester uses the relevant PHY test filter characteristics as defined in Section 6.9.
3. The Lower Tester and the IUT exchange Mode-0 transmissions.
4. The FFO of first Mode-0 transmission, $FFO[1]$, is measured according to Section 4.8.1. For each CS sub-event used in the measurement, $FFO_E = FFO[1]$.

5. For each Main-Mode CS step, calculate the expected carrier frequency $f_E[k] = f_0\,[k](1 + 10^{-6}\,FFO_E\,)$.
6. For each Mode-2 step, the Lower Tester down converts the signals by $f_E\,[k]$, sent by the Lower Tester and the IUT. See [11] Section 6.1.
7. For each phase measurement period, excluding the tone extension slot, within each Main-Mode step, the Lower Tester measures the average phase (see [11] Section 6.2) sent by the Lower Tester during the IUT's valid region (see [11] Section 6.4) and references this to the IUT's antenna port. Denote this value as $\varphi_{RX}[k,p]$, where p is the antenna pair.
8. For each phase measurement period, excluding the tone extension slot, within each Main-Mode step, the Lower Tester measures the average phase (see [11] Section 6.2) sent by the IUT during the Lower Tester's valid region (see [11] Section 6.4) and references this to the IUT's antenna port. Denote this value as $\varphi_{TX}[k,p]$, where p is the antenna pair.
9. The Lower Tester obtains the PCT$[k,p]$ parameters reported by the IUT from the LE CS Subevent Result event.
10. The Upper Tester calculates the internal phase offset $\theta_C[k,p]$ using the measured values of $\varphi_{RX}[k,p]$, $\varphi_{TX}[k,p]$ as well as the value of PCT$[k,p]$ reported by the IUT.
11. For each antenna pair p, the Upper Tester calculates the linear regression parameters $\alpha[p]$ and $\beta[p]$ as described in [11] Section 6.2. Values of $\theta c,uw[k,p]$ are only used in the calculation of the linear regression when the value of the Tone_Quality_Indicator[k] is the highest quality that the IUT supports.
12. Repeat Steps 1–11 139 times in order to obtain a total of 10,000 values of $\theta c,uw[k,p]$.
13. Repeat Steps 1–12 for Lower Tester FFO values of –50 ppm and 50 ppm.

- Test Condition

  Common test case conditions and parameters defined in Section 4.3 apply.

- Expected Outcome

  <u>Pass verdict</u>

  For each antenna pair, the solution to the linear regression satisfies:

  - For 95% of CS sub-events:
    - $|\alpha[p]| < 2\pi\ \times 1.7\ \mathrm{ns}$

    and

    - for 95% of the values of $\theta c[k,p]$ within each CS sub-event:

      $|principal(\alpha[p]f_E[k] + \beta[p] - \theta c,uw[k,p])| < 0.28\ \mathrm{rad}$

5 Test case mapping

The Test Case Mapping Table (TCMT) maps test cases to specific requirements in the ICS. The IUT is tested in all roles for which support is declared in the ICS document.

The columns for the TCMT are defined as follows:

Item: Contains a logical expression based on specific entries from the associated ICS document. Contains a logical expression (using the operators AND, OR, NOT as needed) based on specific entries from the applicable ICS document(s). The entries are in the form of y/x references, where y corresponds to the table number and x corresponds to the feature number as defined in the ICS document for RFPHY [3].

If a test case is mandatory within the respective layer, then the y/x reference is omitted.

Feature: A brief, informal description of the feature being tested.

Test Case(s): The applicable test case identifiers are required for Bluetooth Qualification if the corresponding y/x references defined in the Item column are supported. Further details about the function of the TCMT are elaborated in [1].

For the purpose and structure of the ICS/IXIT, refer to [1].

Item	Feature	Test Case(s)
RFPHY 1/1 OR RFPHY 1/3	Transmitter functionality	RFPHY/TRM/BV-03-C RFPHY/TRM/BV-05-C RFPHY/TRM/BV-06-C
(RFPHY 1/1 OR RFPHY 1/3) AND NOT RFPHY 1/15	Transmitter functionality, not Power Class 1	RFPHY/TRM/BV-01-C
RFPHY 1/15	Transmitter functionality, Power Class 1	RFPHY/TRM/BV-18-C
RFPHY 1/8 AND NOT RFPHY 1/15	Transmitting Constant Tone Extensions, not Power Class 1	RFPHY/TRM/BV-15-C
RFPHY 1/8	Transmitting Constant Tone Extensions	RFPHY/TRM/BV-16-C
RFPHY 1/8 AND RFPHY 1/15	Transmitting Constant Tone Extensions, Power Class 1	RFPHY/TRM/BV-21-C
(RFPHY 1/1 OR RFPHY 1/3) AND RFPHY 1/4 AND NOT RFPHY 1/15	Transmitter functionality, not Power Class 1 LE 2M PHY	RFPHY/TRM/BV-19-C
RFPHY 1/4 AND RFPHY 1/15	Transmitter functionality, Power Class 1 LE 2M PHY	RFPHY/TRM/BV-20-C
RFPHY 1/4 AND RFPHY 1/8 AND NOT RFPHY 1/15	Transmitting Constant Tone Extensions, not Power Class 1 LE 2M PHY	RFPHY/TRM/BV-22-C
RFPHY 1/4 AND RFPHY 1/8 AND RFPHY 1/15	Transmitting Constant Tone Extensions, Power Class 1 LE 2M PHY	RFPHY/TRM/BV-23-C

Item	Feature	Test Case(s)
RFPHY 1/2 OR RFPHY 1/3	Receiver functionality	RFPHY/RCV/BV-01-C RFPHY/RCV/BV-03-C RFPHY/RCV/BV-04-C RFPHY/RCV/BV-05-C RFPHY/RCV/BV-06-C RFPHY/RCV/BV-07-C
(RFPHY 1/1 OR RFPHY 1/3) AND RFPHY 1/4	Transmitter functionality LE 2M PHY	RFPHY/TRM/BV-08-C RFPHY/TRM/BV-10-C RFPHY/TRM/BV-12-C
(RFPHY 1/2 OR RFPHY 1/3) AND RFPHY 1/4	Receiver functionality, LE 2M PHY	RFPHY/RCV/BV-08-C RFPHY/RCV/BV-09-C RFPHY/RCV/BV-10-C RFPHY/RCV/BV-11-C RFPHY/RCV/BV-12-C RFPHY/RCV/BV-13-C
RFPHY 1/4 AND RFPHY 1/8	LE 2M PHY, Transmitting Constant Tone Extensions	RFPHY/TRM/BV-17-C
RFPHY 1/4 AND RFPHY 1/5	LE 2M PHY, Stable Modulation Index - Transmitter	RFPHY/TRM/BV-11-C
RFPHY 1/4 AND RFPHY 1/6	LE 2M PHY. Stable Modulation Index - Receiver	RFPHY/RCV/BV-20-C RFPHY/RCV/BV-21-C RFPHY/RCV/BV-22-C RFPHY/RCV/BV-23-C RFPHY/RCV/BV-24-C RFPHY/RCV/BV-25-C
RFPHY 1/5	Stable Modulation Index - Transmitter	RFPHY/TRM/BV-09-C
RFPHY 1/6	Stable Modulation Index - Receiver	RFPHY/RCV/BV-14-C RFPHY/RCV/BV-15-C RFPHY/RCV/BV-16-C RFPHY/RCV/BV-17-C RFPHY/RCV/BV-18-C RFPHY/RCV/BV-19-C
(RFPHY 1/2 OR RFPHY 1/3) AND RFPHY 1/7	Receiver Functionality, LE Coded PHY	RFPHY/RCV/BV-26-C RFPHY/RCV/BV-27-C RFPHY/RCV/BV-28-C RFPHY/RCV/BV-29-C RFPHY/RCV/BV-30-C RFPHY/RCV/BV-31-C
(RFPHY 1/1 OR RFPHY 1/3) AND RFPHY 1/7	Transmitter Functionality, LE Coded PHY	RFPHY/TRM/BV-13-C RFPHY/TRM/BV-14-C

Item	Feature	Test Case(s)
RFPHY 1/6 AND RFPHY 1/7	Stable Modulation Index - Receiver, LE Coded PHY	RFPHY/RCV/BV-32-C RFPHY/RCV/BV-33-C RFPHY/RCV/BV-34-C RFPHY/RCV/BV-35-C RFPHY/RCV/BV-36-C RFPHY/RCV/BV-37-C
RFPHY 1/11 AND NOT RFPHY 1/12	2 µs Antenna Sampling During Constant Tone Extension Reception (AoD)	RFPHY/RCV/IQC/BV-01-C RFPHY/RCV/IQDR/BV-07-C
RFPHY 1/4 AND RFPHY 1/11 AND NOT RFPHY 1/12	LE 2M PHY, 2 µs Antenna Sampling During Constant Tone Extension Reception (AoD) for 2 Ms/s PHY	RFPHY/RCV/IQC/BV-03-C RFPHY/RCV/IQDR/BV-09-C
RFPHY 1/13 AND NOT RFPHY 1/14	1 µs Antenna Sampling During Constant Tone Extension Reception (AoD)	RFPHY/RCV/IQC/BV-02-C RFPHY/RCV/IQDR/BV-08-C
RFPHY 1/4 AND RFPHY 1/13 AND NOT RFPHY 1/14	LE 2M PHY, 1 µs Antenna Sampling During Constant Tone Extension Reception (AoD) for 2 Ms/s PHY	RFPHY/RCV/IQC/BV-04-C RFPHY/RCV/IQDR/BV-10-C
RFPHY 1/12	2 µs Antenna Switching and Sampling During Constant Tone Extension Reception (AoA)	RFPHY/RCV/IQC/BV-05-C RFPHY/RCV/IQDR/BV-11-C
RFPHY 1/4 AND RFPHY 1/12	LE 2M PHY, 2 µs Antenna Switching and Sampling During Constant Tone Extension Reception (AoA) for 2 Ms/s PHY	RFPHY/RCV/IQC/BV-06-C RFPHY/RCV/IQDR/BV-12-C
RFPHY 1/9	2 µs Antenna Switching During Constant Tone Extension Transmission (AoD)	RFPHY/TRM/PS/BV-01-C RFPHY/TRM/ASI/BV-05-C
RFPHY 1/4 AND RFPHY 1/9	LE 2M PHY, 2 µs Antenna Switching During Constant Tone Extension Transmission (AoD) for 2 Ms/s PHY	RFPHY/TRM/PS/BV-03-C RFPHY/TRM/ASI/BV-07-C
RFPHY 1/10	1 µs Antenna Switching During Constant Tone Extension Transmission (AoD)	RFPHY/TRM/PS/BV-02-C RFPHY/TRM/ASI/BV-06-C
RFPHY 1/4 AND RFPHY 1/10	LE 2M PHY, 1 µs Antenna Switching During Constant Tone Extension Transmission (AoD) for 2 Ms/s PHY	RFPHY/TRM/PS/BV-04-C RFPHY/TRM/ASI/BV-08-C
Channel Sounding		
RFPHY 1/16	Channel Sounding, Transmitter, LE 1M	RFPHY/TRM/CS/BV-01-C
RFPHY 1/16 AND RFPHY 3/10	Channel Sounding, Transmitter, LE 2M	RFPHY/TRM/CS/BV-02-C
RFPHY 3/9	Channel Sounding, Transmitter, LE 2M 2BT	RFPHY/TRM/CS/BV-03-C
RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter, LE 2M 2BT, Mode-3	RFPHY/TRM/CS/BV-04-C
RFPHY 1/16 AND RFPHY 3/2	Channel Sounding, Transmitter-Receiver, LE 1M	RFPHY/TRM-RCV/CS/BV-01-C RFPHY/TRM-RCV/CS/BV-04-C
RFPHY 3/2 AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2	RFPHY/TRM-RCV/CS/BV-05-C

Item	Feature	Test Case(s)
RFPHY 3/2 AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3	RFPHY/TRM-RCV/CS/BV-06-C
RFPHY 1/16 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M	RFPHY/TRM-RCV/CS/BV-02-C RFPHY/TRM-RCV/CS/BV-07-C
RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3	RFPHY/TRM-RCV/CS/BV-08-C
RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT	RFPHY/TRM-RCV/CS/BV-03-C RFPHY/TRM-RCV/CS/BV-09-C
RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3	RFPHY/TRM-RCV/CS/BV-10-C
RFPHY 3/2 AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2, Reflector	RFPHY/TRM-RCV/CS/BV-11-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2, Reflector, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-19-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/3a AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2, Reflector, 2:2	RFPHY/TRM-RCV/CS/BV-20-C
RFPHY 3/2 AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3, Reflector	RFPHY/TRM-RCV/CS/BV-12-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3, Reflector, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-21-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/3a AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3, Reflector, 2:2	RFPHY/TRM-RCV/CS/BV-22-C
RFPHY 3/2 AND RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3, Reflector	RFPHY/TRM-RCV/CS/BV-13-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3, Reflector, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-23-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/3a AND RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3, Reflector: 2:2	RFPHY/TRM-RCV/CS/BV-24-C
RFPHY 3/2 AND RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3, Reflector	RFPHY/TRM-RCV/CS/BV-14-C

Item	Feature	Test Case(s)
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3, Reflector, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-25-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/2 AND RFPHY 3/3a AND RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3, Reflector: 2:2	RFPHY/TRM-RCV/CS/BV-26-C
RFPHY 3/1 AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2, Initiator, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-15-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2, Initiator	RFPHY/TRM-RCV/CS/BV-27-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/3a AND RFPHY 3/6	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-2, Initiator: 2:2	RFPHY/TRM-RCV/CS/BV-28-C
RFPHY 3/1 AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3, Initiator, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-16-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3, Initiator	RFPHY/TRM-RCV/CS/BV-29-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/3a AND RFPHY 3/7	Channel Sounding, Transmitter-Receiver, LE 1M, Mode-3, Initiator, 2:2	RFPHY/TRM-RCV/CS/BV-30-C
RFPHY 3/1 AND RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3, Initiator, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-17-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3, Initiator	RFPHY/TRM-RCV/CS/BV-31-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/3a AND RFPHY 3/7 AND RFPHY 3/10	Channel Sounding, Transmitter-Receiver, LE 2M, Mode-3, Initiator, 2:2	RFPHY/TRM-RCV/CS/BV-32-C
RFPHY 3/1 AND RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3, Initiator, CS Antenna Array	RFPHY/TRM-RCV/CS/BV-18-C

Item	Feature	Test Case(s)
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3, Initiator	RFPHY/TRM-RCV/CS/BV-33-C
RFPHY 1/1 AND RFPHY 1/2 AND RFPHY 3/1 AND RFPHY 3/3a AND RFPHY 3/7 AND RFPHY 3/9	Channel Sounding, Transmitter-Receiver, LE 2M 2BT, Mode-3, Initiator, 2:2	RFPHY/TRM-RCV/CS/BV-34-C
RFPHY 3/8	Channel Sounding, Transmitter, LE 1M, TX/SNR	RFPHY/TRM/CS/BV-05-C
RFPHY 3/7 AND RFPHY 3/8	Channel Sounding, Transmitter, LE 1M, Mode-3, TX/SNR	RFPHY/TRM/CS/BV-06-C
RFPHY 3/8 AND RFPHY 3/10	Channel Sounding, Transmitter, LE 2M, TX/SNR	RFPHY/TRM/CS/BV-07-C
RFPHY 3/7 AND RFPHY 3/8 AND RFPHY 3/10	Channel Sounding, Transmitter, LE 2M, Mode-3, TX/SNR	RFPHY/TRM/CS/BV-08-C
RFPHY 3/8 AND RFPHY 3/9	Channel Sounding, Transmitter, LE 2M 2BT, TX/SNR	RFPHY/TRM/CS/BV-09-C
RFPHY 3/7 AND RFPHY 3/8 AND RFPHY 3/9	Channel Sounding, Transmitter, LE 2M 2BT, Mode-3, TX/SNR	RFPHY/TRM/CS/BV-10-C

Table 5.1: Test case mapping

6 Appendix

6.1 Reference Signal Definition

The Bluetooth low energy reference signal, either as wanted or an interfering signal, has the following characteristics defined in [6] Chapter 4.6.

Payload content of the wanted signal is a PRBS9 sequence and is identical for all transmitted packets.

In test cases where an interfering signal is used, the interferer is continuously modulated with PRBS15 data (i.e., no packet structures or pauses in the signal). The interfering signal has settled at least 1 ms prior to the activation of the wanted signal.

The Lower Tester used for the qualification tests has the ramp up characteristics shown in Figure 6.1.

- t_{rampup} is the time from when the Lower Tester output is 40 dB below the final output power (x dBm) to the time when the output power has reached a level within ±3 dB of the final output power.
- $t_{settling}$ is the time from when the Lower Tester output is 40 dB below the final output power (x dBm) to the time when the output power has reached a level within ±1 dB of the final output power.
- t_{p0} is the time at which the first preamble bit begins.

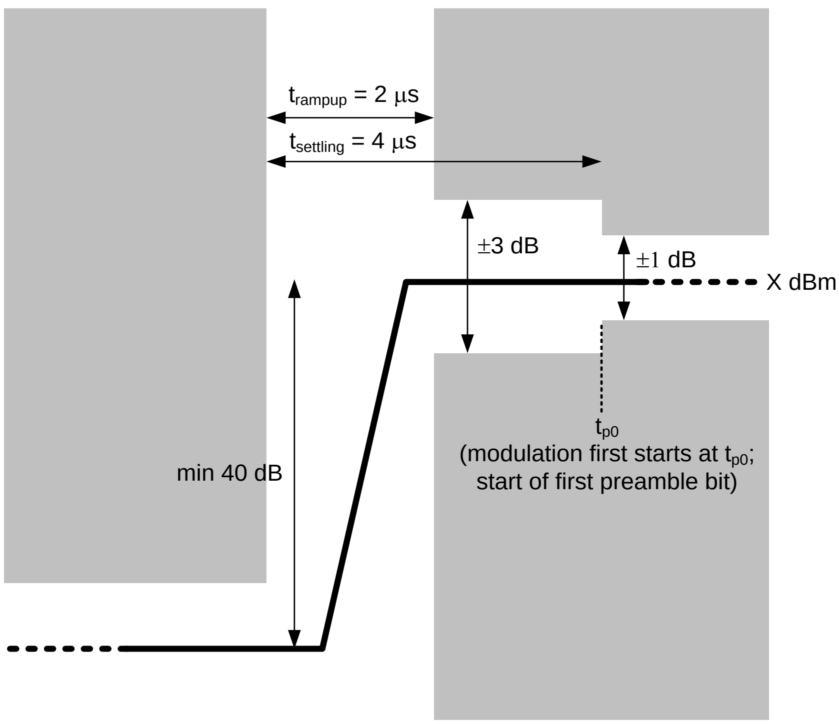

Figure 6.1: Lower Tester ramp-up characteristics requirement, modulation first starts at t_{p0}

6.2 Normal Operating Conditions (NOC)

6.2.1 Normal Temperature and Air Humidity

The normal operating temperature is declared by the equipment manufacturer as an IXIT value. The NOC test temperature is within ±10°C of this value.

Operating air humidity range is declared by the product manufacturer as maximum and minimum values (IXIT). The air humidity level for the NOC tests is within the declared range.

The temperature and air humidity values during the test is recorded in the test documentation.

6.2.2 Nominal Supply Voltage

The IUT supply voltage under normal operating conditions is the nominal supply voltage as declared by the IUT manufacturer.

The nominal supply voltage is recorded in the test documentation.

6.3 Packet Error Rate / Bit Error Rate Measurements

The Packet Error Rate (PER) measurement is used in all measurements testing receiver characteristics in the Bluetooth low energy RFPHY Test Suite. PER tests are based on the direct test mode described in [4].

6.3.1 PER Test Definition

PER tests are based on counting the number of packets received by the IUT out of a series of consecutive LE test packets transmitted by the Lower Tester. The test is performed with frequency hopping disabled.

The packet error rate is defined as follows:

$$PER = \left(\mathbf{1 -} \frac{\textbf{Number of packets received by the EUT passing CRC}}{\textbf{Total number of packets transmitted by the tester}} \right) \cdot 100\%$$

The Lower Tester transmits LE test packets with PRBS9 payload as defined in [4], Section 4 to the IUT. Upon request from the Lower Tester to the IUT, the IUT reports the number of LE test packets that has been correctly received (i.e., passing CRC) since last request. Refer to [4] for detailed description of the direct test mode.

The sensitivity level based on BER measurements is defined as the input power level at which a BER of value specified in Table 6.1 is achieved measured with a reference signal as described in Section 6.1, and packet with PRBS9 payload as described in [4], Section 4.

Maximum Supported Payload Length in Receiver (bytes)	BER (%)
37	0.1
≥38 and ≤63	0.064
≥64 and ≤127	0.034
≥128 and ≤255	0.017

Table 6.1: Sensitivity BER level by maximum payload length in receiver

The PER corresponding to the acceptable BER limit is calculated according to the formula below:

PER = $(1 - X^{[(MAX\_RX\_LENGTH * 8) + 72]}) \times 100\%$

- X = 1 – BER,
- i.e., X=0.99900 if MAX_RX_LENGTH=37,
- X=0.99936 if 38 ≤ MAX_RX_LENGTH ≤ 63,
- X=0.99966 if 64 ≤ MAX_RX_LENGTH ≤ 127,
- X=0.99983 if 128 ≤ MAX_RX_LENGTH ≤ 255.
- MAX_RX_LENGTH is the maximum supported payload length in IUT's receiver and it is declared in RFPHY IXIT proforma [5] in range of 37 ~ 255.
- 72 in the formula is total length of synchronization word, PDU header, PDU length & CRC parts in LE test packet in bit unit.

6.3.2 BER to PER Mapping

This PER requirement defined in Section 6.3.1 equates to the corresponding BER value under the following assumptions:

- Bit errors are randomly distributed with a rectangular error probability density function
- Bit errors are not correlated

Furthermore, the following reasoning is applied (using an example of BER to PER mapping based on a BER value of 0.1% and MAX_RX_LENGTH of 37 bytes):

- The probability of a particular bit being in error at a BER of 0.1% is 0.001
- It follows that the probability of a bit being OK under the same condition is 0.999
- Examining the impact of a bit error in the LE test packet with a 37-byte payload length:

Preamble (8 bit)	Packet can be recovered2
Sync word (32 bit)	Error; Packet is lost
Packet type field (16 bit)	Error; Packet is lost
Payload (296 bit)	Error; Packet is lost
CRC (24 bit)	Error; Packet is lost

- The number of significant bits in a 37-byte payload LE test packet is thus 368 bits (out of a total of 376 bits).
- The probability of a 368 bit sequence containing no bit errors is $0.999^{368} = 0.692$
- Resulting PER requirement is then (1 - 0.692)*100% = 30.8%

The sensitivity BER by maximum payload length in the receiver corresponds to the PER requirements listed in Table 6.2 below:

Maximum Supported Payload Length in Receiver (bytes)	PER
37	30.8%
38	21.4%
39	21.8%
40	22.2%

[2] The effect of errors in the preamble is implementation dependent. In general, a bit error in the preamble does not automatically imply that the packet is lost. It is therefore assumed that an error in the preamble is "allowed" and that the packet is recoverable.

Maximum Supported Payload Length in Receiver (bytes)	PER
41	22.6%
42	23.0%
43	23.4%
44	23.8%
45	24.2%
46	24.5%
47	24.9%
48	25.3%
49	25.7%
50	26.1%
51	26.5%
52	26.8%
53	27.2%
54	27.6%
55	27.9%
56	28.3%
57	28.7%
58	29.0%
59	29.4%
60	29.8%
61	30.1%
62	30.5%
63	30.8%
64	18.0%
65	18.2%
66	18.5%
67	18.7%
68	18.9%
69	19.1%
70	19.3%
71	19.6%
72	19.8%
73	20.0%
74	20.2%
75	20.4%
76	20.6%
77	20.9%
78	21.1%
79	21.3%
80	21.5%
81	21.7%
82	21.9%
83	22.1%
84	22.4%
85	22.6%
86	22.8%
87	23.0%
88	23.2%

Maximum Supported Payload Length in Receiver (bytes)	PER
89	23.4%
90	23.6%
91	23.8%
92	24.0%
93	24.2%
94	24.4%
95	24.6%
96	24.8%
97	25.1%
98	25.3%
99	25.5%
100	25.7%
101	25.9%
102	26.1%
103	26.3%
104	26.5%
105	26.7%
106	26.9%
107	27.1%
108	27.3%
109	27.5%
110	27.7%
111	27.9%
112	28.0%
113	28.2%
114	28.4%
115	28.6%
116	28.8%
117	29.0%
118	29.2%
119	29.4%
120	29.6%
121	29.8%
122	30.0%
123	30.2%
124	30.4%
125	30.5%
126	30.7%
127	30.9%
128	17.0%
129	17.1%
130	17.2%
131	17.3%
132	17.5%
133	17.6%
134	17.7%
135	17.8%
136	17.9%

Maximum Supported Payload Length in Receiver (bytes)	PER
137	18.0%
138	18.1%
139	18.2%
140	18.3%
141	18.5%
142	18.6%
143	18.7%
144	18.8%
145	18.9%
146	19.0%
147	19.1%
148	19.2%
149	19.3%
150	19.4%
151	19.6%
152	19.7%
153	19.8%
154	19.9%
155	20.0%
156	20.1%
157	20.2%
158	20.3%
159	20.4%
160	20.5%
161	20.6%
162	20.8%
163	20.9%
164	21.0%
165	21.1%
166	21.2%
167	21.3%
168	21.4%
169	21.5%
170	21.6%
171	21.7%
172	21.8%
173	21.9%
174	22.0%
175	22.1%
176	22.2%
177	22.4%
178	22.5%
179	22.6%
180	22.7%
181	22.8%
182	22.9%
183	23.0%
184	23.1%

Maximum Supported Payload Length in Receiver (bytes)	PER
185	23.2%
186	23.3%
187	23.4%
188	23.5%
189	23.6%
190	23.7%
191	23.8%
192	23.9%
193	24.0%
194	24.1%
195	24.2%
196	24.3%
197	24.4%
198	24.5%
199	24.6%
200	24.7%
201	24.8%
202	24.9%
203	25.0%
204	25.2%
205	25.3%
206	25.4%
207	25.5%
208	25.6%
209	25.7%
210	25.8%
211	25.9%
212	26.0%
213	26.1%
214	26.2%
215	26.3%
216	26.4%
217	26.5%
218	26.6%
219	26.7%
220	26.8%
221	26.9%
222	27.0%
223	27.1%
224	27.2%
225	27.3%
226	27.4%
227	27.5%
228	27.6%
229	27.7%
230	27.8%
231	27.9%
232	27.9%

Maximum Supported Payload Length in Receiver (bytes)	PER
233	28.0%
234	28.1%
235	28.2%
236	28.3%
237	28.4%
238	28.5%
239	28.6%
240	28.7%
241	28.8%
242	28.9%
243	29.0%
244	29.1%
245	29.2%
246	29.3%
247	29.4%
248	29.5%
249	29.6%
250	29.7%
251	29.8%
252	29.9%
253	30.0%
254	30.1%
255	30.2%

Table 6.2: PER level by maximum payload length in receiver

6.4 Definition of the Position of Bit p0

Bit p0 is defined as the first bit in the preamble sequence. The start of p0 is defined to occur at the point in time 56 bit periods before the instant at which the modulated carrier passes through the nominal channel frequency immediately prior to the deviation corresponding to the first bit of the payload field.

The start of bit p0 is calculated using averaging based on the position of all the zero crossings in the packet:

For the m zero crossings in the packet, the i'th zero crossing time instant is t(i) in µs; this is the start of bit p(i).

The start of bit p0 is then calculated as:

$$t_0 = \frac{1}{m}\sum_{i=1}^{m}\left(t(i) - p(i)\right) \quad [\mu s]$$

6.5 Measurement Uncertainty

Table 6.3 contains the measurement accuracy requirements for the test cases described in this document. The test equipment used for the tests must have measurement accuracy within the listed limits. The verdict decision limits for each test case take the measurement uncertainty listed in Table 6.3 into account. All figures in the table reflect a 95% confidence level.

Type of measurement	Measurement accuracy requirement
Conducted measurements: Absolute RF power (wanted channel) Absolute RF power (unwanted emissions in the 2400 – 2483.5 MHz band) Absolute RF power (unwanted emissions outside the 2400 – 2483.5 MHz band)	 ± 1.2 dB ± 3 dB ± 3 dB[3]
Relative RF power: Relative RF power (wanted channel)	 ± 1 dB
Radiated measurements: Absolute RF power (wanted channel) Radiated emissions (for unwanted emissions)	 ± 6 dB ± 6 dB
Absolute frequency: Absolute frequency (RF frequencies) Absolute frequency (Frequency deviation of modulated signal)	 ± 5 kHz ± 4 kHz
Relative frequency: Relative frequency (Frequency drift of carrier during modulation)	 ± 1 kHz

Table 6.3: Measurement accuracy requirements

6.6 Packet Lengths

Note: Symbols with names beginning “PL_” are only defined and used within this section.

For each symbol in the first column of Table 6.4, the value of the symbol is the greater of the values of the symbols in the other two columns.

MAX_TX_LENGTH	PL_ADV_L	PL_DTX_1M
MAX_TX_LENGTH_2M	PL_ADV_X	PL_DTX_2M
MAX_TX_LENGTH_CODED_S2	PL_ADV_X	PL_DTX_C2
MAX_TX_LENGTH_CODED_S8	PL_ADV_X	PL_DTX_C8
MAX_RX_LENGTH	PL_SCN_L	PL_DRX_1M
MAX_RX_LENGTH_2M	PL_SCN_X	PL_DRX_2M
MAX_RX_LENGTH_CODED_S2	PL_SCN_X	PL_DRX_C2
MAX_RX_LENGTH_CODED_S8	PL_SCN_X	PL_DRX_C8

Table 6.4: Overall Inputs for Packet Length Symbols

If the Link Layer of the IUT supports the Advertising Extension feature, then:

- PL_ADV_L and PL_ADV_X equals TSPX_AdvOctets_Max.
- PL_SCN_L and PL_SCN_X equals 255.

[3] For frequencies above 4 GHz, a measurement accuracy requirement of ± 4 dB applies

Otherwise:

- PL_ADV_L and PL_SCN_L equals 37.
- PL_ADV_X and PL_SCN_X equals 31.

If the Link Layer of the IUT supports the Data Length Extension feature, then for each symbol in the first column of Table 6.5, the value of the symbol is the lesser of the values of the expressions in the other two columns ("⌊X⌋" means the greatest integer less than or equal to X).

PL_DTX_1M	TSPX_TxOctets_Max+4	⌊TSPX_TxTime_Max ÷ 8 – 10⌋
PL_DTX_2M	TSPX_TxOctets_Max+4	⌊TSPX_TxTime_Max ÷ 4 – 11⌋
PL_DTX_C2	TSPX_TxOctets_Max+4	⌊TSPX_TxTime_Max ÷ 16 – 28⌋
PL_DTX_C8	TSPX_TxOctets_Max+4	⌊TSPX_TxTime_Max ÷ 64 – 11⌋
PL_DRX_1M	TSPX_RxOctets_Max+4	⌊TSPX_RxTime_Max ÷ 8 – 10⌋
PL_DRX_2M	TSPX_RxOctets_Max+4	⌊TSPX_RxTime_Max ÷ 4 – 11⌋
PL_DRX_C2	TSPX_RxOctets_Max+4	⌊TSPX_RxTime_Max ÷ 16 – 28⌋
PL_DRX_C8	TSPX_RxOctets_Max+4	⌊TSPX_RxTime_Max ÷ 64 – 11⌋

Table 6.5: Maximum Lengths When Data Length Extension is Supported

Otherwise, the values of all the symbols in the first column of Table 6.5 are 31.

Note: For each symbol in the first column of Table 6.6, the reference for that symbol in [5] is given in the second column. The third and fourth columns give the minimum and maximum permitted values for the symbol.

TSPX_AdvOctets_Max	LL:P4:19 on the LL tab	37	255
TSPX_RxOctets_Max	LL:P4:17 on the LL tab	27	251
TSPX_RxTime_Max	LL:P4:18 on the LL tab	328	17040
TSPX_TxOctets_Max	LL:P4:15 on the LL tab	27	251
TSPX_TxTime_Max	LL:P4:16 on the LL tab	328	17040

Table 6.6: References

6.7 Number of Valid IQ Sample Pairs

This section and its subsections are explanatory.

A controller can return IQ sample pairs where either I or Q, or both, are marked as 'No Valid Sample Available'. These IQ sample pairs are discarded as invalid. Invalid IQ sample pairs are not used in the magnitude, relative phase, and reference phase deviation calculations.

The number of valid IQ sample pairs required per non-reference antenna for the IQ Samples Coherency tests is chosen as 10,000. The same number of valid IQ sample pairs is chosen for the IQ Dynamic Range tests, to maintain consistency across the tests.

6.7.1 Maximum Number of Packets for IQ Coherency Measurements

The tests require LE packets to be sent with maximum length CTE comprising of 1 µs or 2 µs slots. The number of collected IQ sample pairs per packet is either 74 or 37, respectively. The measurements are performed using IQ sample pair groups that must include non-reference antenna transmissions. Using the pre-defined switching pattern (x000, …, where x is a non-reference antenna), a maximum of 18 sample pairs groups for 1 µs slots and 8 sample pairs groups for 2 µs slots that include all required IQ sample measurements are possible from every CTE.

The following tables show the number of IQ sample pairs returned by the IUT for different number of non-reference antenna for 1us and 2us switching slots, respectively.

Number of non-reference antennae	1	2	3
1	18	0	0
2	9	9	0
3	6	6	6

Table 6.7: Number of I/Q samples per antenna element for 1 µs switching slots

Number of non-reference antennae	1	2	3
1	8	0	0
2	4	4	0
3	2	3	3

Table 6.8: Number of I/Q samples per antenna element for 2 µs switching slots

Table for the number of packets transmitted required to obtain 10,000 IQ sample pairs per non-reference antenna on the receiver is shown below:

Number of non-reference antennae	1 µs switching slot	2 µs switching slot
1	556	1250
2	1112	2500
3	1667	3334

Table 6.9: Number of packets required for 10,000 IQ sample pairs

The Table 6.9 assumes that IUT receives all packets successfully, and all the IQ sample pairs reported are marked valid.

The number of packets transmitted required for the test needs to be increased to allow for both lost packets and invalid IQ sample pairs. A 20% allowance to account for lost packets and invalid IQ sample pairs is recommended. The IUT reports IQ sample pairs at a rate of TSPX_IQ_Report_Rate. The number of packets transmitted by the Lower Tester for the measurement needs to scale by the following factor:

$$ceil\left\lceil\frac{\text{Number of Transmitted LE Packets per second}}{\text{TSPX\_IQ\_Report\_Rate}}\right\rceil$$

This is the recommended maximum number of packets transmitted by the Lower Tester for the coherency tests.

6.8 Antenna Gain

If it is necessary for Regulatory test purposes, the TX peak antenna gain is used and declared by the manufacturer.

6.9 Tester Filter Characteristics

This section defines the PHY-dependent Lower Tester settings used for the RF channel filter (see Table 6.10) and the FM demodulator (see Table 6.11).

Frequency (for 1 Ms/s)	Frequency (for 2 Ms/s)	Frequency (for 2 Ms/s; BT=2.0)	Attenuation
$\pm$650 kHz Passband ripple: 0.5 dB (within $\pm$ 550 kHz)	$\pm 1.3\ MHz$ Passband ripple: 0.5 dB (within $\pm$ 1.1 MHz)	$\pm 7.8\ MHz$ Passband ripple: 0.5 dB (within $\pm$ 4.4 MHz)	3 dB
$\pm$1.0 MHz	$\pm 2.0\ MHz$	$\pm 9.2\ MHz$	14dB
$\pm$2.0 MHz	$\pm 4.0\ MHz$	$\pm 11.0\ MHz$	44 dB

Table 6.10: Lower Tester minimum channel filter attenuation characteristics

FM Demodulator Characteristic	1 Ms/s PHY	2 Ms/s PHY	2 Ms/s; BT=2.0 PHY
Bandwidth (minimum)	$2.0\ MHz$	$4.0\ MHz$	$16.0\ MHz$

Table 6.11: Lower Tester FM demodulation characteristics

7 Revision history and acknowledgments

Revision History

Publication Number	Revision Number	Date	Comments
0	RF-PHY.TS/4.0.0	2009-12-15	Prepare for publication.
	4.0.1r0 4.0.1r1	2010-12-01-2011-02-02	TSE 3408: TRM-LE/CA/BV-03-C , TRM-LE/CA/BV-04-C: updates 5, 6 TSE 3462 Rename test case in Tables 7.2 and 7.3 : TSE 3945: Remove Section 7.2 and refer to ESR05, eventually to be moved to core spec Vol 6, Part D Section 4. See also TSE 4204. TSE 4204: Additional changes for E3696 (see also TSE 3945)
1	4.0.1	2011-07-18	Prepare for publication.
	4.0.2r0	2012-09-06	TSE 4906: Change to test procedure of TRM-LE/CA/BV-03-C added, "AND skip to next frequency if the increased frequency equals to fTX or "fTX - 1MHz" or "fTX + 1MHz".
2	4.0.2	2012-11-15	Prepare for Publication
	4.0.3r1	2013-05-31	TSE 5041: Editorial correction in step 3 of the test procedure for test case RCV-LE/CA/BV-01-C, incorrect cross-reference. TSE 5042: Editorial correction to the cross-reference in Figure 6.7 in RCV-LE/CA/BV-03-C that referenced “Table 6.4” when it should have referenced “6.3”. TSE 5043: Editorial correction to the cross-reference in Figure 6.8 in RCV-LE/CA/BV-04-C that referenced “Table 6.5” when it should have referenced “6.4”. TSE 5044: Editorial correction in the 3rd paragraph of the pass verdict for test case RCV-LE/CA/BV-04-C.
	4.0.3r2,	2013-06-03	BTI Review, comments from Miles.
	4.0.3r3	2013-06-04	BTI Review, comments from Dan. Updated Copyright Notice to 2013. Changed Table reference to figure reference in Step 4 of TRM-LE/CA/BV-06-C.
	4.0.3r4	2013-06-04	BTI Review, additional comments from Dan TRM-LE/CA/BV-04-C was an incorrect heading level, changed it to the test case heading level which updated the section from 6.3 to 6.3.4.
3	4.0.3	2013-07-02	Prepare for Publication
	4.1.0r01	2013-11-11	Revision to accommodate v 4.1
4	4.1.0	2013-12-03	Prepare for Publication
	4.1.0 – Template Conversion	2014-01-23	Template Conversion into Template_TS_2014r02

Publication Number	Revision Number	Date	Comments
	4.1.1r00	2014-01-23	TSE 5507: Correctly formatted the TC IDs for TRM-LE/CA/BV-01-C, TRM-LE/CA/BV-02-C, TRM-LE/CA/BV-03-C, TRM-LE/CA/BV-04-C, TRM-LE/CA/BV-05-C, TRM-LE/CA/BV-06-C, TRM-LE/CA/BV-07-C, RCV-LE/CA/BV-01-C, RCV-LE/CA/BV-02-C, RCV-LE/CA/BV-03-C, RCV-LE/CA/BV-04-C, RCV-LE/CA/BV-05-C, RCV-LE/CA/BV-06-C, RCV-LE/CA/BV-07-C.
	4.1.2r00	2014-10-21	TSE 5635: Corrected a statement that had lost the superscript, “The probability of a 368 bit sequence containing not bit errors is 0.999^368 = 0.692”
	4.1.2r01	2014-11-05	BTI Review, Magnus, Removed Test Suite Structure illustration.
	4.2.0r00	2014-11-07	Integrated CRs from RF-PHY TS 4 1 0-Data_Length_Increase_r02.
	4.2.0r01	2014-11-24	Updated Test Case numbering convention to match convention in TCRL (added “BV” and dashes).
5	4.2.0	2014-12-04	Prepare for TCRL 2014-2 publication
	4.2.1r00	2015-05-06	TSE 6142: Updated Section 6.6 to be consistent with revised sensitivity levels in Core spec. Revised Pass verdicts accordingly for TP/RCV-LE/CA/BV-01-C, TP/RCV-LE/CA/BV-03-C, TP/RCV-LE/CA/BV-04-C, TP/RCV-LE/CA/BV-05-C, TP/RCV-LE/CA/BV-06-C. TSE 6100: Deleted “EIRP” in TP/TRM-LE/CA/BV-01-C Pass verdict. TSE 6140: Revised References section to remove redundant entries and correct errors. Updated instances of those references throughout the document. TSE 6340: Corrected equation in step 5 of TP/TRM-LE/CA/BV-03-C TSE 6368: Corrected references to other steps in steps 8 and 12 of TP/TRM-LE/CA/BV-03-C
	4.2.1r01	2015-05-18	TSE 6413: Revised PER value in Pass verdict of TP/RCV-LE/CA/BV-07-C
	4.2.1r02	2015-06-03	Editorial: Universal change from EUT to IUT Removal of redundant Section 6.5 (Test Conditions Summary)
6	4.2.1	2015-07-14	Prepared for TCRL 2015-1 publication
	4.2.2r00	2015-10-09	TSE 6369: Changed interval for frequency drift rate #0 in Figure 4.5 and updated the pass criterion frequency for TP/TRM-LE/CA/BV-06-C. TSE 6622: Removed TP/TRM-LE/CA/BV-02-C, TP/TRM-LE/CA/BV-04-C, TP/TRM-LE/CA/BV-07-C, and TP/RCV-LE/CA/BV-02-C.

Publication Number	Revision Number	Date	Comments
			TSE 6682: Revised initial conditions for TP/TRM-LE/CA/BV-01-C, TP/TRM-LE/CA/BV-03-C, TP/TRM-LE/CA/BV-05-C, TP/TRM-LE/CA/BV-06-C, TP/RCV-LE/CA/BV-01-C, TP/RCV-LE/CA/BV-03-C, TP/RCV-LE/CA/BV-04-C, TP/RCV-LE/CA/BV-05-C, TP/RCV-LE/CA/BV-06-C, and TP/RCV-LE/CA/BV-07-C. Also added Section 6.8 Packet Lengths.
	4.2.2r01	2015-10-27	Reviewed by Dave Richter. Editorial changes resulting from TSE 6622: Removed Section 6.4 (EOC); removed other references to extreme conditions throughout; removed references to normal conditions throughout where they became redundant with the removal of extreme operating conditions.
	4.2.2r02	2015-11-03	Reviewed by Magnus Sommansson. Reinstated "Test Condition" test sections with instructions to perform tests at normal operating conditions.
	4.2.2r03	2015-11-18	Integrated changes for Core Specification Addendum 5 (CSA5): Added references and updated pass verdict for TP/TRM-LE/CA/BV-01-C [Output power].
7	4.2.2	2015-12-22	Prepared for TCRL 2015-2 publication
	4.2.3r00	2016-02-11	TSE 6818: Added Section 4.4 Common Test Case Conditions. The following changes applied to all test cases: First initial condition moved to Section 4.4. Added new test condition with cross-reference to Section 4.4. Deleted test condition moved to Section 4.4.
	4.2.3r01	2016-03-02	TSE 6917: Relaxation measurement criteria changed in TP/RCV-LE/CA/BV-03-C from "does not apply" exceptions to "does apply" admissions.
	4.2.3r02	2016-04-07	TSE 6395: Updated Initial Condition of test case TP/RCV-LE/CA/BV-01-C. Corrected "2) to 3)" to "2) to 4)." Changed modulation frequency to 1250 Hz. Second to last sentence reworded slightly. MSC updated. Changed f_{mod} to "1250 Hz" and T/4 to "200 μs."
8	4.2.3	2016-07-13	Prepared for TCRL 2016-1 publication
	5.0.0r00	2016-07-07	Integrated changes for Core Specification 5.0 release: 2MBPS_Test_Cases_CRr12: Global edit. Added 5 new sections for test cases TRM-LE/CA/BV-07-C – 11-C. Added 18 new sections for test cases TP/RCV-LE/CA/BV-08-C – 25-C. BLR_Test_Cases_CRr12: Global edit. Added 2 new sections for test cases TP/TRM-LE/CA/BV-12-C & 13-C. Added 12 new sections for test cases TP/RCV-LE/CA/BV-26-C – 37 C.
	5.0.0r01	2016-06-28	Issue 7189: Updated test case TP/TRM-LE/CA/BV-12-C: Updated Steps 4, 8, and 9. Deleted Steps 8–12. Updated Pass Verdict. Issue 7286: Entire "Packet Lengths" section rewritten.

Publication Number	Revision Number	Date	Comments
	5.0.0r02	2016-09-02	Issue 7553: Added sum symbol (∑) to step 6 in test case TP/TRM-LE/CA/BV-07-C. Global edits: Removed/replaced “must” in Pass verdict. Updated legacy test text: Changed “…at 1 Ms/s” to “…uncoded data at 1 Ms/s.” Deleted condition from legacy tests. Reference instead Section 4.4, Common Test Case Conditions. Updated Test Condition to reference Section 4.4. Step numbering corrected in test case TP/RCV-LE/CA/BV-09-C and TP/RCV-LE/CA/BV-11-C. Replaced all occurrences of “at NOC” with “uncoded data at 1 Ms/s.”
	5.0.0r03	2016-09-20	Issue 7643: Updated description of interference signal in Test Procedure for test cases TP/RCV-LE/CA/BV-03-C, 05-C, 09-C, 11-C, 28-C, and 29-C.
	5.0.0r04	2016-10-03	Issue 7733: Added missing space between sentences in Test Purposes > Conformance section. Updated test case TP/RCV-LE/CA/BV-03-C: Changed “Steps 2 to 4” to “Steps 2 to 3.” Changed “Steps 2 to 6” to “Steps 2 to 5.” Updated Initial Condition, Test Procedure, and Pass Verdict of test case TP/RCV-LE/CA/BV-24-C to align with style in test case TP/RCV-LE/CA/BV-18-C. Issue 7774: Changed test cases TP/TRM-LE/CA/BV-07-C – 13-C to TP/TRM-LE/CA/BV-08-C – 14-C, respectively, in test case headings, TCMT, and Appendix.
	5.0.0r05	2016-10-10	TSE 7551: Deleted notes from test case TP/TRM-LE/CA/BV-01-C.
	5.0.0r06	2016-10-12	TSE 7450: Standardized “Pass Verdict” wording for test case TP/TRM-LE/CA/BV-01-C.
	5.0.0r07	2016-11-08	Issue 7806: In the TP/TRM-LE/CA/BV-14-C: Updated steps 4-6 (including Figure 4.6) in test procedure to match symbols before and after all 16-symbol blocks; Removed "|f0 – f3|" from Pass Verdict, and adjusted “n” range for |”fn – f(n-3)|.” Issue 7905: For TP/RCV-LE/CA/BV-09-C, updated interference frequency selection formula in step 4 of test procedure and updated adjacent channels in table and Pass Verdict.
	5.0.0r08	2016-11-22	Removed obsolete TC references that got accidentally reintroduced with the Shanghai CRs. Removed TP/TRM-LE/CA/BV-02-C from 6.2.2. Removed TP/TRM-LE/CA/BV-02-C and –BV-04-C as well as TP/RCV-LE/CA/BV-02-C from 6.2.3
9	5.0.0	2016-12-13	Approved by BTI. Prepared for TCRL 2016-2 publication.

Publication Number	Revision Number	Date	Comments
	5.0.1r00	2017-03-08	TSE 7818: In RF-PHY/TRM-LE/CA/BV-01-C, updated Pass Verdict and added IEEE term “shall”. TSE 8337: See notes below for TSE 8339. TSE 8338: See notes below for TSE 8339. TSE 8339: In RF-PHY/RCV-LE/CA/BV-03-C and RF-PHY/RCV-LE/CA/BV-09-C, updated figure: Changed interference signal level from "-67dBm + C/I + Lt" to "-67dBm - C/I + Lt". In RF-PHY/RCV-LE/CA/BV-28-C, updated figure: Changed interference signal level from "-89dBm + C/I + Lt" to "-72dBm - C/I + Lt". In RF-PHY/RCV-LE/CA/BV-29-C, updated figure: Changed interference signal level from "-91dBm + C/I + Lt" to "-79dBm - C/I + Lt". Note: TSE 8339 includes TSE 8337 and TSE 8338.
	5.0.1r01	2017-05-10	Converted to new Test Case ID conventions as defined in TSTO v4.1.
10	5.0.1	2017-07-05	Approved by BTI. Prepared for TCRL 2017-1 publication.
	5.0.2r00	2017-08-18	TSE 9161: In Frequencies for Testing: Peripheral and Central Devices, reorganized RF-PHY/TRM-LE/CA/BV-13-C and RF-PHY/TRM-LE/CA/BV-14-C and deleted RF-PHY/TRM-LE/CA/BV-04-C in the test case(s) table. Added the following 20 TCIDs to Appendix > In Frequencies for Testing: Broadcaster and Observer Devices section: RF-PHY/TRM-LE/CA/BV-13-C - …14-C, RF-PHY/RCV-LE/CA/BV-14-C - …25-C, and RF-PHY/RCV-LE/CA/BV-32-C - …37-C. TSE 9173: Deleted test in Test Strategy. Deleted Provisional RF Testing and Test Equipment sections from Test Cases > Introduction section.
	5.0.2r01	2017-09-19	AoA/AoD: Integrated the AoA/AoD CR into the Reference section and test cases RF-PHY/TRM-LE/CA/BV-01-C, RF-PHY/TRM-LE/CA/BV-06-C, and RF-PHY/TRM-LE/CA/BV-12-C. Added new test cases RF-PHY/TRM-LE/CA/BV-15-C - …17-C. Added new tests to TCMT.
	5.0.2r02	2017-10-02	TSE 9858: Resized RF-PHY/TRM-LE/CA/BV-06-C Figures 4.4 and 4.5 to fit portrait page. TSE 9895: Fixed RF-PHY/RCV-LE/CA/BV-31-C test procedure typo in data coding scheme.
	5.0.2r03	2017-10-13	TSE 9859: Revised the RF-PHY/TRM-LE/CA/BV-05-C “Frequency deviation measurement principle for 10101010-payload sequence” figure.
	5.0.2r04	2017-10-31	TSE 9161: Reorganized RF-PHY/TRM-LE/CA/BV-13-C and RF-PHY/TRM-LE/CA/BV-14-C in the test case(s) table in “Frequencies for Testing: Peripheral and Central Devices.”
11	5.0.2	2017-12-07	Approved by BTI. Prepared for TCRL 2017-2 publication.

Publication Number	Revision Number	Date	Comments
	5.0.3r00-02	2018-01-26 – 2018-06-08	Issue 10132 : deleted AoA/AoD text from test cases RF-PHY/TRM-LE/CA/BV-01-C (section 4.4.1), RF-PHY/TRM-LE/CA/BV-06-C (section 4.4.4), and RF-PHY/TRM-LE/CA/BV-12-C (section 4.4.9). TSE 10106 (rating 1): Changed “TRM-LE/CA” to “TRM” and “RCV-LE/CA” to “RCV” in test case names. TSE 10106 : fixed integration error. Applied change to two more instances in test case RF-PHY/TRM/BV-11-C.
12	5.0.3	2018-07-02	Approved by BTI. Prepared for TCRL 2018-1 publication.
	5.0.4r00-r04	2018-08-20 - 2018-10-25	Incorporated RF-PHY.DF.Test CRr09: Added 20 new test cases to spec text, TCMT, and Appendix Table 6.2: RF-PHY/TRM/IQC/BV-01-C – 08-C; RF-PHY/RCV/IQC/BV-01-C – 12-C. Added 2 new sections: "Test Setups Examples" (Section 4.6) and "Error Measurement for IQ Samples" (Section 6.8). Issue 11046: Various clarifications and typo corrections for IQ sample test material. Sections: Tx Power Stability, AoD Transmitter; Antenna switching integrity, AoD Transmitter; IQ Samples Coherency, AoD Receiver; IQ Samples Coherency, AoA Receiver; IQ Samples Dynamic Range, AoD Receiver; IQ Samples Dynamic Range, AoD Receiver; Appendix. Issue 11081: Clarifications and typo corrections for IQ sample test material. Issue 11085: Clarified test procedure step repetition in IQ Samples Coherency and Dynamic Range test cases. TSE 11072 (rating 1): Fixed typo in revision date on first page. TSE 10897 (rating 2): Changed Interference Signal #2 from 1 Ms/s to 2 Ms/s for test case RF-PHY/RCV/BV-11-C. Issue 11082: Comprehensive re-write of the IQ Sample Appendix section for clarity and accuracy. Integration review, renaming from /TRM/IQC/BV-01.. -04-C to “/TRM/PS/BV-01-C etc., from /TRM/IQC/BV-05..08-C to /TRM/ASI/BV-05-C etc., from /RCV/IQC/BV-07..-12-C to /RCV/IQDR/BV-07 etc.
	5.1.0	2018-11-13	Updated revision number to 5.1.0 to align with the adoption of Core Specification version 5.1
13	5.1.0	2018-12-07	Approved by BTI. Prepared for TCRL 2018-2 publication.

Publication Number	Revision Number	Date	Comments
	5.1.1r00–r02	2019-03-29–2019-05-15	TSE 11535 (rating 1): Updated TCMT Item to LL 9/22 for test cases RF-PHY/TRM/PS/BV-02-C, 04-C; and RF-PHY/TRM/ASI/BV-06-C, BV-08-C. TSE 11732 (rating 1): Updated the test procedure in the "IQ Samples Dynamic Range, AoD Receiver" and "IQ Samples Dynamic Range, AoA Receiver" sections. TSE 11791 (rating 2): TCMT-only change to accommodate ICS/IXIT updates.
14	5.1.1	2019-08-01	Approved by BTI. Prepared for TCRL 2019-1 publication.
	p15r00–r02	2019-09-06 – 2019-11-12	TSE 12097 (rating 3): Updated pass verdict for “IQ Samples Coherency, AoD Receiver” section, which affects test cases RF-PHY/RCV/IQC/BV-01-C – -04-C. Updated pass verdict for “IQ Samples Coherency, AoA Receiver” section, which affects test cases RF-PHY/RCV/IQC/BV-05-C and -06-C. TSE 12098 (rating 1): Updated test step for “IQ Samples Coherency, AoD Receiver” section, which affects test cases RF-PHY/RCV/IQC/BV-01-C – -04-C, and test step for “IQ Samples Coherency, AoA Receiver” section, which affects test cases RF-PHY/RCV/IQC/BV-05-C and -06-C. TSE 12127 (rating 2): Updated TCMT to take into account the PHYs for the IQ sample tests. TSE 12384 (rating 1): Clarified expected outcome text and fixed subscripting of text in test cases RF-PHY/TRM/BV-16-C and -17-C. Revised document numbering convention, setting last release publication of 5.1.1 as p14; added publication number column to Revision History.
15	p15	2020-01-07	Approved by BTI on 2019-12-22. Prepared for TCRL 2019-2 publication.
	p16r00–r07	2020-01-31 – 2021-06-04	TSEs 12505, 12947, 12948 (rating 2): Editorial adjustment that involved removing Section 6.2 and the testing frequencies tables in Sections 6.2.1 and 6.2.2, adding testing frequencies tables to the test condition section of each test case, and moving the introduction text from Section 6.2 regarding direct test mode, etc. to Section 4.2 *“Common Test Case Conditions”.* (Note: All changes for TSEs 12505, 12947, and 12948 are flagged for this integration as TSE 12505, as they use a single CR to incorporate all of the changes required for all three TSEs.) TSE 12941 (rating 2): Updated TCMT to include “2Ms/s” to better align with ICS; affected test cases RF-PHY/RCV/IQC/BV-03-C, -04-C, and -06-C; RF-PHY/RCV/IQDR/BV-09-C, -10-C, and -12-C; RF-PHY/TRM/PS/BV-03-C and -04-C; and RF-PHY/TRM/ASI/BV-07-C and -08-C.

Publication Number	Revision Number	Date	Comments
			TSE 13402 (rating 2): Edited test steps and pass verdicts to address an issue with requiring too many packets to be transmitted per test. Affected sections containing test cases RF-PHY/RCV/IQC/BV-01-C –-06-C and RF-PHY/RCV/IQDR/BV-07-C – -12-C. TSE 14692 (rating 2): Updated TCMT to fix a mapping error. TSE 16485 (rating 4): To address E16372 regarding Transmit Power Level for Power Class, moved RFPHY/TRM/BV-01-C into a TC Config table with new TC RFPHY/TRM/BV-18-C and updated Pass verdict. Updated TCMT accordingly. TSE 16596 (rating 1): Corrected an error in the formulae calculating amplitude A in the “IQ Samples Dynamic Range, AoD Receiver” and “IQ Samples Dynamic Range, AoA Receiver” sections by updating step 4 and the Pass verdict. TSE 16697 (rating 1): Updated title/header and document ID; updated all instances of “RF PHY” and “RF-PHY” to “RFPHY” to align with the latest naming conventions. Template-related and consistency checker editorials. Editorial corrections to properties requiring subscript formatting (e.g., f_{RX} and f_{TX}).
16	p16	2021-07-13	Approved by BTI on 2021-06-27. Prepared for TCRL 2021-1 publication.
	p17r00–r04	2021-08-26 – 2021-11-29	TSE 16706 (rating 2): Changed test items related to LE 2M to not test CH0/12/39. Simplified the frequency tables by combining roles where they contained the same test frequencies and removing Tx frequencies from Rx tests (and vice versa). Added MHz units to frequency tables. Changed n=2 and n=37, to n=1 and n=38 for 2 Ms/s tests. Removed 2 Ms/s reference from the section containing tests RFPHY/TRM/BV-01-C and -18-C and from -15-C. Overall affected TCs as follows: RFPHY/TRM/BV-01-C, -03-C, -05-C, -06-C, -08-C – -18-C; RFPHY/TRM/PS/BV-01-C – -04-C; RFPHY/TRM/ASI/BV-05-C – -08-C; RFPHY/RCV/BV-01-C and -03-C – -37-C; RFPHY/RCV/IQC/BV-01-C – -06-C; and RFPHY/RCV/IQDR/BV-07-C – -12-C. TSE 17311 (rating 2): Updated the initial conditions and test procedure of the section containing RFPHY/TRM/BV-01-C and -18-C to use Antenna Gain G as specified in the IXIT. Added a section in the Appendix on Antenna Gain. TSE 17395 (rating 1): Editorial corrections to fix superscript formatting in Section 6.3.2 and add a 0 to 0.9990 in Section 6.3.1 to align with the significant figures in the rest of the bulleted list. TSE 17727 (rating 1): Updated Acknowledgments list. Performed template-related editorial work, including aligning the copyright page with v2 of the DNMD.

Publication Number	Revision Number	Date	Comments
17	p17	2022-01-25	Approved by BTI on 2021-12-27. Prepared for TCRL 2021-2 publication.
	p18r00–r03	2022-02-03 – 2022-04-08	TSE 17597 (rating 4): To address a need for 2M versions of certain tests, updated the “Output power” section, modifying Test Purpose, Initial Condition, and test steps. Affected test cases are RFPHY/TRM/BV-01-C, -15-C, and -18-C (note that -15-C was removed as a freestanding TC and is now in the TC Config table in this test group); new test cases are RFPHY/TRM/BV-19-C – -23-C. Updated the TCMT accordingly. TSE 17599 (rating 2): Added default frequencies for testing in Section 4.2. Deleted “Frequencies for Testing” tables and made related edits in the Test Condition sections in RFPHY/TRM/BV-01-C, -03-C, -05-C, -06-C, -08-C – -17-C and RFPHY/RCV/BV-01-C, -03-C, -05-C, -06-C, -08-C – -12-C, -14-C, -15-C, -17-C, -18-C, -20-C – -24-C, -26-C – -29-C, -32-C – -35-C. TSE 18260 (rating 2): Updated TCMT items for RFPHY/RCV/IQC/BV-01-C – -04-C RFPHY/RCV/IQDR/BV-07-C – -10-C. TSE 18298 (rating 1): Corrected missing superscript formatting in Section 6.3.1. TSE 18348 (rating 2): Updated TCMT items for RFPHY/TRM/BV-15-C, -16-C, and -18-C. TSE 18387 (rating 2): Added “Fields and Bits Reserved for Future Use” section. TSE 18554 (rating 2): Updated the expected outcome for RFPHY/TRM/BV-12-C. TSE 18635 (rating 1): Updated the test procedure and expected outcome for RFPHY/TRM/BV-16-C. Performed template-related formatting fixes. Replaced all mentions of “Common Test Case Conditions” with a link to that section heading.
18	p18	2022-06-28	Approved by BTI on 2022-05-31. Prepared for TCRL 2022-1 publication.
	p19r00	2022-09-27	TSE 20370 (rating 1): Updated some of the drawings/pictures for TCs RFPHY/TRM/BV-05-C and -16-C.
19	p19	2023-02-07	Approved by BTI on 2022-12-28. Prepared for TCRL 2022-2 publication.
	p20r00–r01	2023-03-10 – 2023-04-04	TSE 22581 (rating 1): For consistency, replaced the instances of “DUT” with “IUT” in RFPHY/RCV/BV-07-C, -13-C, -19-C, -25-C, -30-C, -31-C, -36-C, and -37-C. TSE 22909 (rating 2): Reformatted the following test cases into a table-driven structure: RFPHY/TRM/BV-03-C, -05-C, -06-C, -08-C – -14-C, -16-C, and -17-C; and RFPHY/RCV/BV-01-C and -03-C – -37-C.

Publication Number	**Revision Number**	**Date**	**Comments**
20	p20	2023-06-29	Approved by BTI on 2023-06-05. Prepared for TCRL 2023-1 publication.
	p20ed2 r00–r01	2023-08-07 – 2023-08-25	TSE 23263 (rating 1): In the “C/I and Receiver Selectivity Performance” section, updated the captions to align with the section title, replaced the figure, and revised the parameter table to correct the labels and subscripted text. Replaced the figure in the “Blocking Performance” section. TSE 23337 (rating 1): Replaced the figure in the “Intermodulation Performance” section.
	p20 edition 2	2023-08-28	Approved by BTI on 2023-08-24. Prepared for edition 2 publication.
	p21r00–r01	2023-08-28 – 2023-10-30	TSE 23568 (rating 1): Updated a test step in the section containing RFPHY/TRM/BV-05-C, -09-C – -11-C, and -13-C. TSE 24252 (rating 1): Added a reference to Core v5.0 LL spec.; updated the requirements for RFPHY/TRM/BV-13-C and updated the test steps and Pass verdict for the section containing that TC as well as -05-C and -09-C – -11-C.
21	p21	2024-07-01	Approved by BTI on 2024-05-22. Prepared for TCRL 2024-1 publication.
	p22r00–r09	2024-07-09 – 2024-08-20	Incorporated CS_RFPHY.TS_CR_r13 (which includes Test Issues 23205, 23293, 23331, 23332, 23361, 23362, 23363, 23364, 23365, 23378, 23379, 23381, 23382, 23384, 23404, 23419, 23422, 23424, 23425, 23500, 23501, 23502, 23503, 23504, 23506, 23594, 23693, 23694, 23696, 23701, 23706, 23711, 23732, 23736, 23737, 23738, 23776, 23842, 23923, 23993, 24023, 24033, 24043, 24049, 24133, 24135, 24137, 24138, 24139, 24141, 24142, 24143, 24146, 24147, 24149, 24150, 24151, 24153, 24177, 24181, 24231, 24232, 24330, 24331, 24332, 24410, 24411, 24418, 24419, 24478, 24483, 24515, 24531, 24599, 24601, 24602, 24614, 24618, 24619, 24621, 24623, 24624, 24625, 24627, 24630, 24639, 24645, 24646, 24655, 24656, 24657, 24659, 24660, 24669, 24681, 24717, 24769, 24776, 24789, 24808, 24809, 24838, 24844, 24850, 24867, 24868, 24893, 24894, 24895, 25028, 25029, 25040, 25042, 25053, 25055, 25111, 25112, 25120, 25139, 25140, 25141, 25142, 25143, 25148, 25149, 25150, 25157, 25166, 25209, 25240, 25278, 25282, 25299, 25428, 25443, 25479, 25498, 25511, 25512, 25525, 25585, 25617, 25632). To account for the Channel Sounding feature of Core v6.0, added references to Core v6.0 Vol. 6 Part A and Vol. 6 Part F; added Channel Sounding to the TC feature naming conventions table; updated the “Common test case conditions and parameters” section; added new sections for “Default Frequencies”, “Channel Sounding Default Frequencies”, and “Common Parameters and Variables” (with subsections); added new subsections for TRM TCs (new TCs

Publication Number	Revision Number	Date	Comments
			RFPHY/TRM/CS/BV-01-C – -10-C) and a new section for TRM-RCV TCs (new TCs RFPHY/TRM-RCV/CS/BV-01-C – -18-C) and updated the TCMT accordingly; added a new section to the Test Setup Examples section for Channel Sounding setup; and added a new subsection to the Appendix for Test Filter Characteristics. Incorporated Test Issues 24727, 25785, 25798, 25850. TSE 25482 (rating 1): Performed editorial updates throughout the TCMT. TSE 26029 (rating 2): Updated the TCMT to remove RFPHY 1/1 and RFPHY 1/2 from the Channel Sounding section (now covered by the revised prerequisite to Table 3 in the ICS).
22	p22	2024-09-04	Approved by BTI on 2024-08-14. Prepared for TCRL 2024-2 publication.
	p22ed2r00–r03_BTI	2024-10-29 – 2024-11-01	TSE 26134 (rating 1): Updated the drawing used for Figures 4.2, 4.3, and 4.8. TSE 26208 (rating 1): Corrected an equation in the test procedure for the section containing RFPHY/TRM-RCV/CS/BV-04-C – -10-C. TSE 26209 (rating 1): Corrected test steps for the section containing RFPHY/TRM-RCV/CS/BV-11-C – -18-C. TSE 26312 (rating 1): Corrected the Subevent_Len value in the Channel Sounding Test Command Parameters table. TSE 26331 (rating 1): Corrected the test procedure for the section containing RFPHY/TRM/CS/BV-03-C and -04-C. TSE 26424 (rating 1): Per E26162, updated “antennas” to “antennae” globally in running text. TSE 26546 (rating 1): Moved the “Test Setup Examples” section to earlier in the document with other common test case conditions and updated wording as necessary.
	p22 edition 2	2024-11-12	Approved by BTI on 2024-11-12. Prepared for edition 2 publication.

Publication Number	Revision Number	Date	Comments
	p23r00–r04	2024-11-12 – 2024-11-25	TSE 25993 (rating 2): Added cross-references to the Test Equipment Setup section in the initial condition section for several Channel Sounding test groups. Updated Channel Sounding TCMT entries as necessary. TSE 26020 (rating 4): Updated the test procedure for RFPHY/TRM/CS/BV-01-C and -02-C. Updated the initial conditions and combined the Role and PHY columns in the TC configuration table in the Channel Sounding Phase Measurement Accuracy section. Updated the TCID descriptions for RFPHY/TRM-RCV/CS/BV-11-C – -18-C, added new TCs RFPHY/TRM-RCV/CS/BV-19-C – -34-C, and updated the TCMT accordingly. TSE 26206 (rating 1): Updated a test step in the section containing RFPHY/TRM-RCV/CS/BV-01-C, -02-C, and -03-C. TSE 26300 (rating 1): Updated the initial condition in the CS Phase Measurement Accuracy section and corrected an IXIT value in the Test Equipment Setup for Channel Sounding section. TSE 26327 (rating 2): Corrected the TCMT entries for RFPHY/TRM-RCV/CS/BV-05-C and RFPHY/TRM-RCV/CS/BV-15-C to account for a removed ICS item. TSE 26600 (rating 1): Updated test doc title to better align with the associated spec. TSE 26749 (rating 1): Deleted extraneous text from the end of Appendix 6.7.1, Maximum Number of Packets for IQ Coherency Measurements.
23	p23	2025-02-18	Approved by BTI on 2024-12-26. Prepared for TCRL 2025-1 publication.

Acknowledgments

Name	Company
Nils Schapmann	7 Layers
Edward Harrison	Anritsu
Juan Manuel Hidalgo Perdiguero	AT4 wireless
Ángel Romero	AT4 wireless
Totti Huang	Attestation of Global Compliance (Shenzhen) Co., Ltd.
Alexandru Andreescu	Bluetooth SIG, Inc.
Norbert Grünert	Broadcom
Zhang Zhiwei	China Academy of Information and Communications Technology
Peter Flittner	CSR
Magnus Sommansson	CSR
Steven Wenham	CSR
Ole Myrtue	Nokia
Jukka Reunamaki	Nokia

Name	**Company**
Frank Karlsen	Nordic Semiconductor A/S
Miles Smith	Nordic Semiconductor A/S
Tor Ø. Vedal	Nordic Semiconductor A/S
Dave Richter	Qualcomm
Magnus Sommansson	Qualcomm
Peter Dziwior	Rohde & Schwarz
Kenton Payne	Rohde & Schwarz
Clive Feather	Samsung
Rogier Schaeffer	ST Microelectronics
Paul vanOostende	ST Microelectronics
Karim Sharf	Teledyne LeCroy
Øystein Bjørndal	Texas Instruments