APP NOTES

Testing Bluetooth® Low Energy 5.1 Angle of Arrival and Angle of Departure

LITEPOINT

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1. What is Bluetooth LE 5.1?

Bluetooth is a nearly ubiquitous connectivity technology embedded in mobile phones and countless consumer electronics devices. Primarily used for audio streaming and data transfer, Bluetooth technology is also widely deployed for proximity sensing. Proximity sensing uses distance estimation derived from the BT receiver's Receive Signal Strength Indicator (RSSI) measurement. The RSSI method provides however only a crude estimation of distance, as the accuracy is limited by numerous factors like the environment obstacles, attenuation, transmitter power level, receiver calibration etc… Furthermore, the device's direction is unknown since the receiver cannot tell the direction of the incoming signal; it can only detect that the tracked device is located in a circular zone around the receiver.

The RSSI approach has shown good market adoption but its usage is mostly limited to proximity detection. There are many use cases that require a finer accuracy with GPS-like performance for positioning. Applications like real-time locating systems (RTLS) for asset tracking or indoor positioning systems (IPS) require a high level of accuracy, this is why BT SIG has introduced direction finding enhancements as part of Bluetooth 5.1 Core Specification. The BT LE 5.1 capabilities greatly increase positioning accuracy over earlier generations, with the new direction-finding enhancements where Angle of Arrival (AoA) or Angle of Departure (AoD) information can be determined. Depending on implementation, BT LE 5.1 direction finding method could provide down to sub-meter accuracy.

This level of accuracy in positioning opens the doors to countless new use cases for asset or personnel tracking in medical or industrial environments, wayfinding in public or private venues, item finding for smart retail or personal item finding.

2. What is Angle of Arrival (AoA)?

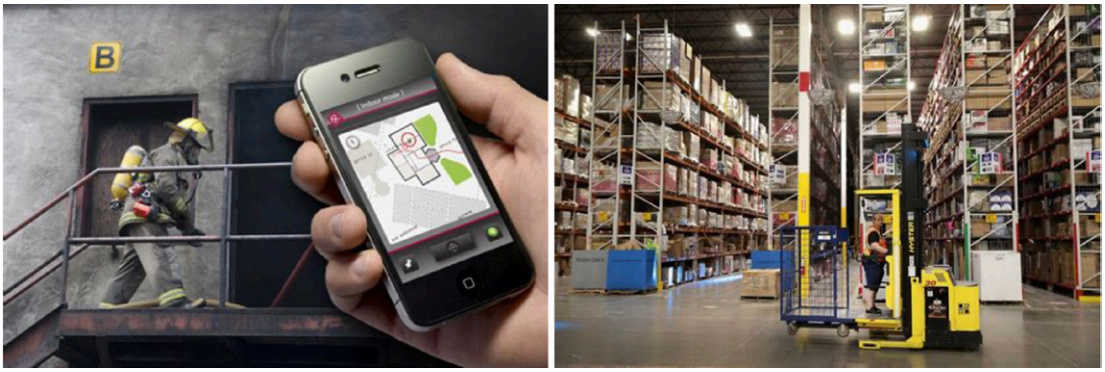


Figure 1: Asset tracking and RTLS Applications using AoA

Angle of Arrival (AoA) is designed to be used in applications like asset tracking, where the moving transmitter sends BT LE 5.1 direction finding signals using a single antenna. Using this method, a fixed receiver equipped with an antenna array (minimum 2 antennas) determines the direction of the transmitter using the angle of the received signal. The angle determination is based on the phase differences of the received signal as detected by the receiver's antenna array.

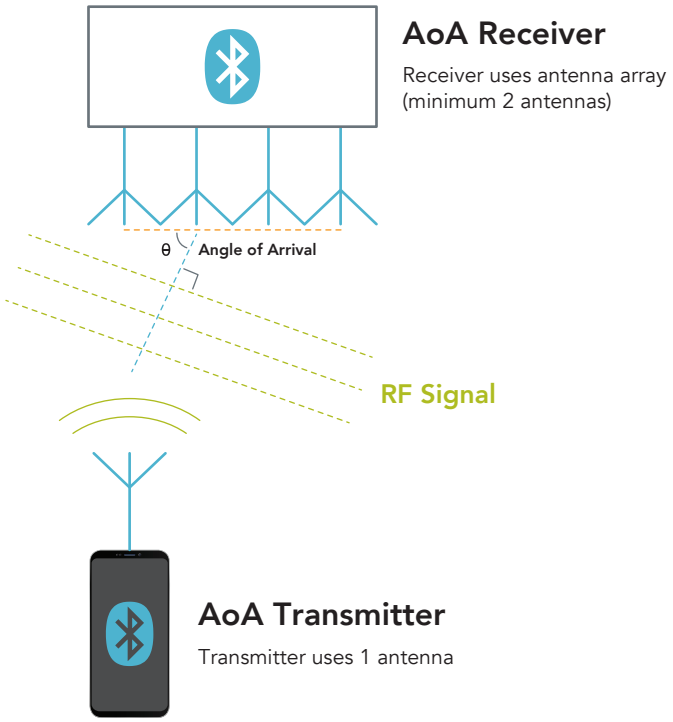


Figure 2: Angle of Arrival method

3. What is Angle of Departure (AoD)?

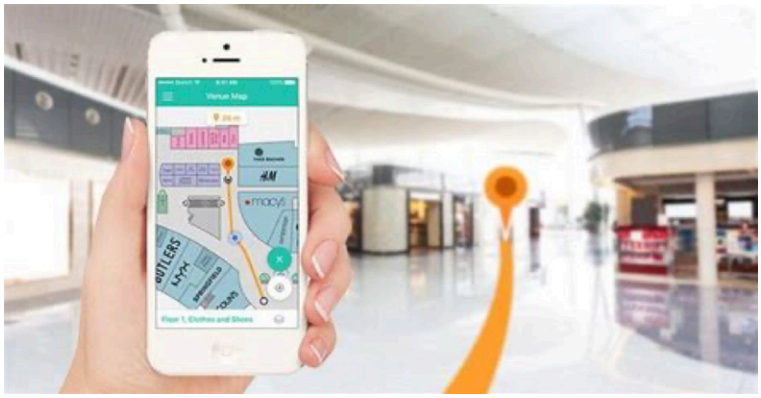


Figure 3: Indoor Navigation Wayfinding using AoD

Angle of Departure (AoD) is designed to be used in applications like wayfinding indoor navigation, where the moving receiver receives BT LE 5.1 direction finding signals using a single antenna. The signal is transmitted by a fixed transmitter switching through an antenna array of minimum 2 antennas. The receiver determines the direction of the transmitter using the phase differences from the incoming signal.

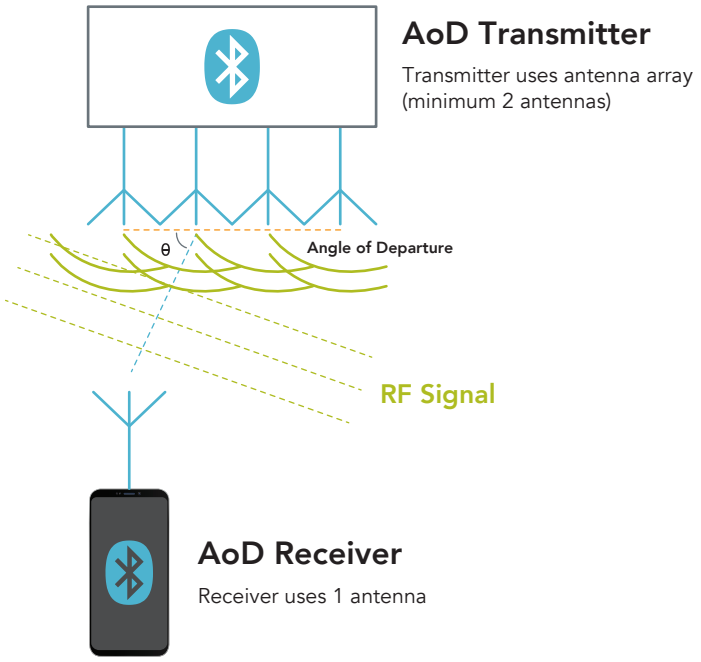


Figure 4: Angle of Departure method

4. Bluetooth LE 5.1 Direction Finding Packets and Constant Tone Extension (CTE)

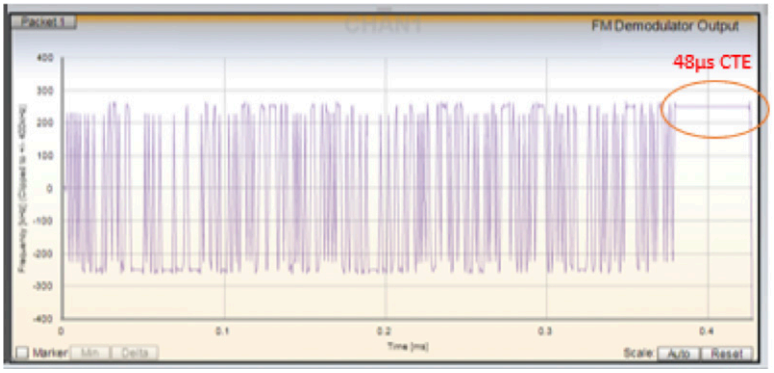


Figure 5: BT LE with 48µs CTE

For direction finding, a Constant Tone Extension (CTE) is optionally added to PDUs.
The CTE field is a bit sequence included at the end of the packets, with the following properties:

- CTE is supported for LE 1M (mandatory) and LE 2M (optional) PHY rates
- CTE is not supported for the coded S=2 and S=8 rates
- CTE field contains a series of modulated 1s
- CTE field is not subject to whitening
- CTE field is not included in CRC
- CTE field duration is 16-160 µs duration (for LE 1M the length is 16 to 160 bits, for LE 2M the length is 32-320 bits)
- The presence of the optional CTE field is indicated by a CP flag in the PDU header
- CTE Time field in the CTEInfo indicates duration of the CTE in units of 8 µs

CTE Type field in the CTEInfo indicates the type and duration of switching slots of CTE

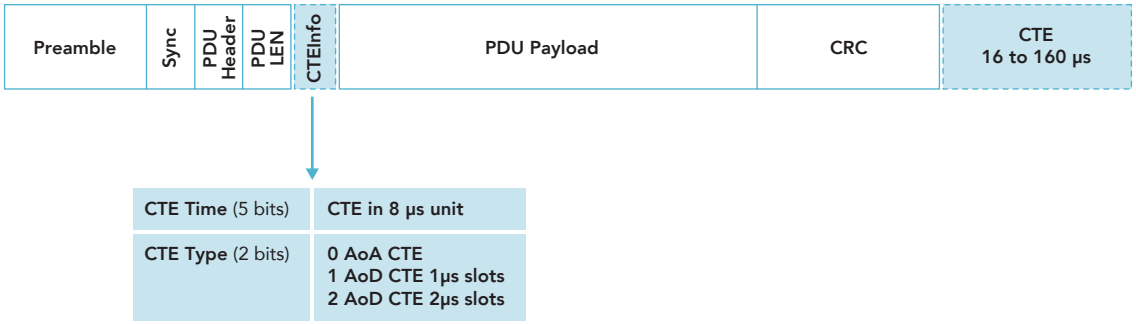


Figure 6: Optional CTE fields in BT LE PDU

5. Antenna Switching and IQ Sampling

5.1 Angle of Arrival Method

- AoA Transmitter

The AoA transmitter uses only a single antenna, therefore the CTE field is transmitted continuously without switching.

- AoA Receiver

The AoA receiver uses an antenna array with 2 or more antennas. The receiver switches between the multiple antennas following a pre-determined switching slot pattern, the time when this switching takes place is determined by the switch slot. IQ sampling of the received CTE signal also takes place during the allocated sampling slot. Slot durations of 2 µs or 1 µs are defined, implementation of 2 µs is mandatory, and 1 µs is optional. When using 1 µs slots, with a max CTE duration of 160 µs, up to 74 switching/sampling slots are available. When using 2 µs slot duration up to 37 switching/sampling slots are available.

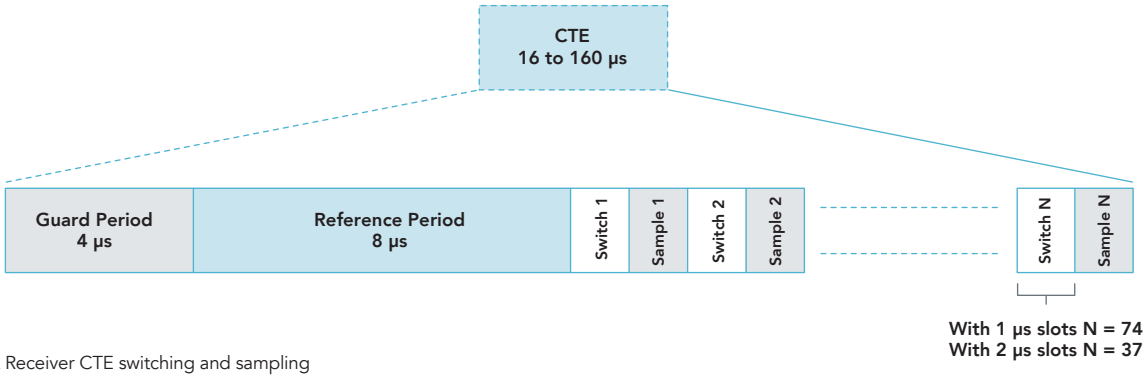


Figure 7: AoA Receiver CTE switching and sampling

5.2 Angle of Departure Method

- AoD Transmitter

The AoD transmitter uses an antenna array with 2 or more antennas. The transmitter switches between the multiple antennas following a pre-determined switching slot pattern, the time when this switching takes place is determined by the switch slot. Slot durations of 2 µs or 1 µs are defined, implementation of 2 µs is mandatory, and 1 µs is optional. When using 1 µs slots, with a max CTE duration of 160 µs, up to 74 switching slots are available. When using 2 µs slot duration up to 37 switching slots are available.

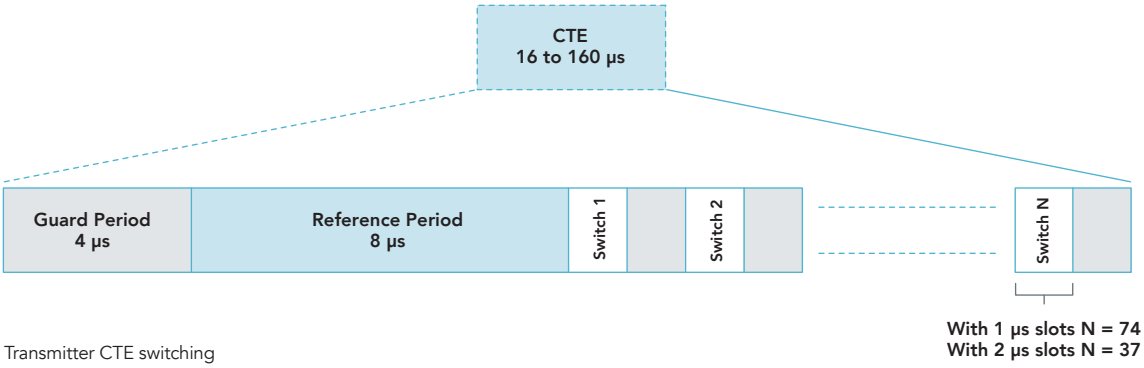


Figure 8: AoD Transmitter CTE switching

- AoD Receiver

The AoD receiver uses a single antenna, therefore no switching is involved, however IQ sampling of the received CTE signal takes place during the sampling slots. Slot durations of 2 µs or 1 µs are defined, implementation of 2 µs is mandatory, and 1 µs is optional. When using 1 µs slots, with a max CTE duration of 160 µs, up to 74 sampling slots are available. When using 2 µs slot duration up to 37 sampling slots are available.

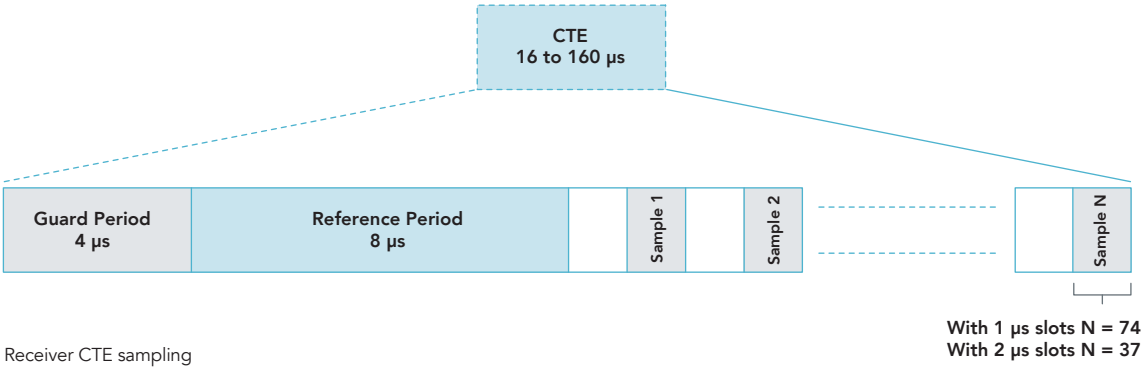
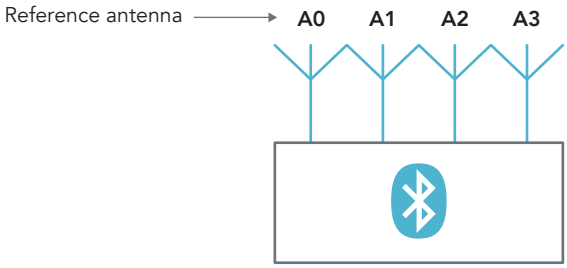


Figure 9: AoD Receiver CTE sampling

5.3 Switching and Sampling Pattern

The switching and sampling pattern is defined by the number of antennas in the array. The reference period uses the reference antenna (A0). During the rest of the CTE duration, the antenna switching pattern is repeated.



Number of Antennas in Array	Switching Pattern
2 (A0, A1)	A0 (ref antenna), A1, A0, A0, A0, A1, A0, A0, A0, A1...
3 (A0, A1, A2)	A0 (ref antenna), A1, A0, A0, A0, A2, A0, A0, A0, A1...
4 (A0, A1, A2, A3)	A0 (ref antenna), A1, A0, A0, A0, A2, A0, A0, A0, A3, A0, A0, A0

Figure 10: Antenna switching pattern

6. Testing Bluetooth LE 5.1 CTE

BT SIG introduced new RF tests (Radio Frequency Physical Layer Bluetooth Test Suite RF-PHY.TS.5.1.0) for Direction Finding validation. The transmitter and receiver tests defined in the RF PHY Test Suite document include new test cases for AoA and AoD. These tests are not hopping and are performed on a single frequency/channel. The test cases and corresponding sections in the test suite document are summarized in the table below:

Direction	Test Name	Test Description	Test Number
Transmitter Test	AoA Output power, With CTE	This test verifies the maximum peak and average power emitted from the DUT when transmitting with a CTE.	4.4.12 RF-PHY/TRM/BV-15-C
	AoA Carrier frequency offset and drift	This test verifies that the carrier frequency offset and carrier drift of the transmitted CTE portion in a transmitted signal with a CTE is within specified limits at normal operating conditions.	4.4.13 RF-PHY/TRM/BV-16-C 4.4.14 RF-PHY/TRM/BV-17-C
	Tx Power Stability AoD	This test verifies 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.	4.4.15.1 RF-PHY/TRM/PS/BV-01-C 4.4.15.2 RF-PHY/TRM/PS/BV-02-C 4.4.15.3 RF-PHY/TRM/PS/BV-03-C 4.4.15.4 RF-PHY/TRM/PS/BV-04-C
	Antenna switching integrity AoD	This test verifies that the antenna switching occurs during the switching slots of the Constant Tone Extension for an AoD transmit signal.	4.4.16.1 RF-PHY/TRM/ASI/BV-05-C 4.4.16.2 RF-PHY/TRM/ASI/BV-06-C 4.4.16.3 RF-PHY/TRM/ASI/BV-07-C 4.4.16.4 RF-PHY/TRM/ASI/BV-08-C
Receiver Test	IQ Samples Coherency, AoD Receiver	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 DUT AoD Receiver from a CTE are within specified limits.	4.5.37.1 RF-PHY/RCV/IQC/BV-01-C 4.5.37.2 RF-PHY/RCV/IQC/BV-02-C 4.5.37.3 RF-PHY/RCV/IQC/BV-03-C 4.5.37.4 RF-PHY/RCV/IQC/BV-04-C
	IQ Samples Coherency, AoA Receiver	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 CTE are within specified limits.	4.5.38.1 RF-PHY/RCV/IQC/BV-05-C 4.5.38.2 RF-PHY/RCV/IQC/BV-06-C
	IQ Samples Dynamic Range, AoD Receiver	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 CTE from a peer device have specified values when varying the dynamic range of the CTE and marks any invalid samples as invalid.	4.5.39.1 RF-PHY/RCV/IQDR/BV-07-C 4.5.39.2 RF-PHY/RCV/IQDR/BV-08-C 4.5.39.3 RF-PHY/RCV/IQDR/BV-09-C 4.5.39.4 RF-PHY/RCV/IQDR/BV-10-C
	IQ Samples Dynamic Range, AoA Receiver	This test group is for generic use and contains two test cases to verify that the I and Q values sampled on receiving and AoA CTE from a peer device have specified values when varying the dynamic range of the CTE and marks any invalid samples as invalid.	4.5.40.1 RF-PHY/RCV/IQDR/BV-11-C 4.5.40.2 RF-PHY/RCV/IQDR/BV-12-C

Table 1: RF PHY Test Cases for Direction Finding

These test cases will be covered in more details in the following sections.

6.1 Complete Test Setup for AoA and AoD Transmitter and Receiver Tests

The IQxel family of products supports the new direction-finding test cases. Combined with IQfact+ software, the solution provides complete test automation of AoA and AoD transmitter and receiver tests including DUT control and DUT IQ samples analysis. DUT control is executed using BT SIG specified DTM (Direct Test Mode) via the HCI (Host Control Interface).

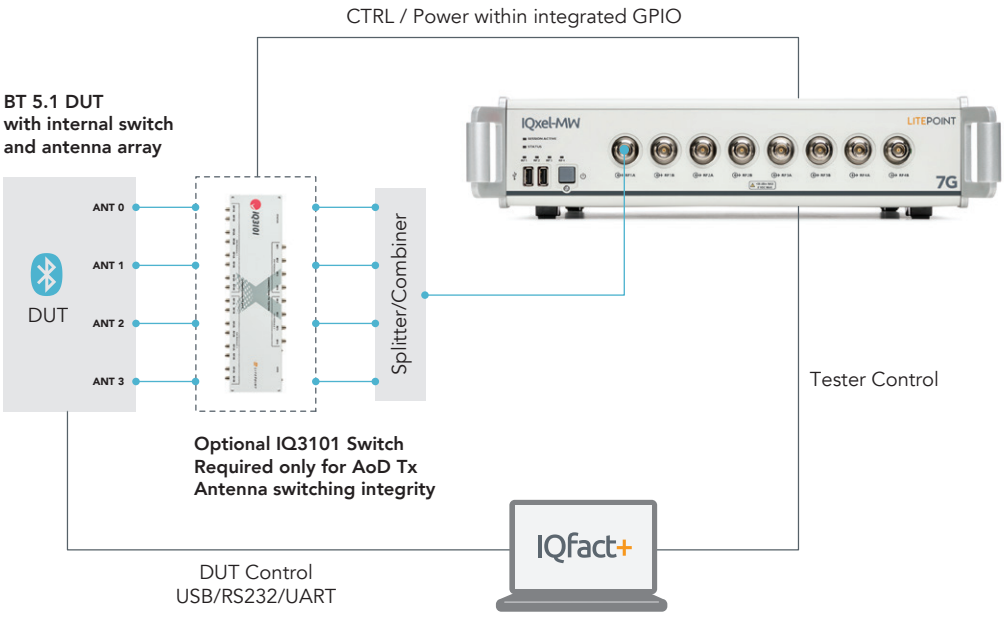


Figure 11: Test Setup Diagram with IQxel and IQfact+

The test setup shows operation for AoA/AoD tests using IQxel-MW 7G, an external splitter/combiner and an optional IQ3101 switch.

The IQ3101 switch is only required for AoD transmitter Antenna switching integrity test cases, it is optional for the other test cases.

7. Angle of Arrival Transmitter Tests

For AoA Transmitter tests, the BT 5.1 DUT transmits the LE Signal with CTE extension using a single antenna. The tester verifies output power (maximum peak and average) with CTE and carrier frequency offset and drift. This test covers test cases 4.4.12 (RF-PHY/TRM/BV-15-C), 4.4.13 (RF-PHY/TRM/BV-16-C), 4.4.14 (RF-PHY/TRM/BV-17-C) of the BT SIG RF PHY Test Suite.

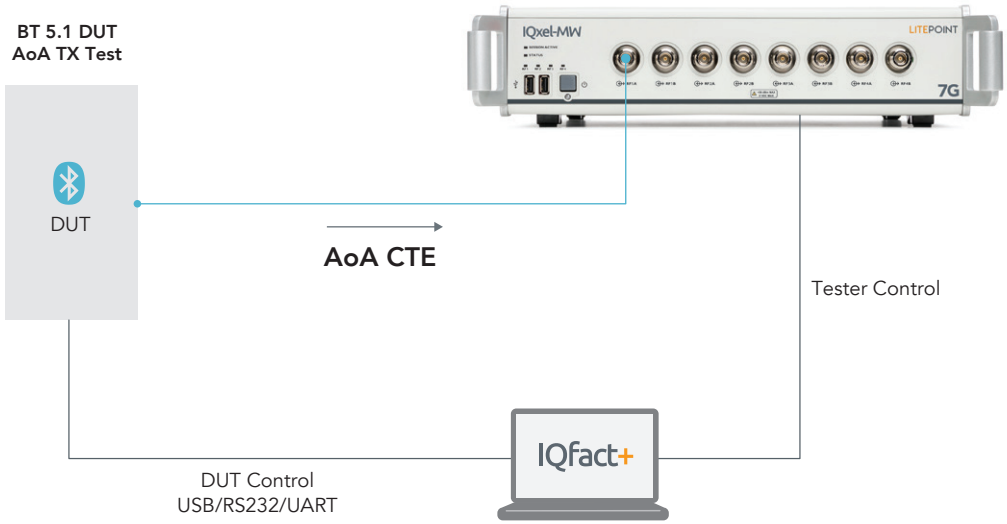


Figure 12: AoA Transmitter test setup

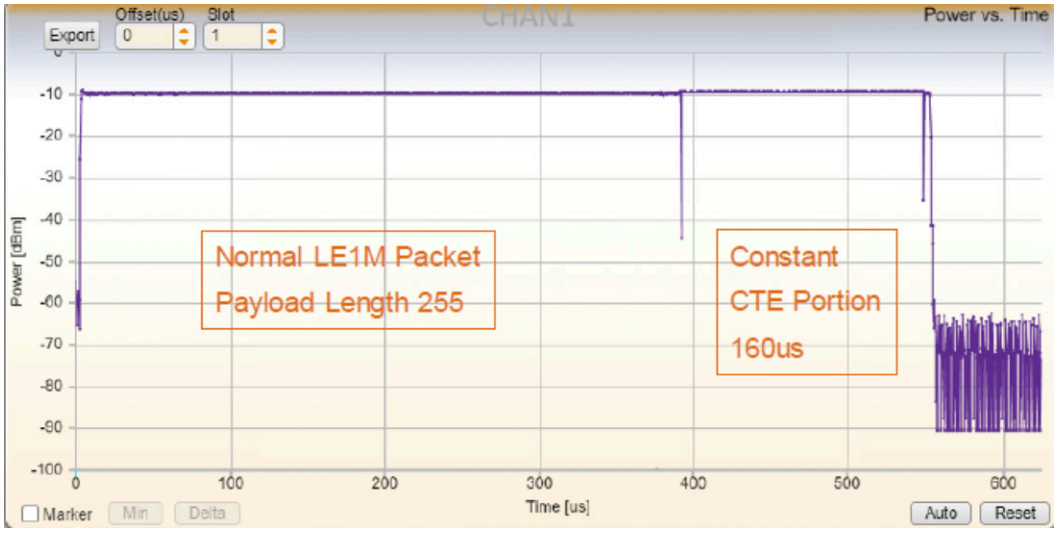


Figure 13: Power vs. Time visualization of AoA Transmitter test signal

7.1 AoA Transmitter Output Power with CTE

Test case 4.4.12 (RF-PHY/TRM/BV-15-C), verifies the maximum peak and average power of AoA transmitted signal containing CTE, this test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional).

7.2 AoA Transmitter CFO and Carrier Drift

Test case 4.4.13 (RF-PHY/TRM/BV-16-C) verifies the carrier frequency offset and carrier drift of the transmitted signal with uncoded data at 1Ms/s with CTE. Test case 4.4.14 (RF-PHY/TRM/BV-17-C), this test verifies the carrier frequency offset and carrier drift of the transmitted signal with uncoded data at 2Ms/s with CTE. This test is executed only if the implementation supports the optional 2M PHY data rate.

7.3 AoA Transmitter IQfact+ Test Results

The following shows a sample AoA Transmitter tests using IQfact+ automation software:

```
CTE_DURATION                                  :       160.00 us     (,)
DELTA_F1_AVERAGE                              :       249.62 kHz    (,)
DELTA_F1_MAX                                  :       245.54 kHz    (,)
DELTA_FS1_Fp                                  :       326.57 kHz    (,)
DELTA_FSI_F0_MAX                              :       325.74 kHz    (,)
DELTA_FSI_FSI3_MAX                            :         3.63 kHz    (,)
FREQ_DEV_SYNC_AVG                             :       249.12 kHz    (,)
FSI_MAX                                       :       322.02 kHz    (,)
FSI_MIN                                       :         1.41 kHz    (,)
INITIAL_FREQ_OFFSET                           :        -3.71 kHz    (,)
PEAK_TO_AVERAGE_POWER                         :         0.67 dBc    (,)
POWER_AVERAGE_DBM                             :        -8.56 dBm    (,)
POWER_PEAK_DBM                                :        -7.89 dBm    (,)
CTE_TYPE                                      : AoA Type
ERROR_MESSAGE                                 : [Info] Function completed.
```

Figure 14: IQfact+ AoA Transmitter test results

8. Angle of Arrival Receiver Tests

For verification of AoA Receiver tests, the tester transmits the LE Test Signal with CTE extension, the test signal and switching pattern is defined in BT Core specifications. The test signal goes through an external splitter. The DUT receives the test signal and reports I/Q values sampled to the tester. The tester calculates and verifies the relative phase and reference phase deviation and dynamic range. This test covers test cases 4.5.38 (RF-PHY/RCV/IQC/BV-05-C, RF-PHY/RCV/IQC/BV-06-C), 4.5.40 (RF-PHY/RCV/IQDR/BV-11-C, RF-PHY/RCV/IQDR/BV-12-C) of the BT SIG RF PHY Test Suite.

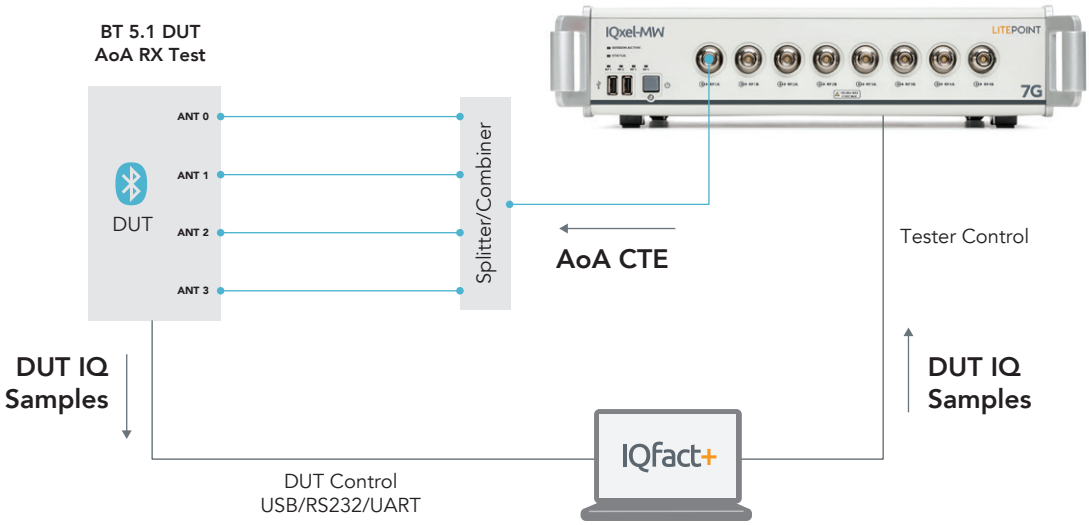


Figure 15: AoA Receiver test setup

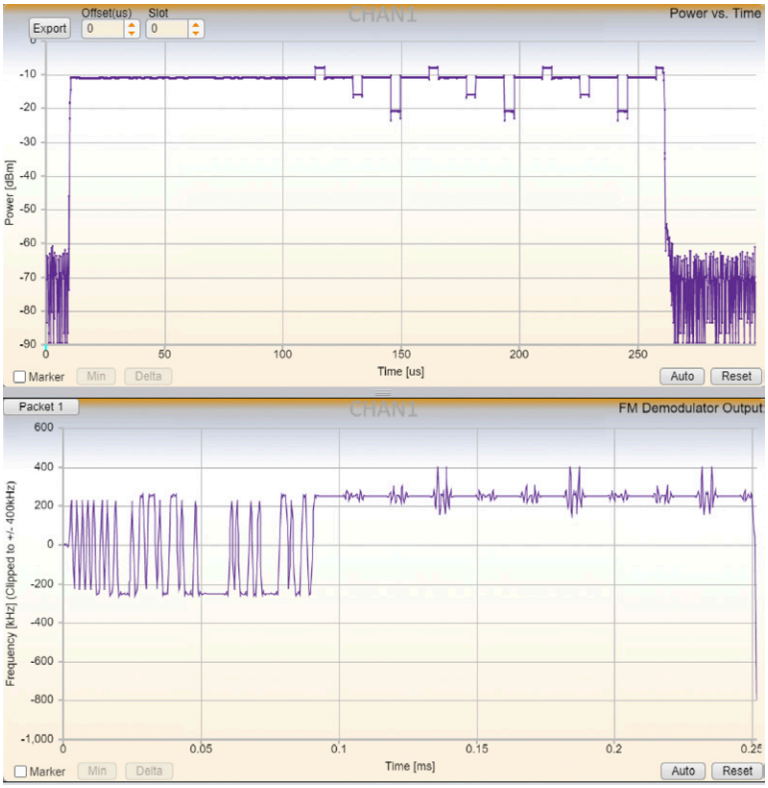


Figure 16: 160us CTE with Power Offset for Dynamic range test

8.1 AoA Receiver IQ Samples Coherency

Test case 4.5.38 (RF-PHY/RCV/IQC/BV-05-C, RF-PHY/RCV/IQC/BV-06-C) verifies that the measured relative phase values derived from I/Q data sampled by the DUT on AoA Receiver waveform are within specified limits. This test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional) using a 2 µs switching/sampling slot duration.

For each frequency tested, the DUT must report at least 10,000 valid IQ sample pairs per antenna. 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 by the specs.

8.2 AoA Receiver IQ Samples Dynamic Range

Test case 4.5.40 (RF-PHY/RCV/IQDR/BV-11-C, RF-PHY/RCV/IQDR/BV-12-C) verifies that the IQ values sampled on receiving AoA receiver waveform have specified values when varying the dynamic range of CTE. This test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional) using a 2 µs switching/sampling slot duration. The signal level applied to each antenna index is defined in Table 2 below.

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

Table 2: Input power value for each antenna index

For each frequency tested, the DUT must report at least 10,000 valid IQ sample pairs per antenna. 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 by the specs.

8.3 AoA Receiver IQfact+ Test Results

The following shows a sample AoA Receiver tests using IQfact+ automation software:

```
SLOT_DURATION                                  :            2 us     (,)
CTE_DURATION                                   :       160.00 us     (,)
MEAN_AMPLITUDE_ANT_1                           :         0.00 dBc    (,)
MEAN_AMPLITUDE_ANT_2                           :        -1.02 dBc    (,)
MEAN_AMPLITUDE_ANT_3                           :         1.17 dBc    (,)
MEAN_AMPLITUDE_ANT_4                           :        -0.38 dBc    (,)
MEAN_RELATIVE_PHASE_ANT_2                      :         0.84 dBm    (,)
MEAN_RELATIVE_PHASE_ANT_3                      :        -1.38 dBm    (,)
MEAN_RELATIVE_PHASE_ANT_4                      :         0.35 dBm    (,)
MEAN_RELATIVE_PHASE_DEV                        :         0.94        (,)
NO_OF_VALID_MEAS_PER_ANT                       :        12.00        (,)
CTE_TYPE                                       : AoA Type
MEAN_AMPLITUDE_CHECK                           : FAIL
MEAN_RELATIVE_PHASE_DEV_CHECK                  : PASS
MEAN_RELATIVE_PHASE_DEV_SUM_CHECK              : PASS
MEAN_RELATIVE_PHASE_SUM_CHECK                  : PASS
RELATIVE_PHASE_CHECK                           : PASS
ERROR_MESSAGE                                  : [Info] Function completed.
```

Figure 17: IQfact+ AoA Receiver test results

9. Angle of Departure Receiver Tests

For verification of AoD Receiver, the tester transmits LE Test Signal with CTE extension, the test signal uses a pre-defined phase pattern to the signals from multiple antennas and the switching pattern is defined in the BT Core specifications. The DUT receives the test signal on a single antenna and reports I/Q values sampled to the tester. The tester calculates and verifies the relative phase and reference phase deviation and dynamic range. This test covers test cases 4.5.37, 4.5.39 of the BT SIG RF PHY Test Suite.

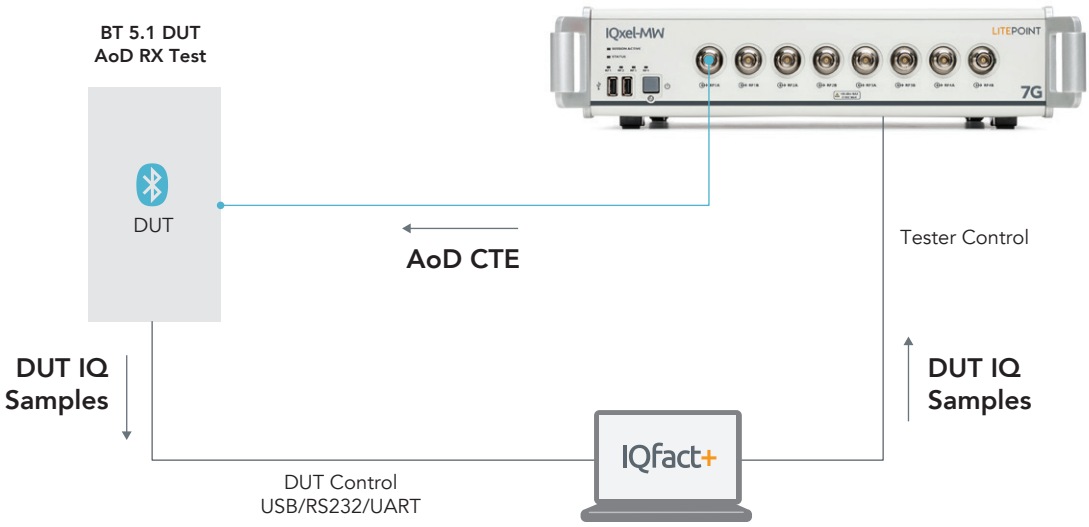


Figure 18: AoD Receiver test setup

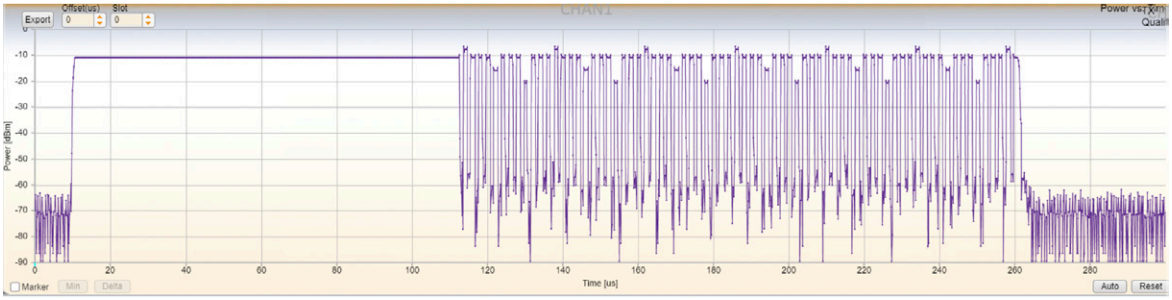


Figure 19: AoD receiver test CTE with power offset for dynamic range test

9.1 AoD Receiver IQ Samples Coherency

Test case 4.5.37 (4.5.37.1 RF-PHY/RCV/IQC/BV-01-C, 4.5.37.2 RF-PHY/RCV/IQC/BV-02-C, 4.5.37.3 RF-PHY/RCV/IQC/BV-03-C, 4.5.37.4 RF-PHY/RCV/IQC/BV-04-C) verifies that the measured relative phase values derived from I/Q data sampled by the DUT on AoD Receiver waveform are within specified limits. This test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional) using a 1 µs (optional) and 2 µs switching/sampling slot duration.

For each frequency tested, the DUT must report at least 10,000 valid IQ sample pairs per antenna. 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 by the specs.

9.2 AoD Receiver IQ Samples Dynamic Range

Test case 4.5.39 (4.5.39.1 RF-PHY/RCV/IQDR/BV-07-C, 4.5.39.2 RF-PHY/RCV/IQDR/BV-08-C, 4.5.39.3 RF-PHY/RCV/IQDR/BV-09-C, 4.5.39.4 RF-PHY/RCV/IQDR/BV-10-C) verifies that the IQ values sampled on receiving AoD receiver waveform have specified values when varying the dynamic range of CTE. This test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional) using a 1 µs (optional) and 2 µs switching/sampling slot duration. The signal level applied to each antenna index is defined in Table 2.

For each frequency tested, the DUT must report at least 10,000 valid IQ sample pairs per antenna. 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 by the specs.

9.3 AoD Receiver IQfact+ Test Results

The following shows a sample AoD Receiver tests using IQfact+ automation software:

```
SLOT_DURATION                                    :            1 us     (,)
CTE_DURATION                                     :       160.00 us     (,)
MEAN_AMPLITUDE_ANT_1                             :         0.00 dBc    (,)
MEAN_AMPLITUDE_ANT_2                             :       -11.24 dBc    (,)
MEAN_AMPLITUDE_ANT_3                             :         3.06 dBc    (,)
MEAN_AMPLITUDE_ANT_4                             :        -3.07 dBc    (,)
MEAN_RELATIVE_PHASE_ANT_2                        :         0.51 dBm    (,)
MEAN_RELATIVE_PHASE_ANT_3                        :        -0.08 dBm    (,)
MEAN_RELATIVE_PHASE_ANT_4                        :        -0.84 dBm    (,)
MEAN_RELATIVE_PHASE_DEV                          :         0.26        (,)
NO_OF_VALID_MEAS_PER_ANT                         :        12.00        (,)
CTE_TYPE                                         : AoD Type 1us
MEAN_AMPLITUDE_CHECK                             : FAIL
MEAN_RELATIVE_PHASE_DEV_CHECK                    : PASS
MEAN_RELATIVE_PHASE_DEV_SUM_CHECK                : PASS
MEAN_RELATIVE_PHASE_SUM_CHECK                    : PASS
RELATIVE_PHASE_CHECK                             : PASS
ERROR_MESSAGE                                    : [Info] Function completed.
```

Figure 20: IQfact+ AoD Receiver test results

10. Angle of Departure Transmitter Tests

For verification of AoD transmit power stability, signal integrity and antenna switching pattern requires an external combiner to combine signal from the DUT antennas to the tester. For antenna switching integrity test an external switch IQ3101 is controlled by the tester to vary the antenna switching pattern. This test covers test cases 4.4.15 and 4.4.16 of the BT SIG RF PHY Test Suite.

10.1 AoD Transmitter Power Stability Test

Test case 4.4.15 (4.4.15.1 RF-PHY/TRM/PS/BV-01-C, 4.4.15.2 RF-PHY/TRM/PS/BV-02-C, 4.4.15.3 RF-PHY/TRM/PS/BV-03-C, 4.4.15.4 RF-PHY/TRM/PS/BV-04-C) verifies 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. This test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional) using a 1 µs (optional) and 2 µs switching/sampling slot duration.

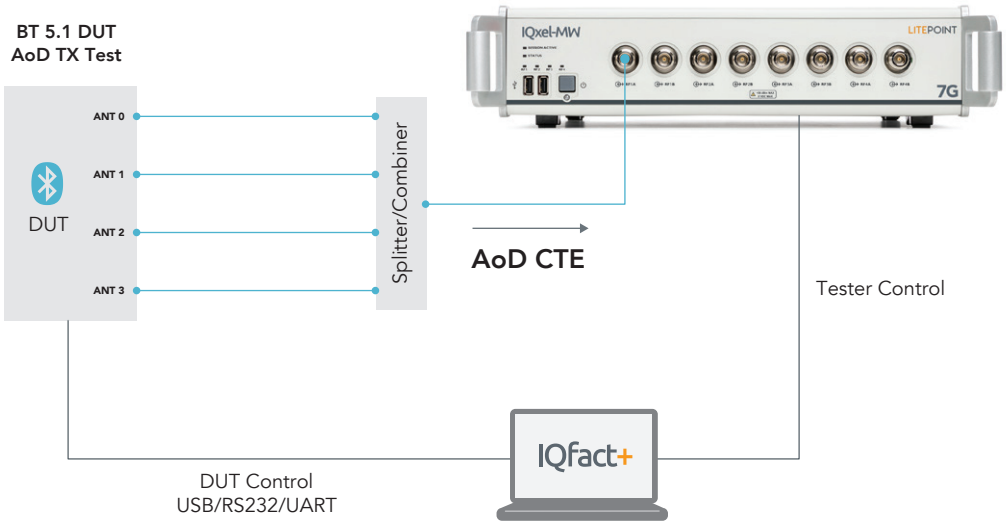


Figure 21: AoD Transmitter power stability test setup

The tester measures the average power during the reference period and on each of the transmit slots in the packet and the deviation compared to the reference period.

10.2 AoD Transmitter Power Stability IQfact+ Test Results

The following shows a sample AoD Transmitter test using IQfact+ automation software:

```
CTE_POWER_AVG_SLOT_10          :        8.40 dBm    (,)
CTE_POWER_AVG_SLOT_11          :        8.39 dBm    (,)
CTE_POWER_AVG_SLOT_12          :        8.44 dBm    (,)
CTE_POWER_AVG_SLOT_13          :        8.67 dBm    (,)
CTE_POWER_AVG_SLOT_14          :        8.40 dBm    (,)
CTE_POWER_AVG_SLOT_15          :        8.39 dBm    (,)
CTE_POWER_AVG_SLOT_16          :        8.45 dBm    (,)
CTE_POWER_AVG_SLOT_17          :        8.71 dBm    (,)
CTE_POWER_AVG_SLOT_18          :        8.39 dBm    (,)
CTE_POWER_AVG_SLOT_19          :        8.40 dBm    (,)
```

Figure 22: Sample IQfact+ AoD Transmitter power stability test results

10.3 AoD Transmitter Antenna Switching Integrity

Test case 4.4.16 (4.4.16.1 RF-PHY/TRM/ASI/BV-05-C, 4.4.16.2 RF-PHY/TRM/ASI/BV-06-C, 4.4.16.3 RF-PHY/TRM/ASI/BV-07-C, 4.4.16.4 RF-PHY/TRM/ASI/BV-08-C) verifies that the DUT antenna switching occurs during the switching slots of the Constant Tone Extension for an AoD transmit. This test requires an external combiner to combine signal from the DUT's multiple antennas as well as the IQ3101 switch. The IQ3101 ensures that the antennas can be switched and terminated automatically. This test is executed for PHY data rates LE 1M (mandatory) and LE 2M (optional) using a 1 µs (optional) and 2 µs switching/sampling slot duration.

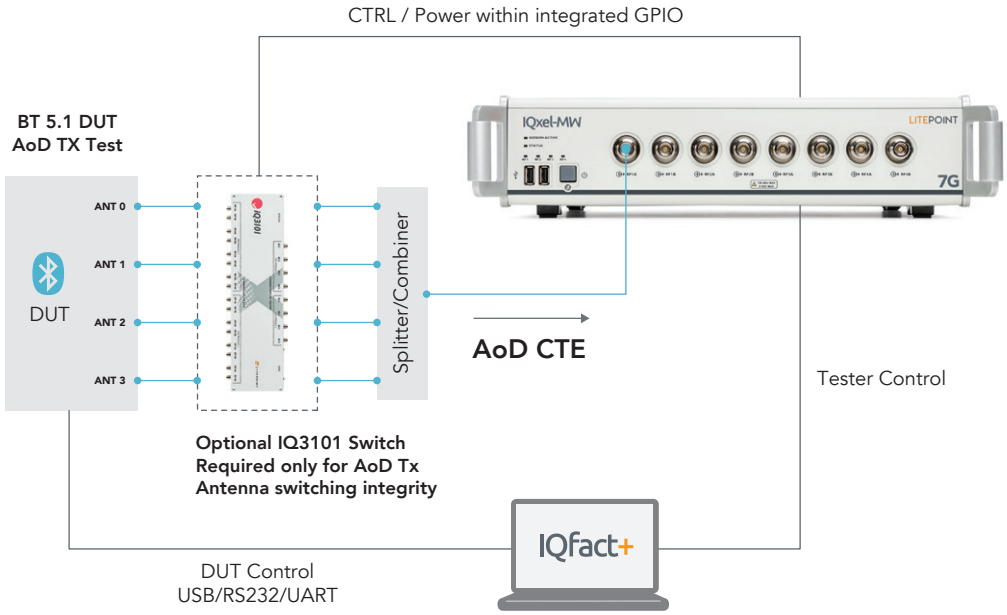


Figure 23: AoD Transmitter antenna switching integrity test setup

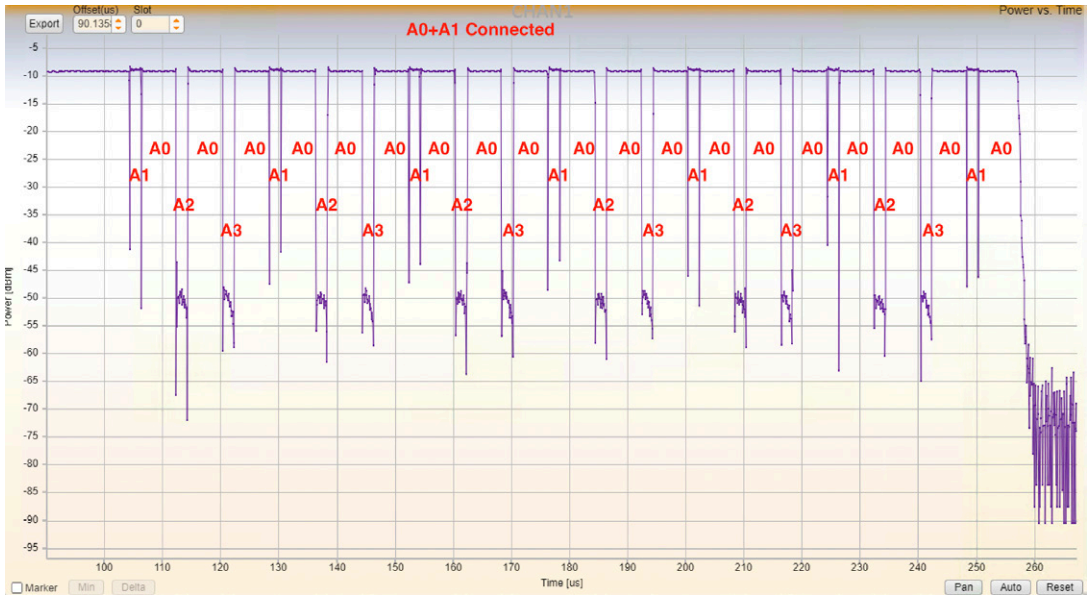


Figure 24: Antenna switching integrity with 4 Antennas and A0 (ref) and A1 connected.

The execution of this test requires multiple steps.

For example, 4 steps are required when validating a 4 antenna DUT with reference antenna A0 and non-reference antenna: A1, A2, A3. Each step requires a different physical connection. This process is automated when using the IQ3101 switch.

Step1: just A0 connected

Step2: just A0+A1 are connected.

Step3: just A0+A2 are connected.

Step4: just A0+A3 are connected

For each step, the average signal power measured when an antenna port is connected shall be 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.

10.4 AoD Antenna Switching Integrity IQfact+ Test Results

The following shows a sample AoD Transmitter test using IQfact+ automation software:

```
CTE_POWER_AVG_ON_A1_1          :        8.66 dBm    (,)
CTE_POWER_AVG_ON_A1_2          :        8.66 dBm    (,)
CTE_POWER_AVG_ON_A1_3          :        8.67 dBm    (,)
CTE_POWER_AVG_ON_A1_4          :        8.68 dBm    (,)
CTE_POWER_AVG_ON_A1_5          :        8.67 dBm    (,)
CTE_POWER_AVG_ON_A1_6          :        8.67 dBm    (,)
CTE_POWER_AVG_ON_A1_7          :        8.66 dBm    (,)
CTE_POWER_AVG_ON_A2_1          :        8.70 dBm    (,)
CTE_POWER_AVG_ON_A2_2          :        8.69 dBm    (,)
CTE_POWER_AVG_ON_A2_3          :        8.70 dBm    (,)
CTE_POWER_AVG_ON_A2_4          :        8.70 dBm    (,)
CTE_POWER_AVG_ON_A2_5          :        8.70 dBm    (,)
CTE_POWER_AVG_ON_A2_6          :        8.70 dBm    (,)
CTE_POWER_AVG_ON_A3_1          :        7.94 dBm    (,)
CTE_POWER_AVG_ON_A3_2          :        7.95 dBm    (,)
CTE_POWER_AVG_ON_A3_3          :        7.95 dBm    (,)
CTE_POWER_AVG_ON_A3_4          :        7.95 dBm    (,)
CTE_POWER_AVG_ON_A3_5          :        7.95 dBm    (,)
CTE_POWER_AVG_ON_A3_6          :        7.94 dBm    (,)
```

Figure 25: Sample IQfact+ AoD transmitter antenna switching test results

References

Radio Frequency Physical Layer Bluetooth Test Suite RF-PHY.TS.5.1.0

Bluetooth Core Specification Version 5.1

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