Bluetooth Test and Beyond
The Bluetooth Special Interest Group (SIG) is a group of companies working together to promote and define the Bluetooth Specification. The Bluetooth SIG was founded in February 1998 by the following group of core promoters:

- Ericsson
- Intel
- IBM
- Toshiba
- Nokia
- Microsoft
- Lucent
- 3Com
- Motorola

Web Site: http://www.bluetooth.org/specification.htm
Bluetooth

v1.2 + BDR
(Basic data Rate)

v2.1 + EDR
(Basic data Rate)

V4.0 + BLE
(Bluetooth Low energy)


v2.0 + EDR
(Enhanced Data Rate)

v3.0 + HS
(High Speed)

V5.0
(2x speed, 4x range, 800% broadcast)

<table>
<thead>
<tr>
<th>Rev</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
</table>
| 5.0 | Dec 06 2016 | • New features added in 5.0:  
  - CSA 5 features (Higher Output Power)  
  - Slot Availability Mask (SAM)  
  - 2 Msym/s PHY for LE  
  - LE Long Range  
  - High Duty Cycle Non-Connectable Advertising  
  - LE Advertising Extensions  
  - LE Channel Selection Algorithm #2  
  • Park State was deprecated and removed  
  • Errata for v2.0 + EDR, v2.1 + EDR, v3.0 + HS + 4.0 + 4.1 + 4.2 (ESR09, ESR10 and ESR11). See also [Vol 1] Part C, Section 9.4. |
# Bluetooth Radio Specification

<table>
<thead>
<tr>
<th>Technical Specification</th>
<th>Classic Bluetooth</th>
<th>Bluetooth Low Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2400 to 2483.5 MHz</td>
<td>2400 to 2483.5 MHz</td>
</tr>
<tr>
<td>Modulation Technique</td>
<td>Frequency Hopping</td>
<td>Frequency Hopping</td>
</tr>
<tr>
<td>Modulation Scheme</td>
<td>GFSK</td>
<td>GFSK</td>
</tr>
<tr>
<td>Modulation Index</td>
<td>0.35</td>
<td>0.5</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>79</td>
<td>40</td>
</tr>
<tr>
<td>Channel Bandwidth</td>
<td>1 MHz</td>
<td>2 MHz</td>
</tr>
<tr>
<td>Nominal Data Rate</td>
<td>1 - 3 Mbps</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Application Throughput</td>
<td>0.7 - 2.1 Mbps</td>
<td>&lt; 0.3 Mbps</td>
</tr>
<tr>
<td>Nodes / Active Slaves</td>
<td>7</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Security</td>
<td>56 to 128 bit</td>
<td>128-bit AES</td>
</tr>
<tr>
<td>Robustness</td>
<td>FHSS</td>
<td>FHSS</td>
</tr>
<tr>
<td>Voice</td>
<td>Capable</td>
<td>Not capable</td>
</tr>
</tbody>
</table>
**Piconet**

Consists of

- One (and only one) master
- More than one slave(s)

Master: the device which initiates data exchange.

Slave: the device which responds to the Master.
Physical Link Definition

• Synchronous Connection-Oriented (SCO) Link
  - circuit switching
  - symmetric, synchronous services
  - slot reservation at fixed intervals

• Asynchronous Connection-Less (ACL) Link
  - packet switching
  - (a)symmetric, asynchronous services
  - polling access scheme
Mixed Link Example
Packet Format
Bluetooth Packet Structure

- Modulation
  - 2402 to 2480MHz, 79 channel.
  - GFSK modulation techniques
  - DPSK added for EDR
- Packet format

<table>
<thead>
<tr>
<th>Packet Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL, POLL, FHS</td>
<td>System packets</td>
</tr>
<tr>
<td>DM1, DM3, DM5</td>
<td>Medium rate</td>
</tr>
<tr>
<td>DH1, DH3, DH5</td>
<td>High rate</td>
</tr>
<tr>
<td>HV1, HV3, HV5</td>
<td>Digitized audio</td>
</tr>
<tr>
<td>DV</td>
<td>Mixed data/voice</td>
</tr>
<tr>
<td>AUX1</td>
<td>Other uses</td>
</tr>
</tbody>
</table>
DM1/DH1

625 µs

72 bits  54 bits  240 bits  = 366 bits
Access code  Header  Payload 30 bytes

Header  Data  CRC
DM1  1  17  2  2/3 FEC

DH1  1  27  2

Information Shared Under NDA – Do Not Distribute
DM5/DH5

3125 µs

72 bits  54 bits  2744 bits  = 2870 bits

Access Code  Header  Payload  343 bytes

DM5  2  224  2/3 FEC  2

DH5  2  339  2

Payload 2/3 FEC

3125 µs  625 µs
LE Packet Structure

Figure 3.5: LE packet structure

Figure 2.1: Link Layer packet format
Link v.s. Non-link Mode Test

- Traditionally, Bluetooth SIG has given manufacturers the option to test with either Link or Non-Link mode.
- Non-link testing is faster: it tests the hardware – not the software.
  - For this reason, LitePoint has always advocated to use Non-Link mode.

**Link Based Test**

**Non-Link Based Test**

- **TCP / UDP**
- **IP**
- **PPP**
- **RF COMM**
- **L2 / CAP**
- **LMP**
- **HCI Interface**
- **Baseband**
- **Bluetooth Radio**

- **PC Driver**
- **LMP**
- **HCI Interface**
- **Baseband**
- **Bluetooth Radio**

**HW**

**SW Stack**

HCl: Host Control Interface
LMP: Link Manager Protocol
L2 / CAP: Logical Link Control and Adaptation Layer Protocol
RF COMM: Serial Port Emulation
**RF testing – NonLink Test**

- All tests are performed without setting up an RF connection.
- Controller(PC) control DUT into test condition.
- Controller(PC) control Tester to capture DUT’s signal to analyze it(TX) or transmit BT packets to DUT(RX).
RF test Cases (BDR + EDR)

• Transmitter tests
  - TRM/CA/01/C (Output Power)
  - TRM/CA/02/C (Power Density)
  - TRM/CA/03/C (Power Control)
  - TRM/CA/04/C (TX Output Spectrum – Frequency range)
  - TRM/CA/05/C (TX Output Spectrum – 20dB Bandwidth)
  - TRM/CA/06/C (TX Output Spectrum – Adjacent channel power)
  - TRM/CA/07/C (Modulation Characteristics)
  - TRM/CA/08/C (Initial Carrier Frequency Tolerance)
  - TRM/CA/09/C (Carrier Frequency Drift)
  - TRM/CA/10/C (EDR Relative Transmit Power)
  - TRM/CA/11/C (EDR Carrier Frequency Stability and Modulation Accuracy)
  - TRM/CA/12/C (EDR Differential Phase Encoding)
  - TRM/CA/13/C (EDR In-band Spurious Emissions)
  - TRM/CA/14/C (Enhanced power control)

• Receiver tests
  - RCV/CA/01/C (Sensitivity - single slot packets)
  - RCV/CA/02/C (Sensitivity – multi-slot packets)
  - RCV/CA/03/C (C/I performance)
  - RCV/CA/04/C (Blocking performance)
  - RCV/CA/05/C (Intermodulation Performance)
  - RCV/CA/06/C (Maximum Input Level)
  - RCV/CA/07/C (EDR Sensitivity)
  - RCV/CA/08/C (EDR BER Floor Performance)
  - RCV/CA/09/C (EDR C/I Performance)
  - RCV/CA/10/C (EDR Maximum Input Level)

All test cases supported by IQxel.
Red arrow (  ) test items require two signal generators.
RF test Cases (BLE)

• Transmitter tests
  - TRM/CA/01/C (Output Power at NOC)
  - TRM/CA/02/C (Power Density at EOC)
  - TRM/CA/03/C (In-band emissions at NOC)
  - TRM/CA/04/C (In-band emissions at EOC)
  - TRM/CA/05/C (Modulation characteristics)
  - TRM/CA/06/C (Carrier frequency offset and drift at NOC)
  - TRM/CA/07/C (Carrier frequency offset and drift at EOC)

• Receiver tests
  - RCV/CA/01/C (Receiver sensitivity at NOC)
  - RCV/CA/02/C (Receiver sensitivity at EOC)
  - RCV/CA/03/C (C/I and receiver selectivity performance)
  - RCV/CA/04/C (Blocking performance)
  - RCV/CA/05/C (Intermodulation Performance)
  - RCV/CA/06/C (Maximum Input Level)
  - RCV/CA/07/C (PER Report Integrity)

All test cases supported by IQxel.

Red arrow (→) test items require two signal generators.
Output Spectrum – BDR: 20dB Bandwidth

- Verification the emissions inside the operating frequency are within the limits.
- Find the highest power value.
- Find the lowest frequency $f_L$ that power drop 20dB below the highest power.
- Find the highest frequency $f_H$ that power drop 20dB below the highest power.
- The difference $\Delta f = |f_H - f_L|$
- Test Criteria:
  - $\Delta f = |f_H - f_L| \leq 1\text{MHz}$

Modulation payload is PRBS 9
EDR: Adjacent Channel Power

![Diagram showing EDR Adjacent Channel Power](image)

**Figure 8.** Transmitter spectral mask for EDR mode Bluetooth signal.

<table>
<thead>
<tr>
<th>Δ Channel Number</th>
<th>Frequency Offset</th>
<th>Transmit Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 MHz</td>
<td>-20 dBm</td>
</tr>
<tr>
<td></td>
<td>≥ 3 MHz</td>
<td>-40 dBm</td>
</tr>
</tbody>
</table>

Table 4. Adjacent Channel Power specifications.
**BLE: Modulation Characteristics**

- Verifies that the modulation characteristics of the transmitted signal are correct (i.e. the frequency deviation is measured with different payload sequences).

- **Test Criteria:**
  
  1. $225 \text{ kHz} \leq \Delta f_{\text{avg}} \leq 275 \text{ kHz}$
  
  2. At least 99.9% of all $\Delta f_{2,\text{max}}$ frequency values recorded over 10 test packets must be greater than 185 kHz
  
  3. $\frac{\Delta f_{2,\text{avg}}}{\Delta f_{1,\text{avg}}} \geq 0.8$

**Note:** $\Delta f_{1,\text{max}}$ is defined as the average of the samples within the bit period.
BLE: Carrier Frequency Offset and Drift

- Verifies that the carrier frequency offset and carrier drift of the transmitted signal

\[ f_{TX} - 150 \text{ kHz} \leq f_n \leq f_{TX} + 150 \text{ kHz} \]
where \( f_{TX} \) is the nominal transmit frequency and \( n = 0, 1, 2, 3 \ldots k \)

\[ |f_0 - f_n| \leq 50 \text{ kHz} \]
where \( n = 2, 3, 4 \ldots k \)

\[ |f_1 - f_0| \leq 20 \text{kHz} \quad \text{and} \quad |f_n - f_{n-5}|_{n=6, 7, 8 \ldots k} \leq 20 \text{kHz} \]

Figure 6.3: Initial frequency offset \((f_0)\) measurement principle

Figure 6.4: Frequency drift measurement principle
**BDR: Sensitivity**

- The sensitivity is tested using non-ideal transmitter (one-slot/multi-slot packet).
- Receive level of DUT is -70dBm
- The tester sends DH1/DH3/DH5 packets to the DUT and payload is PRBS 9.
- Adding dirty transmitter to tester.

  First 20ms using first parameter set
  Second 20ms using second parameter set.
  And so forth.
  After 10\(^{th}\) sets of parameter has been used, the tester uses the first again.

  \[ \text{BER} = \frac{Y}{\xi} \]

  \# payload bits counted in error

  \# payload bits received from DUT

- Test Criteria:
  - \(\text{BER} \leq 0.1\%\) (minimum number of samples, 1,600,000 returned payload bits).
BLE: Sensitivity with “Dirty Packets”

+ Dirty Packets in Bluetooth Low Energy Testing
  The Bluetooth LE PHY Test Spec document specifies the use of “dirty packets” for sensitivity testing
  - Every 50 packets, the Frequency Offset, Modulation Index and Symbol Timing Error are changed to specific value combinations described in the Test Spec
  - Additionally, a defined frequency drift is superimposed on the source output signal the frequency drift phase varies by 180° from packet to packet.
  • Test Criteria: PER ≤ 30.8% (minimum number of samples, 1,500 packet).
+ Comparison of Perfect Packet and Dirty Packet

![Bluetooth LE PER measurement graph](image)
Bluetooth Advanced - A LitePoint BLE OTA Testing
Bluetooth Advanced
Designed for 100% OTA
Advertising Channels
Provides good coverage across entire 2.4GHz band

Advertisement channel spacing enables good test coverage for Low, Mid, High channels. Does not require DUT to support special profiles.
How it Works...
Simplified Handshake and Timing Diagram

DUT transmits Advertising Packet

Tester responds Scan Request

DUT responds Scan Response

DUT transmits Advertising Packet

Tester responds Scan Request

DUT transmits Scan Response

Repeat this sequence with decreasing Scan Request power level until no DUT Scan Response is received
Bluetooth Advanced Test Coverage

- Configurable test plans for transmit & receive measurements

**Transmitter Tests** (@ CH 37, 38, 39):
- Power (Min, Max, Average)
- Delta F1
- Delta F2
- Minimum Deviation
- Frequency Drift
- Frequency Offset
- Adjacent Channel Power
- Advertising Packet Period
- Advertising Payload

**Receiver Tests** (@ CH 37, 38, 39):
- Packet Error Rate
- Sensitivity
Bluetooth Advanced

Key benefits:

- **Get results quickly** with any Bluetooth Smart (Low Energy) device
  - No need to install special software on the DUT
  - No DUT communication port needed
  - No need for special chipset drivers
  - RF can be radiated or conducted

- **Good RF parametric test coverage**
  - Transmitter Power, Modulation quality
  - Receiver Sensitivity
  - Results for Low, Mid, and High channels
  - Advertising Address, Interval, and Payload

- **Simplify Over-The-Air test setup**
  - Calibrate air loss from known TX power or RX sensitivity
Bluetooth 5
BT5 Key Features

2x Speed  Moving from 1Msym/sec to 2Msym/sec
4x Range  “Coding gain” increases range four times
8x Data    Larger packets allows more data per packet

Compliments of the BT SIG website
**BT5.0**

- 2M/500K/125Kbps rates in

<table>
<thead>
<tr>
<th>PHY</th>
<th>Modulation Scheme</th>
<th>Coding Scheme</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Access Header</td>
<td>Payload</td>
</tr>
<tr>
<td>LE 1M</td>
<td>1 Msym/s modulation</td>
<td>Uncoded</td>
<td>Uncoded</td>
</tr>
<tr>
<td>LE 2M</td>
<td>2 Msym/s modulation</td>
<td>Uncoded</td>
<td>Uncoded</td>
</tr>
<tr>
<td>LE Coded (error correction)</td>
<td>1 Msym/s modulation</td>
<td>S=8</td>
<td>S=8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S=2</td>
<td></td>
</tr>
</tbody>
</table>

- Remain channel definition: 2402 + n*2; n:[0 – 39]
**Increased Peak Data Rate**

**BT 4.2**
- 1 bit per symbol
- 1 Msym/sec
- Symbol period = 1us

**BT 5.0**
- 1 bit per symbol
- 2 Msym/sec
- Symbol period = 0.5us
Long Range – Packet Coding

Longer range achieved by adding error correct, which lowers the effective data rate for user data

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Coding Strength</th>
<th>Symbol Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mbps</td>
<td>Uncoded</td>
<td>1M sym/sec</td>
</tr>
<tr>
<td>2 Mbps</td>
<td>Uncoded</td>
<td>2M sym/sec</td>
</tr>
<tr>
<td>125 kbps</td>
<td>Coded with S=8</td>
<td>1M sym/sec</td>
</tr>
<tr>
<td>500 kbps</td>
<td>Coded with S=2</td>
<td>1M sym/sec</td>
</tr>
</tbody>
</table>

Used with S=2 and S=8

Pattern Mapper

- Input bit from the convolutional FEC encode
  - 0: 0011
  - 1: 1100

Used with S=8
**Bluetooth 5.0 Supported Testing (TX)**

- **For all data rate**
  - TP/TRM-LE/CA/BV-01-C [Output power]

- **Test for 1Mbps signal**
  - TP/TRM-LE/CA/BV-03-C [In-band emissions, uncoded data at 1 Ms/s] (ACP).
  - TP/TRM-LE/CA/BV-05-C [Modulation Characteristics, uncoded data at 1 Ms/s]
  - TP/TRM-LE/CA/BV-06-C [Carrier frequency offset and drift, uncoded data at 1 Ms/s]
  - TP/TRM-LE/CA/BV-09-C [Stable Modulation Characteristics, uncoded data at 1 Ms/s]

- **Test for 2Mbps signal**
  - TP/TRM-LE/CA/BV-08-C [In-band emissions at 2 Ms/s]
  - TP/TRM-LE/CA/BV-10-C [Modulation Characteristics at 2 Ms/s]
  - TP/TRM-LE/CA/BV-11-C [Stable Modulation Characteristics at 2 Ms/s]
  - TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s]

- **Test for 125kbps signal**
  - TP/TRM-LE/CA/BV-13-C [Modulation Characteristics, LE Coded (S=8)]
  - TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S=8)]
BT Test with IQfact+
Auto Test Tool – IQfact+

The settings of tester and DUT

Test items

- 1. INSERT_DUT
- 2. INITIALIZE_DUT
- 3. CONNECT_IQ_TESTER
- 4. GLOBAL_SETTINGS
- 5. LOAD_PATH_LOSS_TABLE
- 6. TX_BDR 2402 1DH1
- 7. TX_BDR 2402 1DH3
- 8. TX_EDR 2402 2DH3
- 9. TX_EDR 2402 3DH1
- 10. TX_EDR 2402 3DH5
- 11. TX_LE 2444 1LE
- 12. RX_BDR 2480 1DH1
- 13. RX_BDR 2440 1DH3
- 14. RX_EDR 2444 2DH5
- 15. RX_EDR 2444 3DH5
- 16. RX_LE 2444 1LE
- 17. REMOVE_DUT
- 18. DISCONNECT_IQ_TESTER
Test item of IQfact+ Tx BDR
Test item of IQfact+ Tx EDR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQ MHZ</td>
<td>2440 MHz</td>
</tr>
<tr>
<td>PACKET_LENGTH</td>
<td>0</td>
</tr>
<tr>
<td>TX_POWER_LEVEL</td>
<td>8 Level</td>
</tr>
<tr>
<td>CABLE LOSS_DB</td>
<td>0.00 db</td>
</tr>
<tr>
<td>EXPECTED_TX_POWER_DBM</td>
<td>-99999.99 dBm</td>
</tr>
<tr>
<td>SAMPLING_TIME_US</td>
<td>0.00 us</td>
</tr>
<tr>
<td>PACKET_TYPE</td>
<td>3DH5</td>
</tr>
<tr>
<td>Test Time</td>
<td>1.045 s</td>
</tr>
</tbody>
</table>

$\text{error}()$(s,

- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_2}$: $-31.77$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_3}$: $-49.59$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_4}$: $-51.13$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_5}$: $-51.71$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_0}$: $1.09$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_2}$: $-34.65$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_3}$: $-49.67$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_4}$: $-51.65$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_5}$: $-52.39$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_1}$: $-34.45$ dbm
- $\text{ACP\_MAX\_POWER\_DBM\_OFFSET\_1}$: $-34.69$ dbm

$\text{error}()$(s,

- $\text{CABLE\_LOSS\_DB}$: $29.00$ dB
- $\text{DATA\_RATE\_DETECT}$: $3.00$ Mbps
- $\text{EDR\_EVM\_AV}$: $0.05$
- $\text{EDR\_EVM\_PK}$: $0.14$
- $\text{EDR\_EXTREME\_OMEGA\_0}$: $1.00$ kHz
- $\text{EDR\_EXTREME\_OMEGA\_10}$: $-17.32$ kHz
- $\text{EDR\_OMEGA\_I}$: $-17.56$ kHz
- $\text{EDR\_POW\_DIFF\_DB}$: $0.13$ dB
- $\text{EDR\_PROB\_EVM\_99\_PASS}$: $100.00$ %
- $\text{FREQ\_DEVIATION}$: $163.54$ kHz
- $\text{FREQ\_DEVIATION\_PK\_TO\_PK}$: $395.92$ kHz
- $\text{FREQ\_EST}$: $-15.59$ kHz
- $\text{FREQ\_EST\_HEADER}$: $-17.56$ kHz
- $\text{POWER\_AVERAGE\_DBM}$: $4.19$ dbm
- $\text{POWER\_PEAK\_DBM}$: $7.01$ dbm
- $\text{TARGET\_POWER\_DBM}$: $8.00$ dbm

$\text{error}()$(s,

truncated at TRM/CA/11/C and TRM/CA/10/C

Information Shared Under NDA – Do Not Distribute
BT LE test item vs IQfact+

475.TX_LE 2444 1LE ___________________________________________________________
ANALYZE_POWER_ONLY : 0
FREQ_MHZ : 2444 MHz
PACKET_LENGTH : 0
TRANSMIT_0XF0_SEQUENCE_FOR_DELTA_F1_AVG : 1
TX_POWER_LEVEL : 0 Level
CABLE_LOSS_DB : 0.00 dB
EXPECTED_TX_POWER_DBM : -1 dBm
SAMPLING_TIME_US : 0.00 us
PACKET_TYPE : 1LE
Test Time = 2.856 s
CRC_OK : 1
ACP_MAX_POWER_DBM_OFFSET_0: 8.70 dBm (,)
ACP_MAX_POWER_DBM_OFFSET_1: -11.69 dBm (,)
ACP_MAX_POWER_DBM_OFFSET_2: -38.99 dBm (-20.00)
ACP_MAX_POWER_DBM_OFFSET_3: -47.78 dBm (-30.00)
ACP_MAX_POWER_DBM_OFFSET_4: -52.98 dBm (-30.00)
ACP_MAX_POWER_DBM_OFFSET_5: -55.08 dBm (-30.00)
ACP_MAX_POWER_DBM_OFFSET_6: 8.70 dBm (,)
ACP_MAX_POWER_DBM_OFFSET_7: -11.26 dBm (,)
ACP_MAX_POWER_DBM_OFFSET_8: -38.71 dBm (-20.00)
ACP_MAX_POWER_DBM_OFFSET_9: -47.58 dBm (-30.00)
ACP_MAX_POWER_DBM_OFFSET_10: -53.19 dBm (-30.00)
ACP_MAX_POWER_DBM_OFFSET_11: -56.12 dBm (-30.00)
CABLE_LOSS_DB : 9.50 dB (,)
DATA_RATE_DETECT : 1.00 Mbps (,)
DELTA_F1_AVERAGE : 245.12 kHz (225.00, 275.00)
DELTA_F2_AVERAGE : 229.04 kHz (,)
DELTA_F2_F1_AV_RATIO : 0.93 (0.80,)
DELTA_F2_MAX : 189.77 kHz (,)
DELTA_F0_Fn_MAX : 3.43 kHz (,)
DELTA_F1_F0 : 0.77 kHz (,)
DELTA_Fn_Fn5_MAX : 2.71 kHz (,)
FREQ_DEV_SYNC_AVG : 256.16 kHz (,)
FREQ_OFFSET : 1.50 kHz (-150.00, 150.00)
F_Mp_MAX : 4.55 kHz (,)
POWER_AVERAGE_DBM : 8.15 dBm (,)
POWER_PEAK_DBM : 9.06 dBm (,)
TARGET_POWER_DBM : -1.00 dBm (,)
ERROR_MESSAGE : [Info] Function completed.

6.2.3 TRM-LE/CA/03/C (In-band emissions at NOC)

6.2.5 TRM-LE/CA/05/C (Modulation characteristics)

6.2.6 TRM-LE/CA/06/C (Carrier frequency offset and drift at NOC)

6.2.1 TRM-LE/CA/01/C (Output power at NOC)
BT LE correlation with IQxel GUI

6.2.1 TRM-LE/CA/01/C (Output power at NOC)
- \(-20 \text{ dBm} \leq P_{\text{AVG}} \leq +10 \text{ dBm EIRP}\)
- \(P_{\text{PK}} \leq (P_{\text{AVG}} + 3 \text{ dB})\)

6.2.5 TRM-LE/CA/05/C (Modulation characteristics)
1. \(225 \text{ kHz} \leq \Delta f_{\text{avg}} \leq 275 \text{ kHz}\)
2. At least 99.9\% of all \(\Delta f_{\text{max}}\) frequency values recorded over 10 test packets must be greater than 185 kHz
3. \(\frac{\Delta f_{\text{avg}}}{\Delta f_{\text{avg}}^\text{L}} \geq 0.8\)

6.2.6 TRM-LE/CA/06/C (Carrier frequency offset and drift at NOC)

**Pass Verdict**
- \(f_{\text{TX}} - 150 \text{ kHz} \leq f_{\text{n}} - f_{\text{TX}} + 150 \text{ kHz}\)
  where \(f_{\text{TX}}\) is the nominal transmit frequency and \(n=0,1,2,3...k\)
- \(|f_0 - f_{\text{n}}| \leq 50 \text{ kHz}\)
  where \(n=2,3,4...k\)
- \(|f_1 - f_0| \leq 20\text{kHz} \text{ and } |f_{n-1} - f_{n-2}| \leq 20\text{kHz}\)
IQfact+ for BT5

Transmitter Test:
Configure “Packet Type” as one of the configurations in the test item

Receiver Test:
Configure “Packet Type” and “Waveform Name” in the configuration of the test item
Thank You