Introduction to RWC5020B LoRaWAN® Tester

RedwoodComm

September 2019
Test Solutions for End-devices

Protocol Conformance Tests

- LoRaWAN® Pre-Certification tests
  - EU V1.5, US/CA V1.3, AS V1.1, KR V1.2 and IN V1.1
- LoRaWAN® Protocol Compatibility
  - V1.0.2 / V1.0.3 / V1.1
  - Class A / Class B / Class C
- Analysis of protocol messages and parameters
- Scripts of MAC commands or user data transmission
- Regional parameters
  - EU868, US915, EU433, AU915, CN470, AS923, KR920, IN865, RU864, KZ865

RF Performance Tests

- RX Sensitivity
  - RX1 / RX2 / Ping slot (Class B)
- TX Power
- Frequency Counter

Send packets at low power level
Downlink
SF7 ~ SF12
Uplink
Measure TX power
Test Solutions for Gateways

- **Protocol Conformance Tests**
  - Same as the case of End-devices
    - only except of LoRaWAN® Pre-Certification Tests

- **RF Performance Tests**
  - RX Sensitivity
  - TX Power

- **Semtech’s Non-regression Tests for GWs**
  - TX Output Power Measurement
  - Sensitivity
  - PER / RSSI / SNR
  - Frequency Error Tolerance
  - CW Interferer/Blocker Immunity

Send packets at low power level

![Diagram of test setup](image)
LBT Test Solution

**What is LBT?**
- Listen Before Talk; to prevent interference or collision between devices on common frequency channels

**How to test LBT?**
- Use RWC2020A Interference Generator as an interferer
- For details, refer to the Local Regulations of Japan and Korea
Manufacturing Solution

**Separate T/RX Test**
- Non-signaling test (one-way test)
- Use **Signal Analyzer** function for TX Test by measuring TX power of DUT
- Use **Signal Generator** function for RX Test by testing RX sensitivity of DUT
- A wired control of DUT is mostly required

**Simultaneous T/RX Test**
- Combining the advantages of signaling test and non-signaling test
- Simple protocol is defined between DUT and the tester
- A wired control of DUT is not necessary
Related Specifications

- LoRaWAN® Application Layer Clock Synchronization Specification v1.0.0
- LoRaWAN® Remote Multicast Setup Specification v1.0.0
- LoRaWAN® Fragmented Data Block Transport Specification v1.0.0
# Hardware Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>Range: 400MHz ~ 510MHz, 862MHz ~ 960MHz&lt;br&gt;Resolution: 100Hz&lt;br&gt;Stability vs. +25°C: ±0.5ppm standard&lt;br&gt;Stability vs. Aging: ±1 ppm/1st year</td>
</tr>
<tr>
<td><strong>Output Level</strong></td>
<td>Range: 0dBm ~ -150dBm&lt;br&gt;Resolution: 0.1dB&lt;br&gt;Accuracy: ±1dB&lt;br&gt;Impedance: 50Ω</td>
</tr>
<tr>
<td><strong>Input Level</strong></td>
<td>+30dBm ~ -80dBm for Power Measurement&lt;br&gt;+30dBm ~ -50dBm for Frequency Measurement</td>
</tr>
<tr>
<td><strong>Measurement Accuracy</strong></td>
<td>±1dB for Power&lt;br&gt;±1KHz for Frequency (Single Tone)</td>
</tr>
<tr>
<td><strong>VSWR</strong></td>
<td>Better than 1:1.5</td>
</tr>
<tr>
<td><strong>External Frequency Reference</strong></td>
<td>Frequency: 10MHz&lt;br&gt;Power Range: 0dBm ~ +20dBm</td>
</tr>
<tr>
<td><strong>Remote Programming Ports</strong></td>
<td>RJ45(Ethernet)&lt;br&gt;RS-232C</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>Operating temperature: 5 ~ 40°C&lt;br&gt;Line Voltage: 100 to 240 VAC, 50/60Hz&lt;br&gt;Dimension: 250(w) x 110(h) x 348(d) mm&lt;br&gt;Weight: 5kg</td>
</tr>
</tbody>
</table>
# Ordering Information

## Main Product

<table>
<thead>
<tr>
<th>Order Code</th>
<th>Part Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5020B-00</td>
<td>EDT+GWT+NST</td>
</tr>
<tr>
<td>C5020B-01</td>
<td>EDT+GWT</td>
</tr>
<tr>
<td>C5020B-02</td>
<td>NST</td>
</tr>
<tr>
<td>C5020B-03</td>
<td>EDT</td>
</tr>
<tr>
<td>C5020B-04</td>
<td>GWT</td>
</tr>
<tr>
<td>C5020B-05</td>
<td>EDT+NST</td>
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<td>C5020B-06</td>
<td>GWT+NST</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C2020A-00</td>
<td>Interference Generator</td>
</tr>
</tbody>
</table>

## Options

<table>
<thead>
<tr>
<th>Order Code</th>
<th>Part Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>O5020B-01</td>
<td>LoRaWAN Pre-Cert EU</td>
</tr>
<tr>
<td>O5020B-02</td>
<td>LoRaWAN Pre-Cert SKT</td>
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<tr>
<td>O5020B-03</td>
<td>LoRaWAN Pre-Cert US</td>
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<td>O5020B-04</td>
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<td>O5020B-05</td>
<td>LoRaWAN Pre-Cert KR</td>
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<td>O5020B-06</td>
<td>LoRaWAN Pre-Cert IN</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>O5020B-98</td>
<td>Calibration</td>
</tr>
<tr>
<td>O5020B-99</td>
<td>Maintenance</td>
</tr>
</tbody>
</table>

* All regional parameters of the LoRaWAN® specification are provided in EDT or GWT.
* LoRaWAN® Pre-Certification Tests are add-on options for EDT only.
* The default PC software is provided with purchasing of C5020B-xx.
End Device Test

RWC5020

DUT

Gateway/Server

End Device

Uplink msg

Downlink msg
### EDT – Link Analyzer

- **Blue:** Uplink frames sent by DUT
- **Black:** Downlink frames sent by the tester

#### Data Table

<table>
<thead>
<tr>
<th>L</th>
<th>CH</th>
<th>DR</th>
<th>SF</th>
<th>BW</th>
<th>Pow</th>
<th>Time</th>
<th>FCnt</th>
<th>AckPort</th>
<th>M</th>
<th>dwell</th>
<th>CMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>-28.2</td>
<td>REF</td>
<td>----</td>
<td>0</td>
<td>---</td>
<td>-</td>
<td>1482 Join-request</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>0.0</td>
<td>----</td>
<td>----</td>
<td>0</td>
<td>---</td>
<td>-</td>
<td>1155 Join-accept</td>
</tr>
<tr>
<td>U</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>-29.2</td>
<td>11.9s</td>
<td>0000</td>
<td>0</td>
<td>099</td>
<td>C</td>
<td>1646 DataUp</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>0.0</td>
<td>----</td>
<td>0000</td>
<td>1</td>
<td>000</td>
<td>U</td>
<td>991 NoPayload</td>
</tr>
<tr>
<td>U</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>-29.3</td>
<td>5.00s</td>
<td>0001</td>
<td>0</td>
<td>099</td>
<td>C</td>
<td>1646 DataUp</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>0.0</td>
<td>----</td>
<td>0001</td>
<td>1</td>
<td>000</td>
<td>U</td>
<td>991 NoPayload</td>
</tr>
<tr>
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<td>2</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>-29.5</td>
<td>5.00s</td>
<td>0002</td>
<td>0</td>
<td>099</td>
<td>C</td>
<td>1646 DataUp</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>0.0</td>
<td>----</td>
<td>0002</td>
<td>1</td>
<td>000</td>
<td>U</td>
<td>991 NoPayload</td>
</tr>
<tr>
<td>U</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>-29.5</td>
<td>5.00s</td>
<td>0003</td>
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<td>099</td>
<td>C</td>
<td>1646 DataUp</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>125</td>
<td>0.0</td>
<td>----</td>
<td>0003</td>
<td>1</td>
<td>000</td>
<td>U</td>
<td>991 NoPayload</td>
</tr>
</tbody>
</table>

**Raw data in hexa-decimal format:**
```
01 71 80 80 00 00 00 01 00 00 00 00 01 68 32 48 3F
```

**Duty Cycle:** 23.44%

---

[Image of data table with additional information about time between consecutive frames, contents in a message at cursor, and calculated duty cycle.]
EDT – Link Analyzer

- Select a MAC command to be sent from the configuration
- Configure its parameters according to test purposes
- Push [MAC_SEND] to send it
EDT – Link Analyzer

- **Multiple MAC commands** in a single frame
- **Up to 3 MAC commands**
**EDT – Power Measurement**

- Power vs. Time: continuous monitoring of DUT’s TX Power w.r.t. SF
- Power vs. Channel: continuous monitoring of DUT’s TX Power w.r.t. Channel
- Calculating the maximum/average/minimum values

### Power vs. Time Measurement

**DataUp**: FCN7000E, CH04, 16.3dBm, SF7, CR_4_5

<table>
<thead>
<tr>
<th>Time</th>
<th>SF12</th>
<th>SF11</th>
<th>SF10</th>
<th>SF9</th>
<th>SF8</th>
<th>SF7</th>
<th>ALL</th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>124</td>
<td>23</td>
<td>28</td>
<td>17</td>
<td>16</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Pmax</td>
<td>16.8</td>
<td>16.8</td>
<td>16.6</td>
<td>16.6</td>
<td>16.4</td>
<td>16.4</td>
<td>16.5</td>
</tr>
<tr>
<td>Pavg</td>
<td>16.3</td>
<td>16.4</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
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<tr>
<td>Pmin</td>
<td>16.1</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.1</td>
</tr>
</tbody>
</table>

### Power vs. Channel Measurement

**DataUp**: FCN7000E, CH04, 16.3dBm, SF7, CR_4_5

<table>
<thead>
<tr>
<th>Channel</th>
<th>CH_00</th>
<th>CH_01</th>
<th>CH_02</th>
<th>CH_03</th>
<th>CH_04</th>
<th>CH_05</th>
<th>CH_06</th>
<th>CH_07</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>19</td>
<td>9</td>
<td>16</td>
<td>17</td>
<td>9</td>
<td>17</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Pmax</td>
<td>16.8</td>
<td>16.4</td>
<td>16.7</td>
<td>16.5</td>
<td>16.6</td>
<td>16.4</td>
<td>16.8</td>
<td>16.7</td>
</tr>
<tr>
<td>Pavg</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
</tr>
<tr>
<td>Pmin</td>
<td>16.3</td>
<td>16.1</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
</tr>
</tbody>
</table>
EDT – RX Sensitivity Test

- Determine power range and step for testing
- Select the class of the device and the target RX Window
- The result value is the minimum power level at which the measured PER does not exceed the limit (TARGET_PER)
EDT – Sensitivity Test Scenario

### (1) CERTI_DL_CNT
- **Tester**
  - Join-request
  - Any Packet
  - Downlink Counter (DR=m)
  - LinkADDRreq (Set DR to n)
  - LinkADDRans (DR=n)
- **DUT**
  - Join-accept
  - Activate test mode
  - Downlink
  - Downlink Counter (CNT=k, DR=n)
  - Downlink Counter (CNT=k+1, DR=n)

- **Results**
  - PASS
  - FAIL

### (2) CERTI_ECHO
- **Tester**
  - Join-request
  - Any Packet
  - Downlink Counter (DR=m)
  - LinkADDRreq (Set DR to n)
  - LinkADDRans (DR=n)
  - Echo Request
  - Echo Response (DR=n)
  - Echo Request
- **DUT**
  - Join-accept
  - Activate test mode
  - Downlink
  - Downlink Counter (DR=n)
  - Echo Response (DR=n)

- **Results**
  - PASS
  - FAIL
  - PASS

---

**Activation**

**Change DR**

**Calculate PER**
EDT – Sensitivity Test Scenario

(3) NORMAL_UL

Tester

DUT

Join-request

Join-accept

Uplink (ACK=0, DR=m)

LinkADDRreq (Set DR to n)

LinkADDRans (DR=n)

Confirmed Downlink

Uplink (ACK=1, DR=n)

Confirmed Downlink

Uplink (ACK=0, DR=n)

Confirmed Downlink

Uplink (ACK=1, DR=n)

Confirmed Downlink

PASS

FAIL

PASS

Activation

Change DR

Calculate PER
(4) Class B (Ping-slot)

From this point, DUT shall stop transmitting periodic UL messages for reliable sensitivity testing.
Gateway Test

RWC5020

DUT

End Device

Gateway/Server

Uplink msg

Downlink msg
**GWT – Link Analyzer**

- **Blue**: Downlink frames sent by DUT
- **Black**: Uplink frames sent by the tester

---

<table>
<thead>
<tr>
<th>L CH DR SF EW Pow</th>
<th>Time</th>
<th>FCnt</th>
<th>AckPort</th>
<th>M dwell</th>
<th>CMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>U 1 0 12 125 -10.0</td>
<td>REF</td>
<td>----</td>
<td>0</td>
<td>---</td>
<td>1482 Join-request</td>
</tr>
<tr>
<td>D 1 0 12 125 -28.4</td>
<td>----</td>
<td>----</td>
<td>0</td>
<td>---</td>
<td>1155 Join-accept</td>
</tr>
<tr>
<td>U 0 0 12 125 -10.0</td>
<td></td>
<td>11.7s</td>
<td>0000</td>
<td>0 099</td>
<td>C 1646 DataUp</td>
</tr>
<tr>
<td>D 0 0 12 125 -29.3</td>
<td>----</td>
<td>0000</td>
<td>1</td>
<td>---</td>
<td>U 991 NoPayload</td>
</tr>
<tr>
<td>U 2 0 12 125 -10.0</td>
<td>5.00s</td>
<td>0001</td>
<td>0 099</td>
<td>C 1646</td>
<td>DataUp</td>
</tr>
<tr>
<td>D 2 0 12 125 -29.3</td>
<td>----</td>
<td>0001</td>
<td>1</td>
<td>---</td>
<td>U 991 NoPayload</td>
</tr>
<tr>
<td>U 1 0 12 125 -10.0</td>
<td>5.00s</td>
<td>0002</td>
<td>0 099</td>
<td>C 1646</td>
<td>DataUp</td>
</tr>
<tr>
<td>D 1 0 12 125 -29.3</td>
<td>----</td>
<td>0002</td>
<td>1</td>
<td>---</td>
<td>U 991 NoPayload</td>
</tr>
<tr>
<td>U 2 0 12 125 -10.0</td>
<td>5.00s</td>
<td>0003</td>
<td>0 099</td>
<td>C 1646</td>
<td>DataUp</td>
</tr>
<tr>
<td>D 2 0 12 125 -29.3</td>
<td>----</td>
<td>0003</td>
<td>1</td>
<td>---</td>
<td>U 991 NoPayload</td>
</tr>
</tbody>
</table>

---

**RX1DROffset=0, RXDelay=1, RX2DR=0**

**Fn1** CLEAR  **Fn2** MAC_SEND  **Activated**

**LINK**: Running
Select a MAC command to be sent from the configuration
Configure its parameters according to test purposes
**Multiple MAC commands** in a single frame (Up to commands)
Push [MAC_SEND] to send it
GWT – Power Measurement

- Power vs. Time: continuous monitoring of DUT’s TX Power w.r.t. SF
- Power vs. Channel: continuous monitoring of DUT’s TX Power w.r.t. Channel
- Calculating the maximum/average/minimum values
GWT – RX Sensitivity Test

- Determine power range and step for testing
- The result value is the minimum power level at which the measured PER does not exceed the limit (TARGET_PER)
GWT - Sensitivity Test Scenario

Activation
- Join-request
- Join-accept

Change DR
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=0)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)
- Downlink (ACK=1)
- Confirmed Uplink (DR=n)

Calculate PER
- PASS
- FAIL
- PASS
- PASS
- PASS
- PASS

Tester sets Uplink DR internally
Non-signaling Test

RWC5020

DUT

End Device or Gateway
In Test Mode
Separate T/RX Test with SG/SA

0. Configure the test packet
1. Repeat sending packets
2. Measure TX Power
3. Stop

0. Configure the receiver
2. Measure TX Power
3. Stop

Any form of LoRa test packets can be generated with various flexible protocol parameters

0. Enter RX Test Mode
2. Count # of RX packets
4. Calculate PER

0. Enter TX Test Mode
1. Repeat sending packets

DUT
End-device or Gateway
Manufacturing Solution 2

- **Simultaneous T/RX Test with MFG**

  Applicable to all LoRa products (end-devices & gateways)

  1. **Initiate the test with START_FLAG**

  2. **Send the LoRa test packet (1)**
      - Send the LoRa test packet (2)
      - Send the LoRa test packet (3)
      - **Send the LoRa test packet (N)**
      - Close the test with END_FLAG

  3. **Report the number of received packets (K)**

  Calculate PER

  Measure TX Power

  DUT tx

  Power On

  DUT TX

  DUT RX

  No

  test packet received within TO?

  Yes

  DUT counts the number of packets (N) that received successfully

  END_FLAG received?

  No

  Test verdicts as FAIL by report timeout

  Yes

  DUT transmits the report packet (K value in payload)

  User’s next action
Typical Test Setup
Test Example of a Single DUT

Using MFG Function

- The tester shall be controlled by the user application software via Ethernet.

- DUT’s firmware needs to be modified to adopt the MFG test method.
- It is recommended the DUT is put into RF enclosure(s) to minimize the effect of interferences.
- Any available or efficient method can be adopted for RF connection; either radiated or conducted.
Test Example of Multiple DUTs

[RF TEST]
- The test packets sent by the tester as specified are transferred to each DUT by a splitter at the same time.
- Each DUT counts the number of packets it receives, which is read by the user application software.

[TX TEST]
- A DUT is forced to transmit CW signal.
- The tester measures the power and the frequency* of the CW signal.
- A DUT is forced to send the LoRa test packets.
- The tester measures the power of the test packets.
- The rest of DUTs are tested in turns.

* Frequency measurement is available only in RWCS020B.

- The tester shall be controlled by the user application software via Ethernet.
- This software may also control the DUTs if necessary.
- The DUTs should be put into RF enclosure(s) to minimize the effect of interferences.
- Any available or efficient method can be adopted for RF connection; either radiated or conducted.
PC Software
LoRaWAN® Pre-Certification Tests

LoRa Alliance Conformance Test (EU)
- 1 Test Mode Activation
  - 1.1 Test Mode Activation
- 2 Test Application Functionality
  - 2.1 Test Echo Service
  - 2.2 Test Downlink Counter
- 3 Over The Air Activation
  - 3.1 Over The Air Activation
- 4 Packet Error Rate RX2 default DR
  - 4.1 Packet Error Rate
- 5 Cryptography
  - 5.1 AES Encryption
  - 5.2 Invalid Message Integrity Code
- 6 Downlink Window Timing
  - 6.1 Test RX1 Downlink at +20us
  - 6.2 Test RX2 Downlink at +20us
  - 6.3 Test RX1 Downlink at -20us
  - 6.4 Test RX2 Downlink at -20us
- 7 Frame Sequence Number
  - 7.1 Uplink Sequence Number is Incrementing
  - 7.2 End node Rejects a Frame with Decreasing Sequence Counter

Test Parameters
- Test Mode Activation
- PathLoss: 0.7

CLEAR MON MSG
CLEAR SPY MSG
SAVE SPY MSG

View Remote Message

[TEST TIME] Begin: Finish:
RF Performance Tests
Link Analyzer & Script Editor

RedwoodComm : LoRaWAN AutoTest (Version: 1.172) Local IP: 192.168.0.9

Ver 1.20
LBT Test
## MFG Test

### Utilities - MFG

**Non-Signaling Test**

<table>
<thead>
<tr>
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<th>BW</th>
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<th>Time</th>
<th>FCnt</th>
<th>Port</th>
<th>Data</th>
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<th>Signal Analyzer</th>
<th>MFG</th>
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<td>125</td>
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</table>

**PER:** 0.000 (0/100)  **POW:** 8.9dBm

### Quick Measurement using MFG Scenario

**Step 1:**
- Initiate the test with `START_FLAG`
- `OUT TX`:
  - `OUT`: Transmits `START_FLAG`

**Step 2:**
- `OUT TX`:
  - `OUT`: Sends the LoRa test packet (1)
  - `OUT`: Sends the LoRa test packet (2)
  - `OUT`: Sends the LoRa test packet (3)

**Step 3:**
- `OUT RX`:
  - `Received`: `START_FLAG`
  - `OUT`: Receives the number of packets sent
- `OUT TX`:
  - `OUT`: Sends the report packet (1st packet received successfully)

**Report:**
- `OUT RX`:
  - `Received`: Report
  - `OUT`: Parses the report packet
  - `OUT`: Transmits the report packet
  - `OUT`: Transmits the report packet (2nd packet in sequence)

**View Remote Message**
Semtech’s Non-regression Test for GWs

Ver 1.20
DUT Control with User Commands