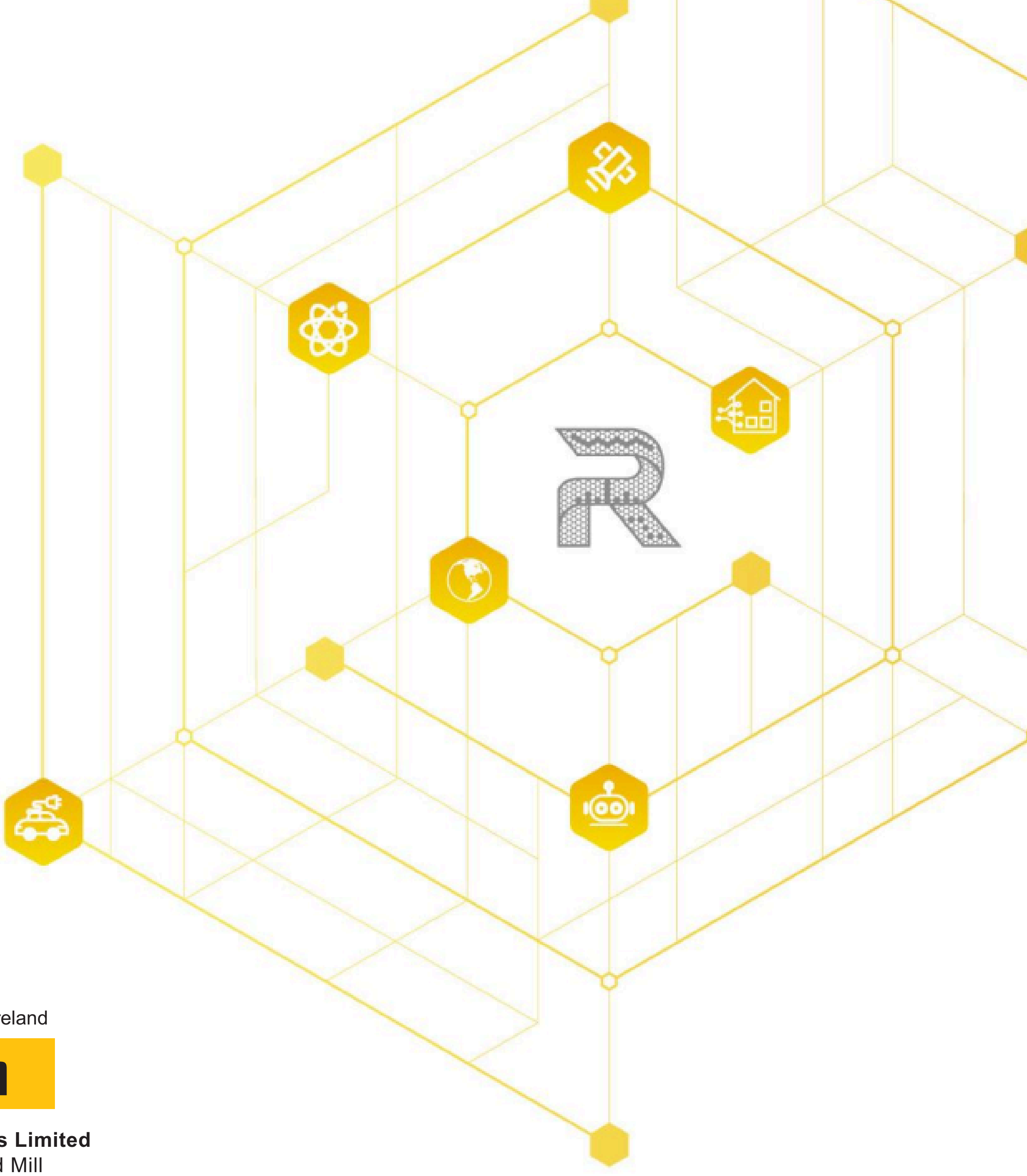
RIGOL

LoRa Signal Analysis Application Note



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ANW01100-1220-0045

1. Document description

1. Content in this guide

The purpose of this application guide is to describe the following:

- Describe the basic concepts, physical layer characteristics, and typical testing requirements of LoRa / LoRaWAN technology
- Describe the main features and operation of the LoRa analysis software that comes with the RSA6000/RSA800 series spectrum analyzers
- Introduction to signal capture, spectrum observation, Chirp demodulated waveform analysis, frequency deviation characteristic measurement using LoRa analysis software, A method for typical test items such as carrier power and frequency error measurement, packet decode verification, and frequency drift analysis
- Describe the instrumentation, connection, and configuration requirements required to complete the above tests
- Describes the safety precautions for the instrument, RF accessories, and DUT during testing

2. Applicable instrument and software version

Category	Product information
Spectrum analyzers	RSA6000/RSA800 Series Spectrum Analyzers
Analysis software options	LORA signal analysis software option (VSA · LORA)
Downloader software version	Refer to the software installation package release notes
Instrument firmware version	Refer to the firmware release notes in the corresponding product manual

Note: Before using this software option, make sure that the instrument has correctly activated the corresponding authorization. Please refer to the RSA6000/RSA800 product brochure or visit the RIGOL website for information on how to activate the license.

3. Scope of applicable standards and agreements

This guide is intended for the physical layer measurement and analysis of LoRa transmit signals, primarily for LoRa signal test scenarios based on the Chirp Spread Spectrum (CSS) modulation scheme. The scope of this guide includes, but is not limited to, the following:

- LoRa transmit signal analysis in common regional frequency bands
- RF signal testing in different spread spectrum factor (SF7 ~ SF12), channel bandwidth (BW 125kHz / 250kHz / 500kHz) and encoding rate (CR) configurations
- Spectral characteristics of LoRa signals, demodulated waveforms, frequency bias characteristics, carrier power, Analysis of physical layer indicators such as carrier frequency error, burst length, payload length, and frequency drift

- Protocol-layer basic decode verification such as packet CRC status, header CRC status, and payload length

Description: This guide focuses on signal capture and analysis at the LoRa physical layer and the underlying decode layer and does not cover all aspects of LoRaWAN network access, network affinity tuning, link budget, or full conformance certification. In the actual testing, make a comprehensive determination in conjunction with the target area regulations and product design specifications.

2. Safety precautions

The LoRa module can transmit up to +30 dBm (1 W) in a specific frequency band (e.g. US915, AU915, etc.). Read the following safety precautions carefully before proceeding to ensure safe measurements and prevent damage to the instrument.

1. Instrument usage precautions

To avoid personal injury and to prevent damage to the instrument or any equipment connected to the instrument, read and observe the following safety precautions before using the RSA6000 Spectrum Analyzer:

- Input Power Limit: The instrument RF input port is sensitive to overpower signals. The output power of the DUT shall be confirmed prior to the test and the power entering the instrument port shall be controlled within a safe range by means of a suitable attenuator. Exceeding the rated input limits may cause permanent damage to the front-end attenuator or mixer.
- Reliable grounding: Ensure that the instrument is securely connected to the protective earth via the protective earth terminal of the power cord. A good grounding not only helps keep operations safe, but also helps to reduce floor noise and improve **measurement stability of** weak **LoRa signals.**
- Maintain ventilation: The instrument generates heat during continuous acquisition, demodulation analysis, and decode processing. Maintain good ventilation on both sides and at the rear of the instrument to avoid blocking the heat sink to prevent performance degradation or damage due to excessive temperature rise.
- Antistatic protection: Static electricity can damage the instrument input circuit. It is recommended to test in an anti-static work area and to discharge static electricity by briefly grounding the inside and outside conductors of the cable before connecting the cable to the instrument.
- Avoid damp and hazardous environments: Do not operate the instrument in wet or flammable or explosive atmospheres and keep the surface of the product clean and dry to avoid short circuits or other safety hazards.
- Stopping operation if a fault is suspected: If an anomaly is suspected, discontinue use and contact a RIGOL authorized service person. Do not disassemble or repair the machine without authorization.

2. Notes on the use of RF accessories

LoRa tests are commonly used for RF accessories such as coaxial cables, attenuators, straighteners, adapters and antennas. For safe testing and reliable results, note the following:

- **Correct connection and disconnection:** When connecting RF accessories, it is recommended to connect the instrument end first and then the DUT end; in reverse order, disconnect the DUT end first. Disconnect the instrument end again to reduce the risk of misconnection and transient shock.
- **Comply with accessory ratings:** Consult the power ratings, frequency ranges and interface specifications for attenuators, cables, straighters and adapters before use. Make sure that their operating conditions meet the test requirements.
- **Connector Inspection and Cleaning:** Before connecting the SMA or N-type interface, inspect the connector bore, center conductor, and external threads for wear, dirt, or metal debris. If necessary, use anhydrous alcohol and special cleaning tools to clean the ports.
- **Avoid excessive bending of cables:** The minimum bending radius of high frequency coaxial cables should be according to the manufacturer's requirements, and excessive bending or twisting is strictly prohibited to avoid impedance mismatch, increased interpolation, or worsening of the dwell waves.

- **High Power DUT recommends adding attenuation:** For LoRa modules with higher transmit power, especially **for** equipment with a power amplifier (PA), it is recommended to use a "fixed attenuator + spectrometer" connection as a preferred method, with additional isolators or additional attenuated links if necessary. to protect the instrument input.
- **OTA Test Note Distance:** If using the open air (OTA) test, the distance and orientation between the antennas should be properly controlled to avoid excessive power at the receiving end due to close coupling.

3. DUT Connection Considerations

When connecting LoRa DUT (DUT), observe the following precautions to ensure test safety and measurement accuracy:

- **Electrostatic protection (ESD):** Both the LoRa module and the instrument RF interface can be affected by electrostatic discharge. Before connecting DUT, it is recommended that the operator wear an antistatic wrist strap and ensure that the test station has a good antistatic grounding.
- **Avoid live plugging:** Stop DUT transmission or switch off DUT power before connecting or disconnecting the RF cable between DUT and the instrument. Hot-plug is strictly prohibited while DUT is transmitting to prevent transient signals from damaging the front of the instrument.
- **Verify Output Power and Band:** Before connecting DUT, verify that the operating band, center frequency, output power, and transmit mode settings are correct. and is consistent with the current test parameters of the instrument.
- **Use DC Block if necessary:** If the DUT RF output has a DC bias, the DC isolators of the appropriate frequency band should be connected in series in the test link to prevent DC components from entering the instrument port.
- **Impedance matching requirements:** Test links are typically built on a 50Ω system. If the DUT output impedance is not a standard 50Ω, use a suitable matching network or impedance translation device to avoid measurement errors due to reflections.
- **Confirm Transmit Mode:** When performing Burst Length, Payload Length, CRC, or Frequency Drift tests, make sure that DUT is working steadily. Repeatable emission pattern to ensure comparability and reproducibility of test results.

3. LoRa signal and test basis

1. LoRa / LoRaWAN Technical Overview

LoRa (Long Range) is a low-power Wide Area Network (LPWAN) core physical layer modulation technology designed for the Internet of Things. It is based on linear frequency modulation spread spectrum (CSS) technology and is extremely resistant to interference, and is one of the underlying RF core technologies for wide-area wireless communications in the Internet of Things.

2. LoRa Common Band and Channel Planning

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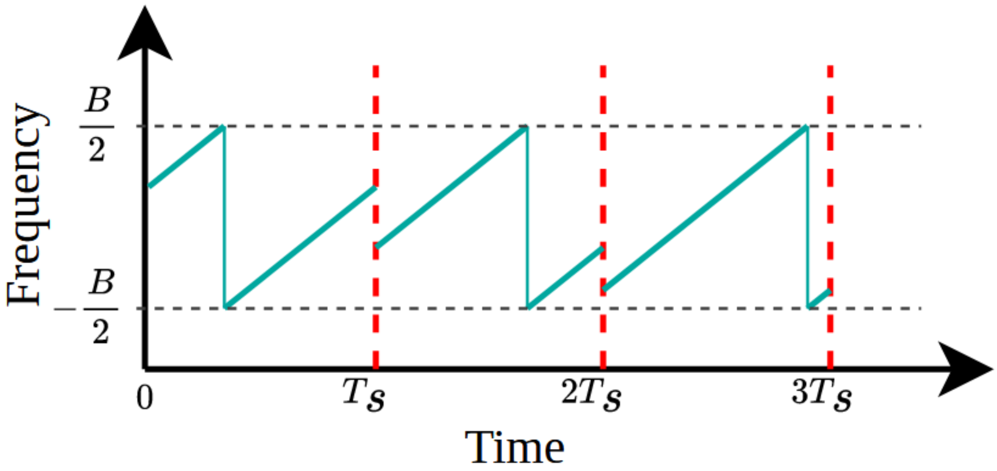
LoRa technology can be used in a variety of operating bands. In real-world testing and channel planning, the RSA6000 series of spectrum analyzers offer wide frequency coverage, providing full coverage of all operating bands of LoRa devices (up to 26.5 GHz). Precise extraction and measurement analysis of specific LoRa channels is possible by precisely configuring the center frequency (Center Freq) and sweep width (Span) in the instrument.

3. CSS Introduction to the principles of modulation

LoRa's exceptional immunity to interference is derived primarily from its CSS (Linear Frequency Modulation Spread Spectrum) modulation scheme. During CSS modulation, each transmission symbol is intentionally applied a frequency offset, as shown in the figure.



This time-linear variation of the frequency forms the basis for communication at the physical layer of LoRa. At the reception and test side of the signal, the system needs to "de-chirp" the signal to determine the index of the symbol to restore the digital bitstream. In the test, the time-domain frequency offset characteristics of this Chirp signal can be directly observed and analyzed through the demodulated waveform view of the instrument.

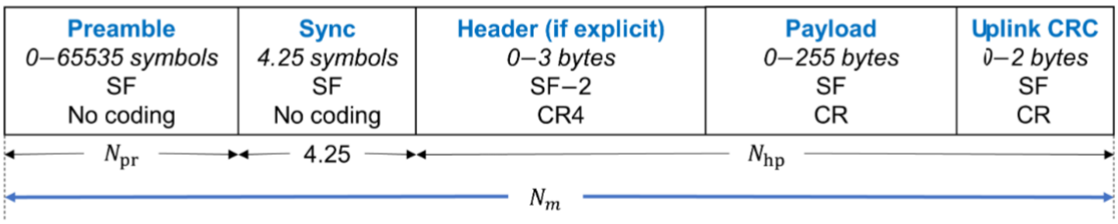
4. SF, BW, CR Parameter Description

The transmission rate, sensitivity, and immunity of LoRa are determined by a combination of the following three core parameters:

- **SF (Spreading Factor):** Defines how many RF code chips each information bit is extended into. LoRa supports variable spread spectrum factors from SF7 to SF12. Higher SF values result in higher reception sensitivity and greater interference resistance over longer coverage distances; however, they can also result in lower data transmission rates. Symbol transfer time extended. The SF configuration of the test instrument must be exactly the same as the DUT for signal interpretation or it will not be able to be modulated.
- **BW (Channel Bandwidth):** Determines the spectrum width the signal occupies, common standard configurations include 125kHz, 250kHz, 500kHz, etc. The higher the bandwidth, the higher the data rate, the shorter the transmission time; the narrower the bandwidth, the higher the reception sensitivity. The more resistant to narrowband interference. This parameter also requires an exact match at the test end.
- **CR (Coding Rate):** Loops error correction encoding for improved transmission reliability, expressed as 4/x (x takes 5, 6, 7, 8). For example, CR1 (4/5) adds 1 redundant error correction bit for every 4 information bits. The more redundant bits (such as CR4 4/8), the more error correction and interference resistance, but the less efficient effective transmission.

5. Introduction to the LoRa frame structure

LoRa's frame structure is designed for burst transmission and is designed to minimize frame overhead, as shown in the figure.



A complete frame of data typically consists of the following parts:

- **Preamble:** Consists of a series of Chirp pulses designed to help the receiver to identify a valid signal in noise and complete time-frequency synchronization.
- **Sync Word:** Used to differentiate between different network or application boundaries.
- **Header:** Both explicit and implicit headers are available. In implicit head mode, transmission omits transmission of head information to reduce signal dwell time in the air, requiring the receiver or test

instrument to manually pre-configure parameters such as the load length that is exactly the same as the transmitter, otherwise it cannot be decoded correctly.

- **Payload and CRC:** Used to carry actual application data. The packet's CRC (Cyclic Redundancy Check) can be turned on or off as needed to further control the frame overhead.

6. LoRa Key Measurements

For the physical and protocol layer characteristics of LoRa signals, the key measurements cover the following four dimensions:

- **Frequency bias and carrier metric:** Includes peak + / peak-, mean square root of frequency bias (RMS), carrier frequency error (Carrier Freq Err) and carrier power.
- **Stability Metrics:** Freq Drift RMS (peak) is core to evaluate the stability of the carrier frequency over time during continuous burst transmission.
- **Time and Length Metrics:** Includes time statistics for Burst Length, Payload Length, and Preamble Length.
- **Decode and Protocol Metrics:** Contains the underlying demodulated bits (de-chirping bits), the upper-layer decoded valid bits, and the intuitive packet CRC state verification (Pass/Fail) and header CRC state.

7. The RSA6000 measures the benefits of LoRa

The RSA6000 series of spectrum analyzers offer the expertise and convenience of R&D validation and automated line testing with a dedicated LoRa measurement application built into VSA (Vector Signal Analysis) mode:

- **Multi-Window Multidimensional Combined Analysis:** The system supports up to 4 view windows open simultaneously, allowing engineers to view RF RF spectrum, AF desodulation spectrum, demodulated waveform, and frequency drift profile against the same screen. Achieve comprehensive signal profiling from macro-frequency domain to micro-modulated domain.
- **Basic Level Piercing and Resolution:** Powerful protocol decoding capability, capable of stripping the received RF signal layer by layer, clearly articulating the process from "demodulated bit stream" (after chirping) to "fully decoded bit" (after error correction resolution), to pinpoint the root cause of protocol layer resolution failure.
- **Efficient, automated verification mechanism:** Provides one-button waveform optimization for the "Auto Scale" function, coupled with an accurate mid-frequency power trigger and trigger-release mechanism to reliably capture occasional bursts. Combined with the visual output of the Decode Information Panel, the CRC Pass/Fail status greatly simplifies the testing process and improves throughput efficiency for metric validation.

4. Description of the LoRa analysis software features

1. Introduction to how the software works

The LoRa measurement capability of the RSA6000 series of spectrum analyzers is a dedicated software application embedded in the VSA (Vector Signal Analysis) operating mode. The core signal analysis process is divided into two key phases: "Demodulation" and "decoding":

- **Demodulation Phase:** The software first underlays the received CSS (linear FM spread spectrum) modulated RF signals, "de-chirp" and reverts them to the original baseband bitstream, providing the underlying data for subsequent channel analysis.
- **Decode Phase:** The decode module provides frame-structure-level deep resolution of the raw bitstream of the demodulated output. The execution process includes frame synchronization, header resolution, CRC verification, de-interweaving and error correction (FEC), The result is precise stripping and restoring pure Payload data.

2. Description of the main screen

Once in LoRa analysis mode, the software's main operator interface is clearly laid out and consists of the following core functional areas:

- **Multi-Window Run Display:** The software supports multiple test views (e.g. spectrum, waveform, data table, etc.) on the same screen, allowing engineers to display multiple test views from time domain, Multidimensional joint signal observations of frequency and modulation domains.
- **Status Display Bar:** Located in a specific area of the interface, provides a visual representation of the current instrument hardware and critical status of measurements. Contains: Input impedance (50Ω / 75Ω), external gain, pre-amplifier (PA) status, input attenuation (auto/manual), Scan Mode (Continuous/Single), Average Status, Current Center Frequency (CF), Channel Bandwidth (CBW), and Trigger Mode Status.
- **Menu and Navigation control area:** Provides shortcut keys (such as adding a view, taking a screenshot, restoring default settings), and guides the user to the frequency via the main menu entrance. Subinterface for configuration of advanced parameters such as amplitude, bandwidth, scan, trigger, and measurement settings.

3. Parameter configuration description

To ensure that the measurement accurately corresponds to the LoRa being measured, the following core parameters need to be finely configured prior to testing:

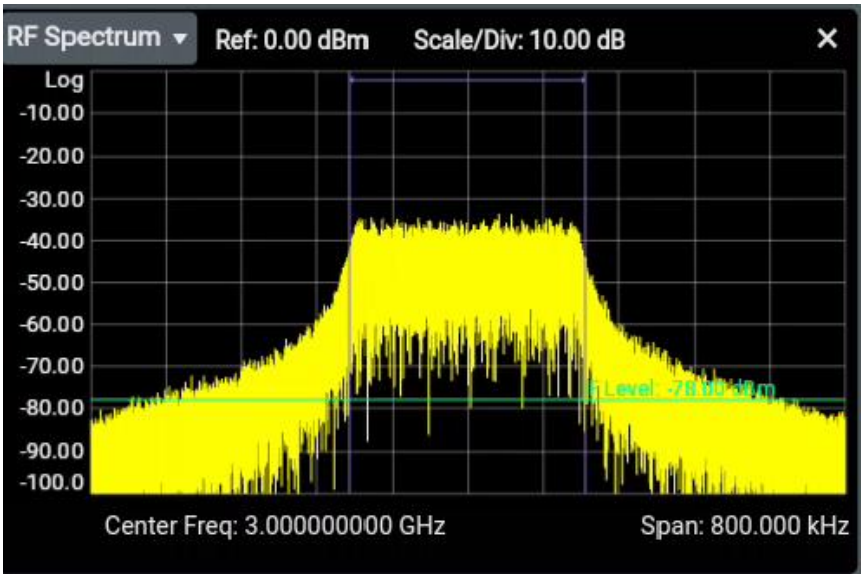
- **Frequency and Trigger Parameters:**
  - **Frequency Configuration:** Center frequency and signal sweep can be set. Modifying the center frequency is equivalent to a translational analysis channel, and the instrument supports precise tuning up to its hardware limits.
  - **Trigger mechanism:** For the burst transmission characteristics of LoRa, the software supports external and medium frequency (IF) power triggering. In the mid-frequency trigger, engineers can precisely set the trigger level, trigger delay (negative setting supported for pre-trigger capture), and trigger suppression time. This effectively avoids false haptations caused by noise or incomplete signals.
- **Demodulation and Decoding Parameters Configuration (Meas Setup):**
  - **Demod:** The spread spectrum factor (SF, range 7~12), channel bandwidth (e.g. 125K, 250K, etc.) and preamble length must be set to exactly the same as the device under test. Failure to do so will directly result in the signal not being demodulated.
  - **Decode Configuration (Decode):** The encoding rate (CR 4/5 to 4/8) needs to be specified to determine whether or not the packet CRC checksum is turned on. Of particular note is the "Implicit Header" switch: If the DUT is in implicit header mode (omitting the header

information to shorten the air time), the test must turn this on and manually pre-configure the exact packet length, otherwise it will not decode correctly. In addition, it is recommended that the "Decode from scratch" feature be turned on to force the software to start parsing from the packet's start frame header to prevent false judgments caused by data truncation.

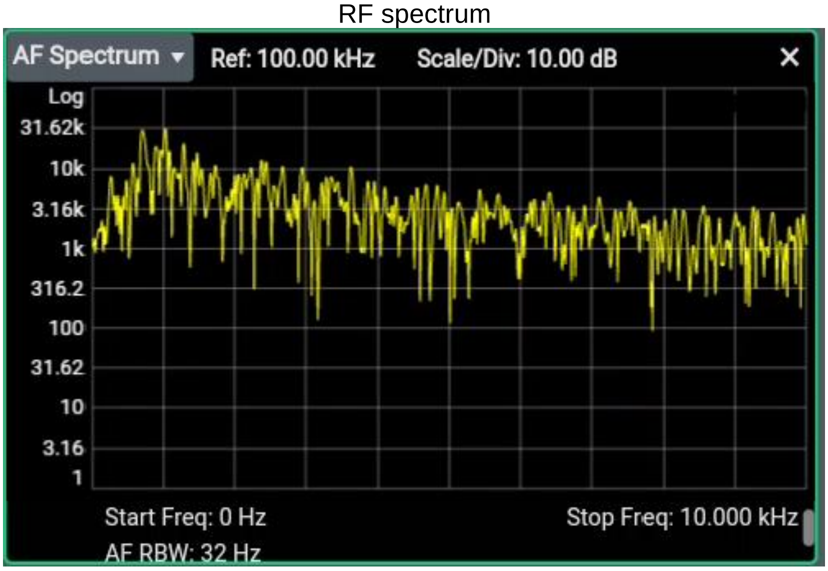
4. Description of the sub window

Analytics software provides a rich view window covering the analysis needs of RF links to the digital dimension:

1. **RF Spectrum and AF Spectrum:** The RF Spectrum View presents the log amplitude distribution of the RF signal on both sides of the center frequency and visually identifies the boundaries of the channel bandwidth (Channel BW) with vertical lines; the AF Spectrum shows the low frequency spectrum characteristics of the signal after demodulation.



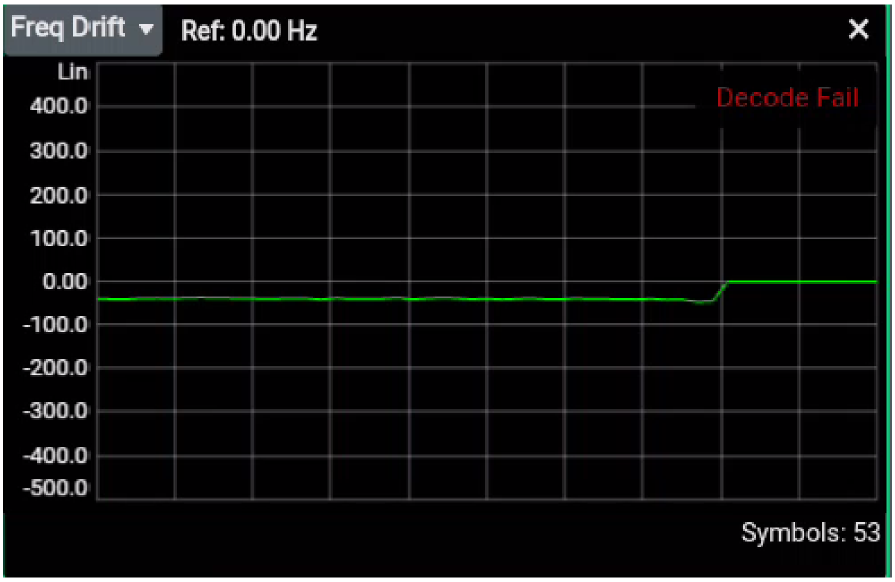
RF spectrum



AF spectrum

2. **Demod Waveform:** Presents a time domain waveform after the Chirp signal is demodulated. The horizontal axis represents time, and the vertical axis directly reflects the instantaneous frequency offset in linear scales (Hz), which is a key view for determining modulation linearity.

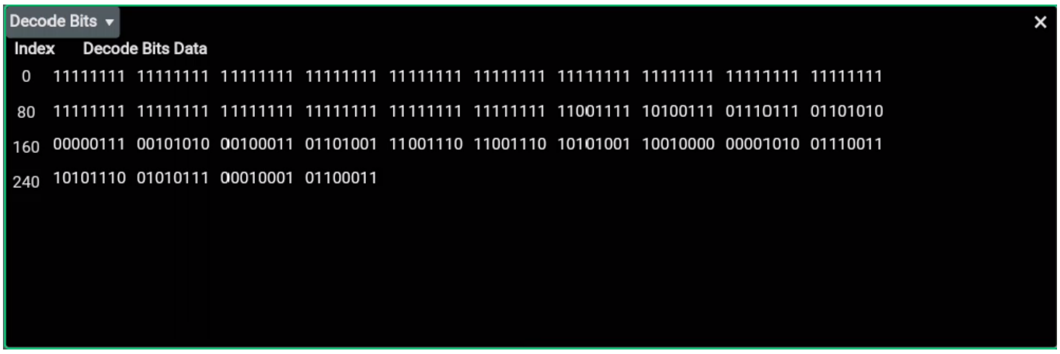
3. **Frequency Drift:** Designed to track carrier stability. The window has a symbol serial number on the horizontal axis and an offset (Hz) of each symbol relative to the center frequency on the vertical axis, creating an intuitive transient frequency drift curve.



4. **Demodulated and Decode Bits:**
    1. **Demodulated bits:** A table listing the bottom-level binary digital index sequence (0/1 bit stream) of the signal as determined by the "de-churn" process.
    2. **Decode bits:** Displays the final valid data bits extracted after protocol layer correction and resolution, including the CRC portion if the data contains a check bit.

Demod Bits

Index	Demod Bits Data									
0	00100000	11001100	00011100	00001100	11100000	11001100	00111000	00010000	11001100	01100111
80	00110000	00011111	00111100	01101000	00101110	11011100	01111001	10110111	11011110	10111100
160	01111001	10110011	01000010	10000011	01100100	01010100	01110001	10011110	01100100	00010011
240	10110000	11101111	00010111	11110101	10110011	11101101	01111101	10111110	01110011	01110110
320	10001110	10001101	01110011	10001111	00000010	00000010	00000010	00000010	00000010	00000010
400	00000010	00000010	00000010							



5. Decode information and measurement results description

The software highly refines all quantitative analysis data into two result panels:

- **Measurement Results:** A numerical indicator that focuses on the underlying physical layer and the modulated quality:
  - **Frequency bias and carrier:** Contains the maximum positive/negative frequency offset (Peak+ / Peak-) of the signal, the frequency bias root mean square value (RMS), and the error of the actual carrier with the set center frequency (Carrier Freq Err) and the carrier average power.
  - **Time Statistics:** Accurately calculates and displays the total burst length, the Preamble Length, and the Payload Length derived from both.
  - **Stability Evaluation:** Quantifies the RMS value of frequency drift and its peak offset (Freq Drift Pk+ / Pk-), and also outputs the maximum/minimum hold values for these drift indicators when averaging mode is turned on.

- **Decoding Info:** Provides diagnostic conclusions at the packet protocol layer:
  - A visual representation of the CRC status of the packet and the verification of the CRC status of the header (Pass or Fail) is the most commonly used direct basis for line quality determination.
  - Simultaneously displays the parsed encoding rate (e.g. CR1-CR4), the actual packet byte length, and the protocol sync byte extracted, helping developers quickly verify the communication protocol configuration.

5. Pre-test preparation

1. Test the connection diagram

Signal source + RSA6000 spectrometer (built-in LoRa option) combination

2. Test mode selection

Before performing LoRa signal analysis, you need to determine how the physical connection between DUT (DUT) and the spectrum analyzer is to be made. One of two methods is recommended:

- **Conducted Test:** Connect the RF output connector (such as SMA or UFL) of DUT directly to the RF input port of the RSA6000 via a low loss RF coaxial cable. This method perfectly shields electromagnetic interference from external space, ensuring absolute accuracy of spectrum, frequency deviation, and demodulation indicators.
- **Radiated Test:** For equipment with finished machine sampling or no RF interface ready. Measure verification by grasping the spatial signals transmitted by the device in the RF shielding box or darkroom by connecting the appropriate test antenna at the RF input of the spectrum analyzer.

3. Required equipment and accessories

- The default input impedance for the RSA6000 is 50Ω. If the output impedance of the system under test (DUT) is 75 Ω, the 75Ω to 50Ω adapter (option) provided by RIGOL must be prepared and connected to prevent measurement error RSA6000 due to impedance mismatch. In addition, if you

plan to trigger a test with an external synchronous signal, you will need to have **the** appropriate BNC cable available to connect it to the (TRIG IN) connector on the back panel of the instrument.
- In addition to the above equipment, it is strongly recommended to have an external RF attenuator (Attenuator) of appropriate attenuation in general conduction testing. Series them in series in the link effectively prevents the momentary overload of the high-power LoRa transmit signal or damage to the sensitive RF front end of the spectrum analyzer.

4. Instrument initialization and warm-up

- To ensure that the instrument is in a known and clean initial state prior to the test, it is recommended that the system settings be returned to the factory default state with a single click through a "Preset" action through the front panel or the system menu.
- In addition, the system setup of the instrument includes a "Auto Cal" function that allows the device to be switched on or off depending on changes in the current test environment to ensure measurement accuracy.
- As per the standard operating practices of the irradiometric instrument, For "Carrier Freq Err" and "Freq Drift" measurements with very high accuracy of the LoRa signal, It is recommended that the RSA6000 Spectrum Analyzer be powered on for at least 30 minutes. This ensures that the internal Local Vibration (LO) module and hardware link temperature drift reaches a fully thermal stable state.

5. DUT Preparation

To complete the accurate resolution of the LoRa signal, in addition to the physical connection in place, the operational status of the DUT itself must be clear.

- The physical and protocol layer demodulation parameters of the test instrument (e.g. spread spectrum factor SF, channel bandwidth BW, encoding rate CR, preamble length, Implicit header status, etc.) must be exactly the same as the actual transmit configuration of the device under test (DUT), otherwise the signal cannot be demodulated or the decode fails directly.
- During the test preparation phase, The testers are required to force DUT into a "Continuous TX" or a "Burst Launch Mode" for a constant cycle using the underlying control software or serial command from DUT. and detail each LoRa modulation parameter table currently issued by DUT. so that the spectrum analyzer can be accurately populated in the next step.

6. The default parameter configuration is recommended

After performing a "Preset Family" operation, the RSA6000 loads a set of recommended factory default configurations for LoRa analysis. Agents can use this as a benchmarking framework and then fine-tune it based on the actual DUT status. The core default parameters are as follows:

- **Frequency and Bandwidth:** Default center frequency is 1 GHz, sweep width (Span) is 200 kHz, channel bandwidth (BW) is 25 kHz by default, AF resolution bandwidth is 96 Hz.
- **Amplitude control:** Default reference value 0 dBm, attenuation mode Auto, maximum mixer level set to -10 dBm, preamplifier (PA) off.
- **Trigger mechanism:** Free Run mode is the default.
- **Demod:** Default Spread Spectrum Factor (SF) is set to 8, demodulated channel bandwidth is matched by default to BW250K, and the preamble length is set to 8 symbols.
- **Decode Parameters:** The "**Decode** Enabled" and "XDE" features are on by default; the default encode rate is set to CR1 (that is, 4/5); the packet CRC check is on by default; and the "Implicit Head" mode is off by default.

7. Troubleshoot common issues

If the results do not meet expectations during test preparation and initial measurements, the underlying logic provided in the manual can be used for quick troubleshooting as follows:

1. **Unable to unmodulate, protocol indicator shows as "----":**

2. The focus is on the "Spread Spectrum Factor (SF)" and "Channel Bandwidth (BW)" in the Measurement Setup Menu. These two core parameters must exactly match the transmit state of the DUT, and any deviation will cause the de-chirp process to fail.
3. **The Load Length is displayed as a negative number or as a "---":**
4. The load length is calculated by the instrument from the "burst length" minus the set preamble length. This behavior usually occurs because the number of the prefix length entered in the "demodulated" menu is too large for the actual burst length captured. Please re-check and modify the preamble settings.
5. **Some packets fail to parse properly (for implicit header mode):**
6. If the DUT uses the "implicit return" mode transmission data to save power consumption, the load length cannot be learned by the test instrument itself because the header information is omitted from the signal. The "Implicit Head" must be turned on in the "Decode Menu" and the corresponding packet length must be entered manually and accurately, otherwise the instrument will not be able to extract valid data and perform CRC verification.
7. **Burst Wave Run does not display steadily:**
8. Free-trigger mode is difficult to consistently capture non-continuous bursts. It is recommended to change the trigger source to "IF Power", set the appropriate trigger level (e.g. -25 dBm) and set the appropriate time interval (e.g. 100 ms) in conjunction with the "Hold-off" function to prevent false hair induced by signal noise or burrs.
9. **There is a fixed deviation in amplitude or power readings:**
10. Verify the impedance environment of the system under test. If the measured end is 75 Ω, in addition to the hardware adapter, the Input/Output menu must be entered and the instrument's "Input Impedance" software setting changed simultaneously to 75 Ω. to ensure that the power conversion formula is accurate.

6. Typical application testing

1. LoRa signal capture and spectrum observation

1. Test purpose

Quickly verify the proper RF emissions of the LoRa device under test by observing RF and AF spectra, check center frequency alignment, signal occupancy bandwidth (OBW), and the presence of significant out-of-band stray emissions.

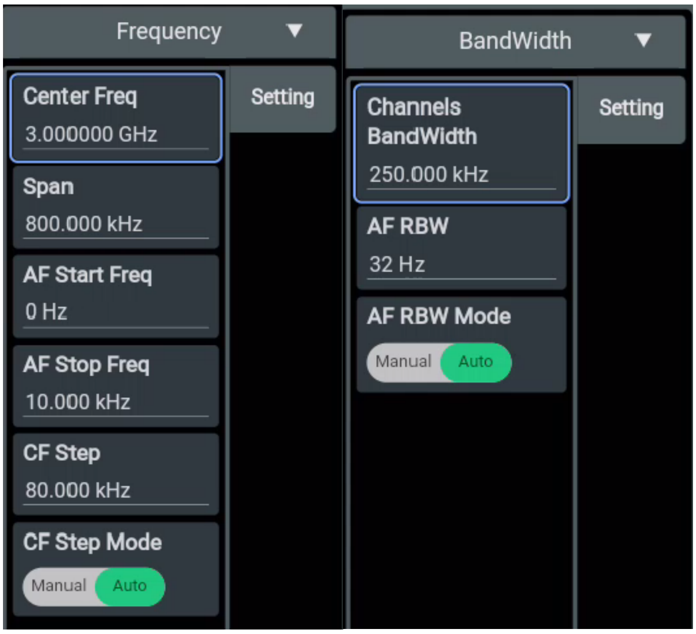
2. Test the connection diagram

Refer to 5.1Test the connection diagram.

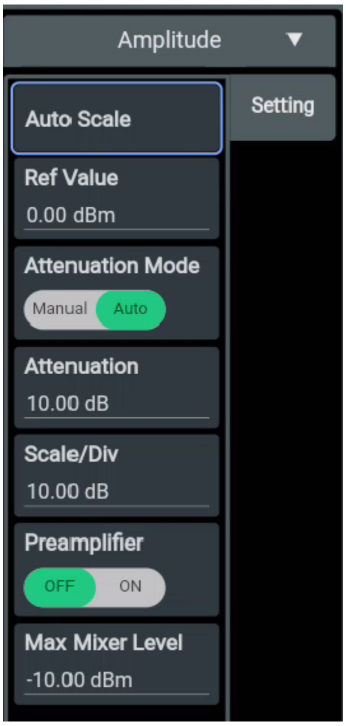
3. Test procedure

1. **Enter the measurement mode:** Click on the operating mode in the lower left corner of the instrument, select LORA > Apply to enter the LoRa dedicated analysis mode.

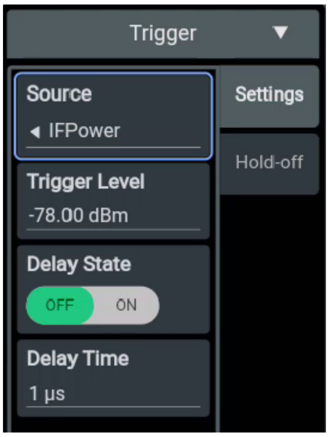
2. **Frequency and Bandwidth Settings:** Sets the exact "" in the Frequency menu; sets the "Span" to override the signal to be tested; and sets the "channel bandwidth" in the Bandwidth menu (CBW) to match the DUT transmission.



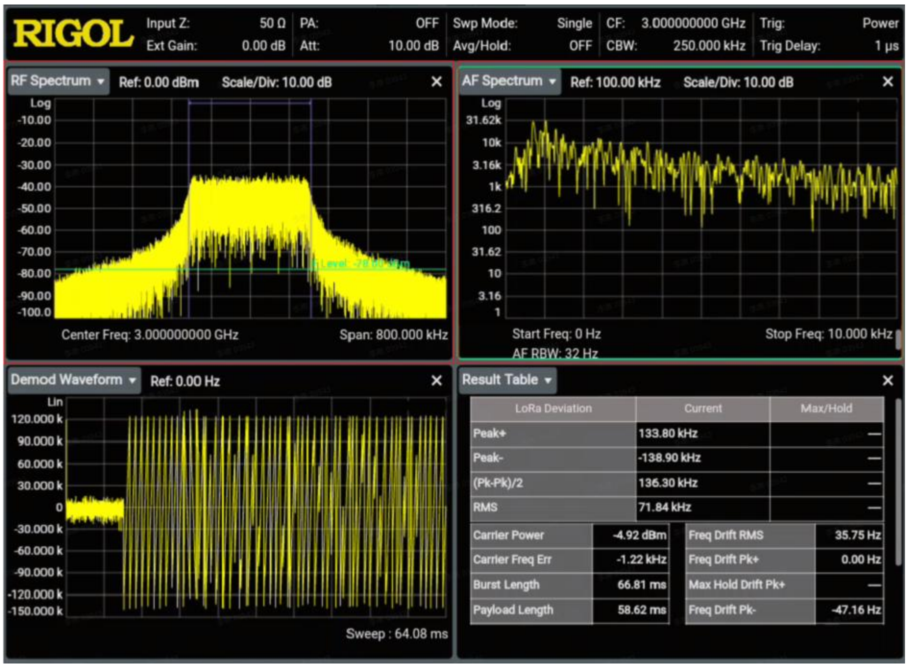
3. **Magnitude Optimization:** By clicking "Auto Scale" in the Amplitude menu, the instrument automatically adjusts the reference level and Y-axis scale to render the signal at the optimal display scale.



4. **Steady Capture:** For non-continuous bursts, it is recommended to enter the Trigger Menu, set the trigger source to "IF Power" and adjust the appropriate trigger level and trigger suppression time.



5. **View Selection:** Make sure the "RF Spectrum" and "AF Spectrum" windows are open on the main interface



4. Test results and analysis

- **RF Spectrum:** The window shows the logarithmic amplitude (dBm) of the signal in relation to the frequency. There is a vertical line at the center frequency to the left and right to visually indicate the set channel bandwidth range. This allows the agent to determine if the signal energy is effectively concentrated within a given channel.
- **AF Spectrum:** Shows the distribution of the low frequency spectrum after the RF signal is demodulated.

2. LoRa Chirp demodulated waveform analysis

1. Test purpose

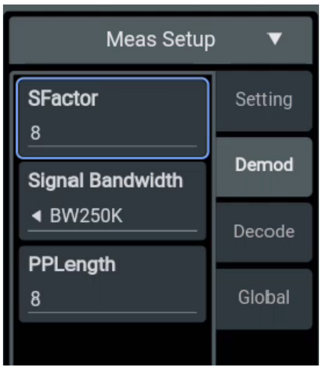
Verify the quality of the linear FM spread spectrum (CSS) modulation at the LoRa physical layer core, observe the linearity of the Chirp signal from the time domain frequency offset waveform, and troubleshoot the underlying RF link.

2. Test the connection diagram

Refer to 5.1Test the connection diagram.

3. Test procedure

1. **Basic Setup:** Complete the signal capture setup in Section 6.1.
2. **Demodulation parameter matching:** Go to the Measurement Setup > Demodulation menu.



3. **Key Action:** The "Spread Spectrum Factor (SF)" and "Channel Bandwidth (BW)" must be set to exactly the same value as the device under test.
4. **Turn on** Waveform **View:** Select and activate the "Demod Waveform" window in the multi-window view.

4. Test results and analysis

- **Demodulated wave window:** Time on horizontal axis and Frequency offset in Hz on linear scale (Linear) on vertical axis.
- **Analytical Value:** The ideal Chirp signal should present a continuous, smooth serrated linear frequency scan waveform. Distorted, nonlinear mutations, or burrs in the waveform indicate a hardware defect in the local vibration or modulation circuitry of DUT.

3. LoRa Deviation

1. Test purpose

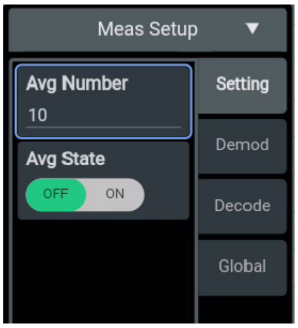
Quantifies the frequency offset of the LoRa signal during modulation to ensure that it meets design specifications, avoiding loss of receive-side demodulation sensitivity due to excessive or small frequency deviation.

2. Test the connection diagram

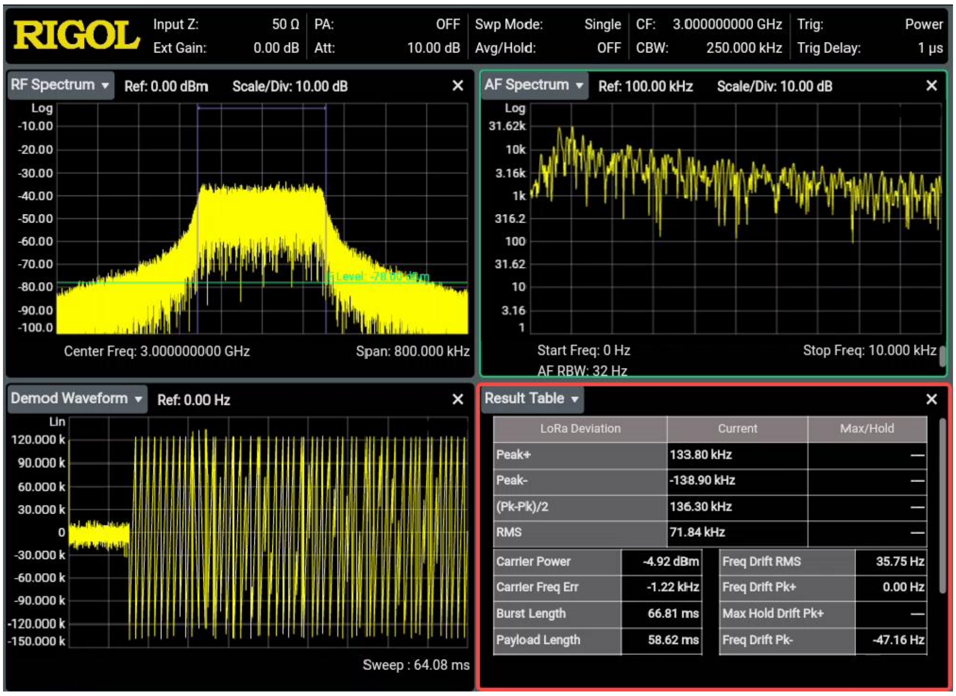
Refer to 5.1Test the connection diagram.

3. Test procedure

1. Make sure the demodulation parameters (SF, BW) are set correctly and the system successfully locks and demodulates the signal.
2. To evaluate the extremes of a series of transmissions, go to the Measurement Settings > Settings, turn on the “Average” Family and set a reasonable “Average” number of times.



3. Look at the "Measurement Results" panel on the main system interface.



4. Test results and analysis

The instrument gives high-precision quantitative data through the "Frequency Deviation Indicator" column, including the current value (Current) and the maximum hold value (Max Hold):

- **Peak+ / Peak-:** Indicates the positive and negative peak of the frequency offset during acquisition, respectively.

- **(Pk-Pk)/2:** Indicates half the peak frequency deviation.
- **RMS:** Represents the root mean square value of the frequency offset during acquisition, reflecting the consistency level of the overall frequency offset.

4. LoRa carrier power and frequency error measurement

1. Test purpose

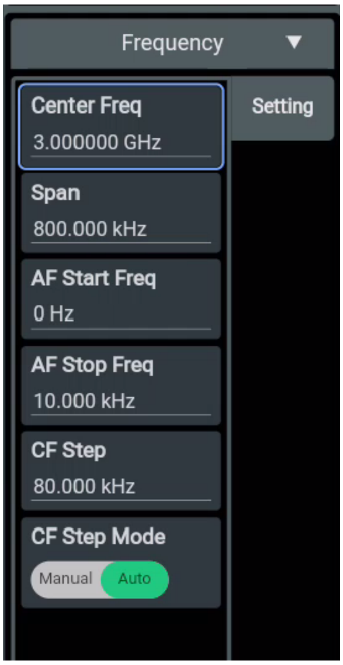
Accurately measures the actual average RF power emitted by the DUT and detects the offset of its carrier center frequency due to erratic crystal temperature or poor calibration to assess hardware transmit performance.

2. Test the connection diagram

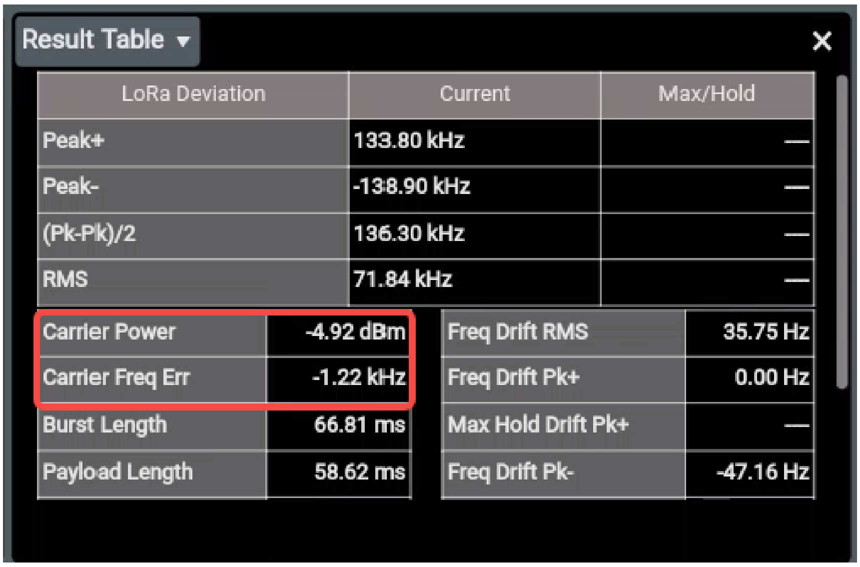
Refer to 5.1Test the connection diagram.

3. Test procedure

1. Sets the DUT to either continuous or high duty cycle burst transmission mode.
2. Enter the nominal center frequency of the target channel in the `Frequency` menu of the instrument.



3. Locate the "Carrier Index" column in the "Measurement result panel."



Result Table

LoRa Deviation	Current	Max/Hold
Peak+	133.80 kHz	—
Peak-	-138.90 kHz	—
(Pk-Pk)/2	136.30 kHz	—
RMS	71.84 kHz	—

Carrier Power	-4.92 dBm	Freq Drift RMS	35.75 Hz
Carrier Freq Err	-1.22 kHz	Freq Drift Pk+	0.00 Hz
Burst Length	66.81 ms	Max Hold Drift Pk+	—
Payload Length	58.62 ms	Freq Drift Pk-	-47.16 Hz

4. Test results and analysis

- **Carrier Power:** Indicates the average power detected at the carrier frequency.
- **Carrier Freq Err:** Displays the exact difference between the center frequency currently tuned by the instrument and the actually detected carrier frequency. If this error is too large, the receiver will not be able to synchronize the time frequency.

5. LoRa packet decode verification

1. Test purpose

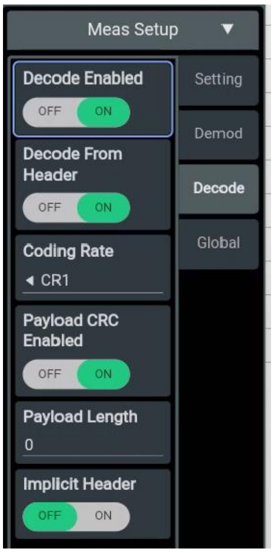
Pass through the RF physical layer to directly verify the correctness of the protocol layer logic. Verify that the received packet CRC is passed, fetching payload data and synchronization bytes.

2. Test the connection diagram

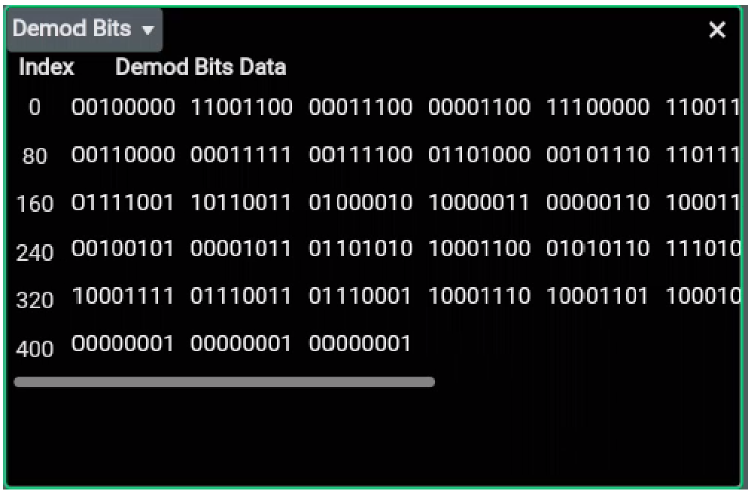
Refer to 5.1Test the connection diagram.

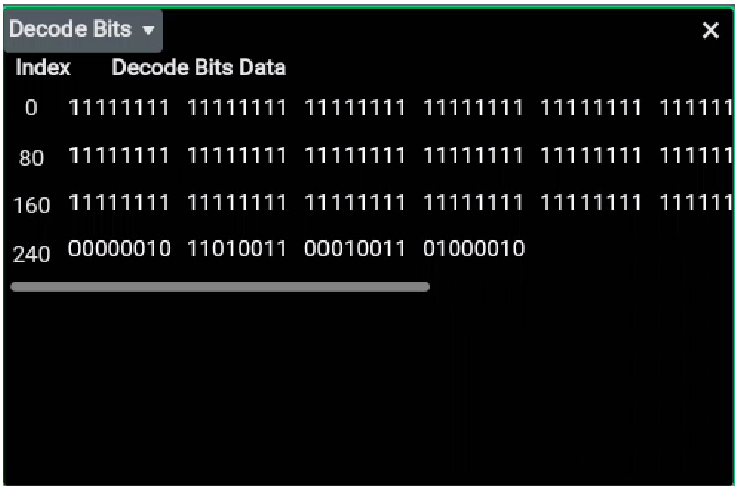
3. Test procedure

   1. Go to the Measurement Setup > Decode menu and set Decode-Enabled and "XID-Decode to On."



2. **Configure protocol parameters:** Set the corresponding “Coding Rate (CR)” (e.g. CR1 4/5) based on the DUT transmission configuration.
3. **Header Pattern Matching:** If the DUT transmission has an implicit header turned on, the "Implicit Header" must be set to on here and the exact "Packet Length" must be filled in manually; if it is an explicit header, it remains off.
4. Make sure that the "Packet CRC Enabled" is turned on.
5. Look at the "Decode Message" and "Decode Bit/Demodulated Bit" window.





4. Test results and analysis

- **Decode Information Panel:** Visually determines packet quality. If the "packet CRC status and the "header CRC status" are shown as Pass, then the protocol communication is normal. The panel also shows the resolved sync byte (Sync Byte #1 / #2) and packet length.
- **Data Penetration:** The "demodulated bit" window displays the bottom-down /1 sequence, while the "decoded bit" window displays the valid bytes of data that were eventually corrected.

6. LoRa Burst Frame Length and Payload Length Analysis

1. Test purpose

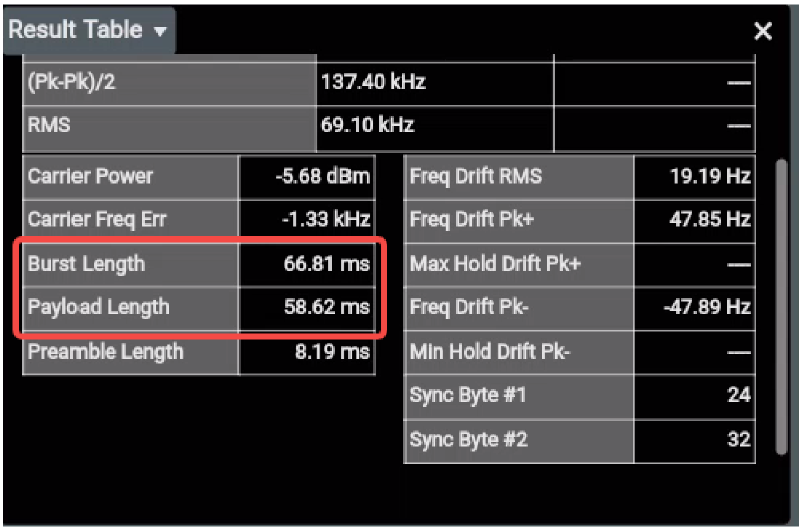
Accurately measures the time overhead at each stage (preamble, payload, total duration) of LoRa burst communication to assess the system's wakeup time and power performance in the air.

2. Test the connection diagram

Refer to 5.1Test the connection diagram.

3. Test procedure

1. A single, complete burst packet is captured with a "IF Power" Stable Image. Specific reference is made to 6.1.3.
2. Go to the Measurement Setup > Demodulation menu and enter the corresponding "preamble length parameter, exactly as the actual preamble setting at DUT. Refer to 6.2.3.
3. Look at the “Demodulated Indicators” column in the “Measurement Results Panel”.



4. Test results and analysis

- **Burst Length:** Displays the total duration of the entire burst in the air.
- **Preamble Length:** The duration of the preamble **is** derived based on the parameters set.
- **Payload Length:** The instrument is calculated from the "Burst **Length** - Preamble **Length**".
  - Troubleshooting Tip: If a negative number or "---" is displayed here, the Preamble length set in the menu is incorrect (greater than the actual burst length) and the modification needs to be checked again.

7. LoRa frequency drift analysis

1. Test purpose

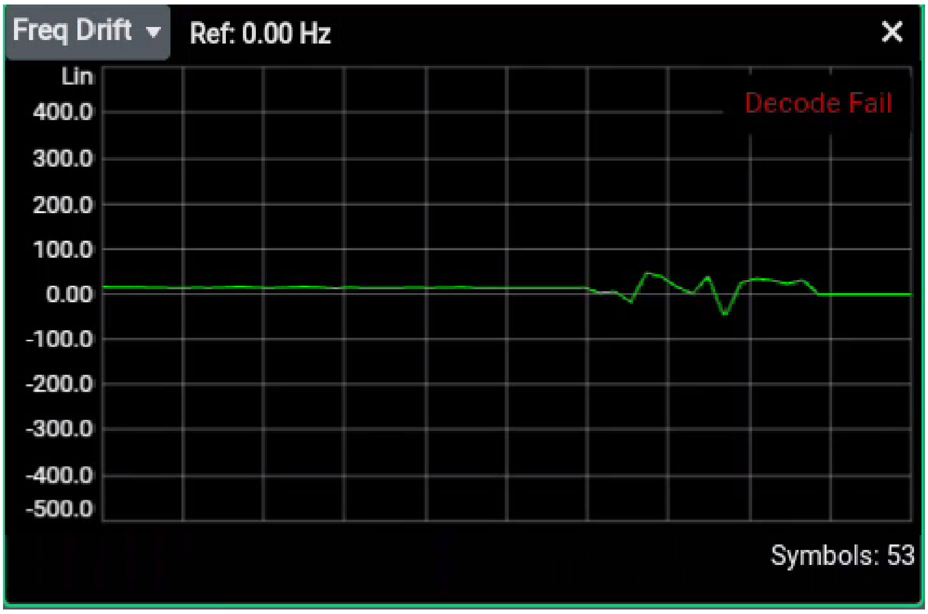
Track the stability changes of the carrier frequency over time (symbol) during long bursts of transmission of the LoRa transmitter and assess the effect of power fluctuations or temperature rises on the local oscillation.

2. Test the connection diagram

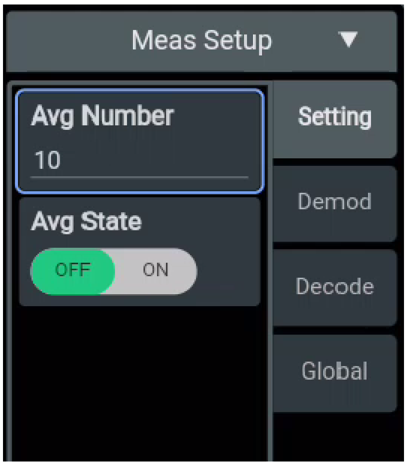
Refer to 5.1Test the connection diagram.

3. Test procedure

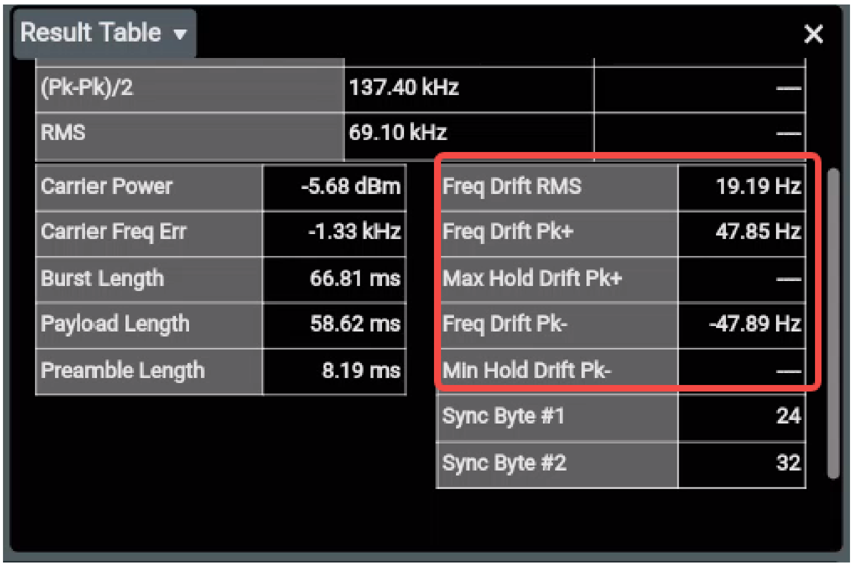
1. Activate and maximize the "Frequency Drift" window.



2. To evaluate the stability boundary over a long period of time, turn on the "Average Status" in Measurement Settings > Settings.



3. This is done in conjunction with the "Frequency Drift" indicator in the "Measurement Results Panel".



Result Table

(Pk-Pk)/2	137.40 kHz		—
RMS	69.10 kHz		—

Carrier Power	-5.68 dBm
Carrier Freq Err	-1.33 kHz
Burst Length	66.81 ms
Payload Length	58.62 ms
Preamble Length	8.19 ms

Freq Drift RMS	19.19 Hz
Freq Drift Pk+	47.85 Hz
Max Hold Drift Pk+	—
Freq Drift Pk-	-47.89 Hz
Min Hold Drift Pk-	—
Sync Byte #1	24
Sync Byte #2	32

4. Test results and analysis

- **Graphical Analysis:** The horizontal axis of the Frequency Drift window is the symbol sequence number starting with the first preamble, and the vertical axis is the offset (Hz) of each symbol relative to the center frequency. Ideally, the curve should converge to a horizontal line.
- **Quantitative:** The "Frequency Drift RMS" gives the mean square offset level for the entire trace; with the averaging function on, the "Max/Min Hold Drift Pk+/-" captures the limit frequency drift value under severe conditions.

7. Summary

1. Summary of LoRa analysis software functionality

The LoRa measurement application of the RIGOL RSA6000 series of real-time spectrum analyzers provides engineers with a one-stop solution for CSS modulated signal analysis. The software has the following core features:

- **Panoramic view representation:** Supports multi-view co-operation of RF spectrum, demodulated waveform (time-frequency linearity), frequency drift, etc., to visualize abstract Chirp spread spectrum signals.
- **Deep demodulation and decoding:** Not only accurately measure underlying RF metrics such as Deviation, carrier power, and time length, but also de-chirp data streams, correct errors, and verify CRC status with one click.
- **Highly automated integration:** No tedious manual calculations, intuitive parameter setting and ease of use greatly reduce the barriers to analytics at the bottom of IoT long-range wireless communications.

2. LoRa Typical Application Value Summary

LoRa is an important physical layer technology for low-power, wide-area IoT applications, requiring high transmit frequency accuracy, spectrum characteristics, demodulation stability, and protocol decode consistency. The RSA6000 LoRa analysis software helps users quickly accomplish the following tasks with integrated measurement and decoding capabilities:

- Quickly capture and identify target LoRa signals
- Verify the transmit consistency in different SF, BW, CR parameter configurations
- Evaluate key metrics such as carrier power, frequency error, and frequency drift
- Verify that the link parameters are configured correctly with CRC status, header resolution, and payload length identification
- Shorten the R&D commissioning, troubleshooting, and batch testing work cycle

For R&D, test, and production testers, the software enables the analysis of key indicators of LoRa transmit signals on a single platform, reducing test complexity. Improve test efficiency and consistency of results.

3. Links to related products and resources

To get the latest firmware updates, complete user manuals or for professional technical support, please visit the official RIGOL channel:

- **Official website:** www.rigol.com
- **RSA6000 Product Page:** Search the "RSA6000" product flyer, data sheet, and list of the latest options.
- **Technical Support & Service:** If you have any questions regarding instrument usage or the automated test code (SCPI) writing process, please contact your local RIGOL sales engineer or call the official technical support line.

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