eRIC-LR2021 Application Note ANLR2021_1

Transmission and Regulatory Design Guide

Scope

This application note provides practical design guidance for OEM engineers integrating the eRIC-LR2021 module into products that must operate within regional transmission restrictions and be prepared for pre-compliance or certification testing. The guide is aimed at both the eRIC-LR2021-HCI variant, where the host MCU controls the LR2021 directly over SPI, and the eRIC-LR2021-S variant, where an onboard ARM MCU presents a UART interface and LPRS firmware manages the radio functions.

The eRIC-LR2021 module is built around Semtech's LR2021 multi-band transceiver and supports sub-GHz operation in 433 MHz, 470 MHz, 490 MHz, 868 MHz and 915 MHz bands together with high-band operation from 1.5 GHz to 2.5 GHz for LS-band NTN/SATCOM and 2.4 GHz ISM applications, subject to firmware, regional spectrum access and product implementation. The module datasheet also states that the key transmission constraints to consider are operating band, effective radiated power, channel access or duty-cycle behaviour, and maximum occupied bandwidth.

Important note

This application note is a technical design aid, not a substitute for formal regulatory review. Regional rules vary by band, country, channel plan, antenna type, end-product enclosure, and certification route. Final compliance remains the responsibility of the end-product manufacturer.

Module context

The eRIC-LR2021 family is offered in HCI and standalone UART forms. The HCI versions expose the LR2021 host interface directly, including BUSY, SPI clock, MISO, MOSI and NSS, while the standalone S versions add an ARM microcontroller and UART control path with optional handshaking. The module

provides two RF ports: a low-frequency path on pad 22 for 433/470/490/868/915 MHz operation and a high-frequency path on pad 24 for 1.5 GHz to 2.5 GHz operation, both intended for 50 ohm antenna systems.

For transmission planning, three module-level figures are especially important. First, the module can support up to 22 dBm output on the sub-GHz path and 12 dBm on the high-frequency path. Second, the module is intended for low-power products and lists receive current of 5.7 mA for sub-GHz receive and low sleep current of 470 nA. Third, the module datasheet states a receive sensitivity down to -141.5 dBm under LoRa SF12 and 125 kHz conditions, which is the basis for long-range low-throughput operating modes.

Regulatory model

The eRIC-LR2021 datasheet reduces practical regulatory design work into four questions: which frequency band is being used, how much output power is being radiated, how often and how long the device transmits, and how much spectral bandwidth the transmission occupies. That framing is useful because those same four variables map directly to the LR2021 configuration commands that an HCI host or LPRS firmware must control.

In practical OEM work, compliance usually comes down to turning regional legal limits into concrete RF settings. Conducted power at the module output is only one part of the answer, because EIRP also depends on matching losses, coax losses if used, and antenna gain. Occupied bandwidth depends on modulation family and modem settings. Airtime depends on payload size, modulation parameters and retry behaviour. Channel access behaviour depends on whether the product is using fixed duty-cycle operation, a network protocol such as LoRaWAN, or a listen-before-talk approach using CAD or RSSI-based clear channel assessment.

From legal limits to RF settings

The safest implementation path is to derive every transmission profile from a small configuration record. Each record should define at least: region, RF path, center frequency or channel, antenna part number, cable loss, antenna gain, target conducted power, target EIRP, modulation family, modem parameters, worst-case packet length, expected transmit interval, and whether LBT, CAD, or duty-cycle restrictions apply. This configuration record then becomes the single source for both firmware setup and compliance calculations.

A useful engineering rule is:

$$EIRP \approx P_{conducted} - L_{feed} + G_{antenna}$$

where conducted power is the power at the module RF port, feed loss is the loss between module and antenna, and antenna gain is the antenna gain referenced in the applicable approval method. This formula is generic RF engineering guidance; the end-product test method and local rules still govern the formal compliance result.

Practical region mapping

The table below gives a design-oriented mapping from common deployment regions to the settings that typically matter most during first implementation. It is intentionally conservative and should be verified against the final regulatory target standard for the shipping product.

Region / use case	Likely RF path	Typical concerns	Recommended starting point
EU 868 SRD	LF path	EIRP cap, duty cycle or LBT, occupied bandwidth	LoRa 125 kHz for long range; moderate conducted power; tightly controlled airtime budget.
US 915 ISM	LF path	Channelization, dwell / hopping strategy depending on protocol, antenna certification	LoRaWAN regional profile or planned private channel map with PALF settings matched to target output power.
433 MHz SRD	LF path	Narrowband channel planning, local power and duty-cycle limits	Prefer lower-rate modes and conservative power until local limits are formally reviewed.
2.4 GHz private link	HF path	Occupied bandwidth, coexistence, antenna pattern, PA limit 12 dBm	FLRC or LoRa 2.4 GHz based on throughput/range trade-off; verify HF PA settings and antenna losses.
1.5–2.5 GHz NTN / SATCOM related	HF path	Service availability, firmware support, network approval model	Treat as application-specific and operator-dependent; verify approved frequencies and service constraints before deployment.

Selecting the RF path and PA

The LR2021 provides separate receive and transmit resources for low-frequency and high-frequency operation. The host selects the transmit frequency with `SetRfFrequency`, selects the receive path with `SetRxPath`, and selects/configures the transmit PA using `SetPaConfig`, `SelPa`, and `SetTxParams`. In the eRIC-LR2021 module, the LF antenna path is exposed on pad 22 and the HF antenna path is exposed on pad 24, so the PCB and antenna system must match the selected RF path.

For sub-GHz operation, the low-frequency PA can deliver up to 22 dBm, but the exact delivered power depends on both `SetTxParams` and the `SetPaConfig` PALF duty-cycle and slice settings. Semtech explicitly warns that non-optimized PA parameters can cause incorrect output power, excessive current, PA damage, or regulatory non-compliance. For 2.4 GHz and adjacent high-band operation, the HF PA supports up to 12 dBm, and only duty-cycle values 16 to 31 are allowed for PAHF to avoid premature ageing.

Recommended PA setup flow

For HCI implementations, the recommended order is:

1. Put the device in a valid configuration state such as Standby RC or Standby XOSC.
2. Set the packet type first using `SetPacketType`.
3. Set the RF frequency using `SetRfFrequency`.
4. Configure the required receive path using `SetRxPath` if receive will follow.
5. Configure the PA with `SetPaConfig`.
6. Apply output power and ramp time using `SetTxParams`.
7. Only then arm transmission with `SetTx` or a test mode command.

That ordering matters because Semtech states that `SetPacketType` must be the first command sent when setting up transceiver operation, and `SetTxParams` depends on the earlier PA configuration.

Example PA starting points

The LR2021 datasheet provides optimized reference settings for common target output powers. These values are especially useful when bringing up the eRIC-LR2021-HCI variant because they reduce guesswork and help anchor pre-compliance measurements to known-good PA combinations.

Band / target	`SetTxParams` target	Supporting PA settings
915 MHz at 22 dBm	22 dBm	PALF duty cycle 7, PALF slices 6 on Semtech reference design.
915 MHz at 14 dBm	14 dBm	PALF duty cycle 4, PALF slices 2 on Semtech reference design.
2.445 GHz at 12 dBm	12 dBm	PAHF duty cycle 16 on Semtech reference design.

2.445 GHz at 8 dBm	10.5 dBm TxParam target shown with PAHF duty cycle 31 for an 8 dBm targeted power row on Semtech reference design.

These should be treated as starting points, not guaranteed end-product settings, because enclosure effects, antenna mismatch, and layout differences change the radiated result.

Occupied bandwidth and modulation choice

The module datasheet lists over-air rates up to 125 kbps for LoRa and up to 2.6 Mbps for FLRC. That wide span means the same module can be used either for maximum range and sensitivity or for much shorter, wider-band bursts intended to minimize airtime.

LoRa bandwidth, spreading factor and coding rate drive both range and airtime. Semtech defines the LoRa symbol rate as bandwidth divided by 2^{SF}, so reducing bandwidth or increasing spreading factor improves sensitivity but lengthens time-on-air. The LR2021 datasheet explicitly notes that occupied bandwidth is subject to regulatory constraints, so not every programmable modem bandwidth is appropriate in every region.

Practical modem selection

- Use **LoRa 125 kHz** when the application needs link budget and can tolerate longer packets and lower network capacity.
- Use **LoRa with wider bandwidths** when shorter airtime matters more than absolute sensitivity and the regional rules allow the occupied bandwidth.
- Use **FLRC** when private high-throughput short-burst links are needed and the band plan supports wider occupied bandwidth, noting that FLRC supports raw bit rates from 260 kbps to 2.6 Mbps depending on the selected mode.
- Use **FSK / GFSK** where protocol compatibility or narrower occupied bandwidth is more important than maximum link budget.

Airtime and duty-cycle planning

In regions that impose duty-cycle constraints, the real design variable is not only transmit interval but worst-case packet airtime. A product that transmits small packets frequently may exceed legal limits more easily than a product that transmits larger packets infrequently, depending on the chosen spreading

factor and retry policy. The eRIC-LR2021 datasheet therefore correctly treats duty-cycle as a core transmission restriction.

A robust design process is to budget airtime in firmware rather than relying on test-time estimates. For each uplink type, calculate the worst-case time-on-air, multiply by the maximum number of transmissions per regulatory observation window, and compare against the allowed duty-cycle or dwell rule. The firmware should then refuse transmissions that would exceed the configured airtime budget for the region.

Implementation recommendation

Maintain a region profile table in firmware containing at least:

- Maximum permitted conducted power for the approved antenna assembly.
- Maximum allowed airtime per hour or per sub-band where applicable.
- Maximum configured bandwidth.
- Allowed channels or hop table.
- Whether channel access must rely on LBT/CAD/CCA.
- Whether a certification test mode lockout is required in field firmware.

This is relevant to both variants: in HCI products the host MCU owns the policy, while in S products the onboard stack or wrapper command layer should enforce it.

Listen-before-talk and channel sensing

The LR2021 offers several mechanisms that can support channel access strategies. For LoRa-specific sensing, it provides Channel Activity Detection, including multi-SF CAD and Fast CAD. For more general RF occupancy checks, it offers clear channel assessment result reporting through `GetCcaResult`, which returns minimum, maximum and average RSSI observed during the previous CCA procedure.

Fast CAD is especially useful for products that must perform frequent channel checks. Semtech states that compared with traditional fixed-threshold CAD, LR2021 Fast CAD can reduce average CAD duration from 5 symbols to approximately 1.5 symbols when the channel is idle, translating to around 70% lower power consumption for LBT and CSMA-style use cases. That makes Fast CAD a particularly attractive feature for battery-powered EU-band private networks that need polite spectrum access.

CAD design guidance

For LoRa private links:

- Use CAD when the main concern is detecting LoRa activity below the noise floor, because RSSI alone is not reliable for spread-spectrum occupancy checks.
- Use multi-SF CAD if the receiver must accept several spreading factors on the same channel, with the highest expected SF configured as the main detector.
- For low-power LBT implementations, consider Fast CAD via the `pnrdelta` mechanism in `SetLoraCadParams`, but validate detection performance in the actual interference environment.

For non-LoRa or mixed-protocol links:

- Use CCA/RSSI results as a coarse channel-busy indicator.
- Calibrate application thresholds experimentally because enclosure noise and nearby digital systems often dominate low-level measurements.

Receive path, image calibration and sensitivity

The LR2021 host must select the correct receive path using `SetRxPath`, including whether boost mode is required. Semtech recommends default rxboost values of 0 for LF and 4 for HF. The command also notes that if image rejection was not calibrated for the current RF frequency, the device can still go to Rx but generates an `RxFreqNoCalErr` error.

This matters for regulatory work because poor image calibration or incorrect path selection can make sensitivity measurements, blocking tests or adjacent-channel tests look much worse than they should. The base datasheet figures, including -141.5 dBm module sensitivity and general receiver bandwidth capability from 3.5 kHz to 3076 kHz in the LR2021, assume correct configuration and a valid RF design.

Antenna system and EIRP control

The eRIC-LR2021 datasheet recommends 50 ohm antenna systems and notes that a quarter-wave 868 MHz monopole is approximately 8.6 cm long. It also notes that a 50 ohm transmission line can be implemented on FR4 as a 3 mm track over ground plane and should be kept as short as possible, and that the module may be fitted with u.FL RF connectors wired in parallel with the RF pads depending on variant.

From a compliance standpoint, antenna choice is as important as PA settings. A modest increase in antenna gain can push an otherwise compliant product over an EIRP limit, while a poor antenna or

mismatched ground reference can degrade efficiency enough that developers respond by raising conducted power and current unnecessarily. The module datasheet also explicitly notes that to meet US FCC requirements the modules must be used with the specified antennas used for testing, with the approved antenna list still marked TBA.

Practical antenna rules

- Lock the antenna part number before pre-compliance RF testing.
- Keep separate approval records for pad-fed and u.FL-fed variants if feed loss or enclosure routing differs materially.
- Treat any enclosure, cable, bracket or nearby metal change as an RF change requiring re-check of conducted and radiated results.
- Maintain a simple EIRP worksheet for every SKU.

Certification-oriented test modes

One of the most useful features of the LR2021 for certification preparation is its direct support for RF test signalling. Semtech's datasheet section on regulatory test signals states that ETSI EN 300 220 testing maps neatly to LR2021 operating modes: D-M1 is an unmodulated carrier using `SetTxCw`, D-M2 is a continuously modulated wideband signal using `SetTxInfinitePreamble`, D-M2a is a non-continuous modulated test using packet transmission such as LoRa SF12 BW500 at 50% duty cycle, and D-M3 is normal application operation. For FCC Part 15.247 style testing, Semtech notes that only an unmodulated carrier and a regular packet transmission are required, with frequency, output power and modulation parameters controlled by the normal radio commands.

This is exactly the type of capability an OEM needs before going to the test lab. It allows the same hardware to produce continuous-wave, continuous modulation and normal application packets without special hardware changes.

Recommended lab-support functions

Whether the product uses HCI or S firmware, provide a protected engineering mode that can:

- Set RF path and frequency.
- Select modulation family.
- Set PA configuration and output power.

- Enter continuous wave mode.
- Enter infinite preamble or continuous modulated mode.
- Send repeated test packets with fixed payload.
- Report packet error rate in receive test setups.
- Lock out these functions in production or require authenticated access.

HCI test sequences

For the eRIC-LR2021-HCI variant, a typical certification-oriented CW transmit setup is:

1. Hardware reset and wait for BUSY to clear after boot calibration.
2. `SetStandby` to Standby RC or Standby XOSC.
3. `SetPacketType` to the intended modulation context if needed.
4. `SetRfFrequency` to the target test channel.
5. `SetPaConfig` for LF or HF PA as appropriate.
6. `SetTxParams` to the desired conducted power and ramp time.
7. Issue `SetTxCw` or `SetTxTestMode` / continuous transmit command according to the chosen modem family and test plan.

For an occupied-bandwidth or maximum-bandwidth test, replace CW with `SetTxInfinitePreamble` or a continuous packet mode using the widest allowed bandwidth and modulation parameters for the specific regulatory objective.

Production firmware safeguards

Because the LR2021 can generate continuous RF test signals, production firmware should not expose unrestricted test commands to end users. In fielded devices, these commands should either be compiled out, protected behind signed service firmware, or enabled only through a secure bootloader or factory cable path. This is not stated explicitly in the datasheets, but it follows directly from the presence of continuous RF test modes and the end-product manufacturer’s compliance responsibility.

Standalone S variant considerations

The standalone eRIC-LR2021-S variant combines the LR2021 with an ARM MCU and presents a UART interface running at 19,200 baud with optional handshake lines. The datasheet states that commands supporting both LoRaWAN and point-to-point connectivity are to be available from May 2026, so application-note guidance for the S version should be framed around expected control capabilities, not undocumented command syntax.

For the S variant, the most helpful architecture is a high-level command set that exposes regulatory intent rather than raw LR2021 registers. For example, instead of asking the host to set arbitrary PA and modem values, define commands such as `SET_REGION`, `SET_CHANNEL`, `SET_TX_PROFILE`, `START_CW_TEST`, `START_MOD_TEST`, `SEND_TEST_PACKET`, and `GET_RF_STATUS`. The internal firmware can then translate those requests into the correct LR2021 sequences and refuse unsafe or non-compliant combinations.

Timing, BUSY handling and deterministic operation

The LR2021 uses a BUSY line to indicate when the chip cannot accept new commands. The datasheet defines mode-switching timing in detail, including approximately 115 microseconds for Standby RC to Rx, about 106 microseconds for Standby RC to Tx, and about 76 microseconds for Standby XOSC to Tx under the stated conditions. The reset sequence also requires NRESET low for at least 100 microseconds, after which the device boots, calibrates, enters Standby RC, and only then accepts SPI commands.

This is important in both application firmware and lab tools. If BUSY is ignored, the host may intermittently misconfigure PA or packet parameters, leading to non-repeatable test behaviour. For the HCI variant, pad 1 is the LR2021 BUSY signal, so it should always be routed to the host MCU and treated as mandatory rather than optional.

Timestamping and measurement support

The LR2021 includes useful timing features for advanced validation. `SetTimestampSource` can assign timestamp sources such as last bit sent, last bit received, FSK sync detected or LoRa header detected, and `GetTimestampValue` returns the delay in 32 MHz clock ticks between the event and the SPI read request. These capabilities are useful when correlating RF events with MCU GPIO captures, gateway timing, or application-layer latency measurements.

For protocol and compliance debugging, map relevant IRQs to DIO lines using `SetDioIrqConfig` and log timestamped events alongside transmitted and received packets. The host interrupt set includes `PreambleDetected`, `SyncwordValid`/`LoRaHeaderValid`, `CadDetected`, `CadDone`, `RxDone`, `TxDone`, `Timeout`, `CrcError`, `LenError`, `LowBattery`, `CmdError` and `Error` among others.

Example engineering profiles

Profile A: EU 868 battery sensor

A conservative starting profile for an EU 868 battery sensor is LoRa on the LF path, 125 kHz bandwidth, moderate output power, and strict airtime budgeting. This leverages the module's strongest link budget region, including the stated -141.5 dBm sensitivity at SF12/125 kHz, while keeping the occupied bandwidth modest. If the application must perform polite channel access, use CAD or Fast CAD before transmit and enforce a firmware airtime accumulator per sub-band.

Profile B: US 915 private link

For a private US 915 point-to-point link, use the LF path with a defined channel map and one of the Semtech reference PA combinations, for example the 14 dBm or 22 dBm starting points from the PALF table depending on the required range and approved antenna assembly. If the application uses hopping or a protocol with repeated bursts, ensure the final behaviour is reviewed against the applicable FCC path for the shipped product.

Profile C: 2.4 GHz short burst telemetry

For a short-range high-throughput telemetry link, the HF path can be paired with FLRC or LoRa 2.4 GHz. The module supports up to 12 dBm on the HF PA, while FLRC can reach up to 2.6 Mbps raw rate depending on modem selection. This can dramatically reduce airtime, but occupied bandwidth and antenna performance become the dominant compliance and coexistence concerns.

Pre-compliance checklist

Before booking a formal test lab, confirm the following on the final hardware revision:

- Correct RF path is selected for each operating band.
- PA configuration matches the chosen band and target power.
- Measured conducted power agrees with the intended EIRP budget using the approved antenna assembly.
- All high-power test modes are accessible only through controlled engineering access.
- Worst-case airtime has been computed for every shipped profile.
- Occupied bandwidth has been checked on a spectrum analyser for each main transmit mode.

- CAD, CCA, retry logic and fallback modes have been validated under interference.
- BUSY handling has been verified under rapid command sequences.
- Firmware logs and versioning identify the exact RF profile under test.

What should be added next

Two follow-on documents would make this application note even stronger. First, an internal regional rule matrix covering each intended shipping geography, antenna option and product SKU would turn this generic guide into a release checklist. Second, a lab companion note with exact HCI byte sequences and S-variant service commands for CW, infinite preamble, packet PER, and receive sensitivity testing would reduce bring-up time for both customers and test houses.

Closing guidance

The eRIC-LR2021 is unusually flexible because it combines a wide frequency span, dual RF paths, high link budget LoRa modes, higher-speed FLRC modes, low-power receive and sleep behaviour, and explicit certification-oriented test signalling in one module platform. That flexibility is a major advantage, but it also means compliant product design depends on disciplined control of RF path selection, PA configuration, antenna choice, occupied bandwidth, and airtime policy.

For that reason, the best design approach is to treat every shipped RF mode as a controlled product feature with a fixed configuration record, measured antenna system, and locked firmware profile. Teams that do this early will move through pre-compliance, certification and customer support much faster than teams that rely on ad hoc RF settings late in development.