# Skywire Global 4G LTE Cat M1, NB-IOT, 2G w/ GNSS Embedded Cellular Modem Datasheet

**NimbeLink Corp**

**Updated: July 2021**

# Table of Contents

# 1.  Introduction

## 1.1  Scope

The aim of this document is to serve as a hardware reference datasheet for the NL-SW-LTE-QBG95-B and NL-SW-LTE-QBG95 Skywire® modem family.

## 1.2  Contact Information

NimbeLink's goal is to make integrating the Skywire modem into your product as easy as possible. Please send any feedback, documentation requests, or technical support questions to Nimbelink's product support team at: product.support@nimbelink.com

For purchasing information, please visit the "Part Ordering Information" section on the modem's product page. Any additional sales questions or requests for quotation can be directed to NimbeLink's sales team at: sales@nimbelink.com

## 1.3  Orderable Part Numbers

| Orderable Device | Firmware Version | 4G LTE Bands | 2G Bands | Cellular Networks |
|---|---|---|---|---|
| NL-SW-LTE-QBG95 | BG95M3LAR02A03_ 01.004.01.004 | **CAT M1 (LTE-FDD):** B1, B2, B3, B4, B5, B8, B12, B13, B14, B18, B19, B20, B25, B26, B27, B28, B66, B85 <br><br> **CAT-NB2 (LTE-FDD):** B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B28, B66, B71, B85 | **EGPRS:** GSM 850, GSM 900, DCS 1800, PCS 1900 | AT&T, Orange, Telstra, Telus, Verizon, Vodafone, And more |
| NL-SW-LTE-QBG95-B | BG95M3LAR02A03_ 01.009.01.009 | | | |

## 1.4  Additional Resources

- Skywire® Global 4G LTE Cat M1 Embedded Modem Product Page
- Skywire® Global 4G LTE Cat M1 AT Command Manual
- Skywire® Global 4G LTE Cat M1 Application Notes
- Skywire NL-SWDK User Manual
- Skywire Hardware Design Developers Guide
- Skywire Hardware Design Checklist
- Skywire Software Developers Guide

## 1.5  Product Overview

The NL-SW-LTE-QBG95 Skywire embedded modem is purpose-designed for IoT applications, particularly those requiring location-based functionality. Based on the Quectel BG95-M3 module, it has full FCC, IC, and carrier end-device certifications, which can save users months of testing and tens of thousands of dollars in cost. Like all Skywire modems, the QBG95 is among the smallest embedded modems in the industry, and is compatible with a wide range of Skywire development kits and microprocessor shields, helping to accelerate product development and prototyping.

LTE Cat M1 modems have the lowest power requirements of any cellular modem type, making them ideal for battery operated, mobile, or off-grid applications. Depending on the application, they may be able to run for years unattended and without requiring a battery replacement or recharge.

## 1.6  Block Diagram
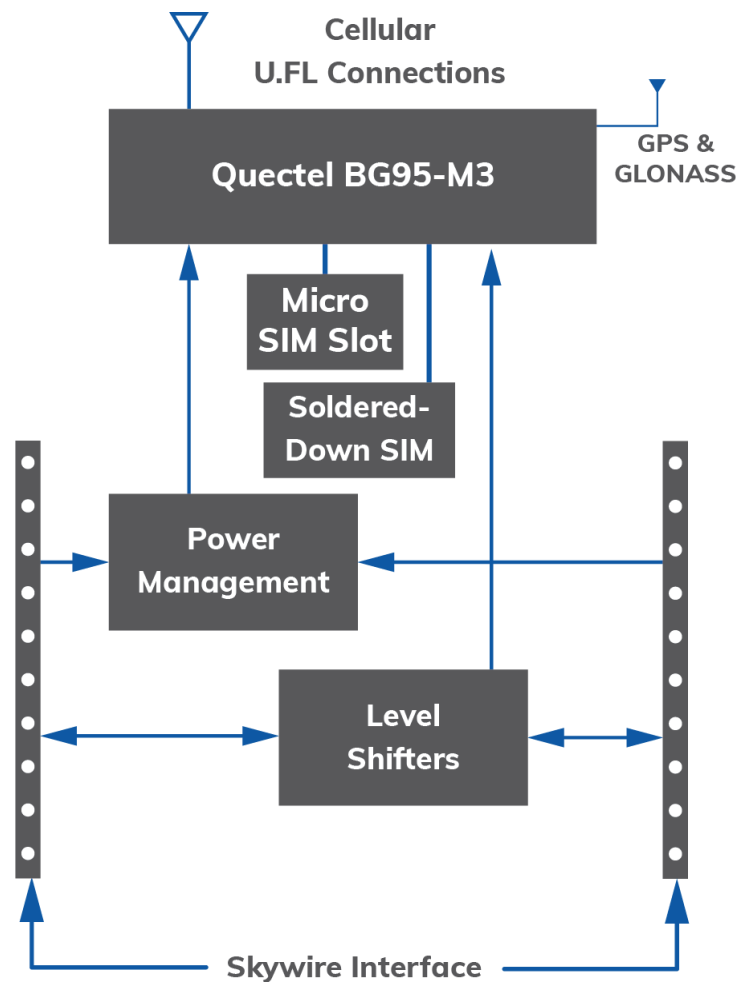
# 2. Technical Specifications

## 2.1 Electrical Specifications

### 2.1.1 Absolute Maximum Ratings

To avoid potential damage to the modem, ensure that all voltages applied to the modem pins do not fall outside of the ranges specified by the max and min ratings:

| Parameter | Signal | Minimum Rating | Maximum Rating |
|---|---|---|---|
| Main Power Supply | VCC | -0.3V | 6.0V |
| I/O Voltage Reference | VREF | -0.3V | 6.5V |
| USB Supply Voltage | VUSB | -0.3V | 5.5V |
| Digital I/O Pins | STATUS_1V8, GNSS_UART_TX, GNSS_UART_RX | -0.3V | 2.09V |

### 2.1.2 Modem Pinout (J1, J2) and Recommended Operating Conditions

The following table details the pinout of the NL-SW-LTE-QBG95 Skywire modem, and recommended ratings for the Skywire interface on connectors J1 and J2.

| Pin | Name | Type | Description | Min | Typ. | Max |
|---|---|---|---|---|---|---|
| 1 (J1-1) | VCC | Input | Main power supply input. Must be implemented | 3.4V | 3.8V | 4.3V |
| 2 (J1-2) | DOUT | Output | UART data out, I/O level tied to VREF. Must be implemented if USB is unused. Otherwise, leave unconnected if unused. | 0V | | VREF |
| 3 (J1-3) | DIN | Input | UART data in, I/O level tied to VREF. Must be implemented if USB is unused. Tie to GND with a 1k resistor if unused. | | | |

For DIN (Pin 3):

| VREF Range | VIL | | VIH |
|---|---|---|---|
| 1.65V to 1.95V | VREF x 0.35V | | VREF x 0.65 |
| 2.3V to 2.7V | 0.7V | | 1.7V |
| 3.0V to 3.6V | 0.8V | | 2V |
| 4.5V to 5.5V | VREF x 0.3V | | VREF x 0.7 |

| Pin | Name | Type | Description | Min | Typ. | Max |
|---|---|---|---|---|---|---|
| 4 (J1-4) | GND | Input | Ground Pin. Must be implemented. | | 0V | |
| 5 (J1-5) | nRESET | Input | Modem reset signal. Must be driven with an open-drain output and should never be driven high. Leave unconnected if unused. | VIL: GND to 0.45V | | |
| 6 (J1-6) | VUSB | Input | USB connection detection. Leave unconnected if the USB interface is unused. | 3.0V | 5.0V | 5.25V |
| 7 (J1-7) | USB_P | I/O | USB positive differential data signal. Requires differential impedance of 90Ω. Leave unconnected if the USB interface is unused. | Compliant with USB 2.0 standard specification. | | |
| 8 (J1-8) | USB_N | I/O | USB differential data bus (-) Requires differential impedance of 90Ω. Leave unconnected if the USB interface is unused. | Compliant with USB 2.0 standard specification. | | |
| 9 (J1-9) | DTR | Input | Data terminal ready signal (sleep mode control), tied to internal reference voltage of 1.8V. Should be tied to GND with 1k pull down resistor. | VIL: GND to 0.54V | | VIH: 1.26V to 5.5V |
| 10 (J1-10) | GND | Input | Ground Pin. Must be implemented. | | 0V | |
| 11 (J2-1) | GND | Input | Ground Pin. Must be implemented. | | 0V | |
| 12 (J2-2) | CTS | Output | Clear To Send hardware flow control signal. Leave unconnected if unused. | 0V | | VREF |
| 13 (J2-3) | STATUS | Output | Indicates the current operation status of the BG95-M3 module. Driven high when the module is on. Leave unconnected if unused. | VOL: 0V to 0.45V | | VOH: 1.35V to 1.8V |

| Pin | Name | Type | Description | Min | Typ. | Max |
|---|---|---|---|---|---|---|
| 14 (J2-4) | VREF | Input | Voltage reference for offboard I/O signals. Must be implemented. | 0V | 1.8V or 3.3V | 5.5V |
| 15 (J2-5) | GND | Input | Ground Pin. Must be implemented. | | 0V | |

| Pin | Name | Type | Description | | | |
|---|---|---|---|---|---|---|
| 16 (J2-6) | RTS | Input | Modem "Request to Send" hardware flow control input. Tie to ground with a 1k ohm resistor if not used. | **VREF Range** | **VIL** | **VIH** |
| | | | | 1.65V to 1.95V | VREF x 0.35V | VREF x 0.65 |
| | | | | 2.3V to 2.7V | 0.7V | 1.7V |
| | | | | 3.0V to 3.6V | 0.8V | 2V |
| | | | | 4.5V to 5.5V | VREF x 0.3V | VREF x 0.7 |

| Pin | Name | Type | Description | Min | Typ. | Max |
|---|---|---|---|---|---|---|
| 17 (J2-7) | GNSS_UART_RXD | Input | GPS UART RXD signal. Fixed 1.8V reference. Leave unconnected if unused. | VIL: -0.3V to 0.6V | | VIH: 1.2V to 2.0V |
| 18 (J2-8) | GNSS_UART_TXD | Output | GPS UART TXD signal. Used to receive GPS data from the modem. Fixed 1.8V reference. **Do not pull-up or drive this pin high during boot.** Leave unconnected if unused. | VOL: 0V to 0.45V | | VOH: 1.35V to 1.8V |
| 19 (J2-9) | RING | Output | Ring Indicator Output. Normally high, 120ms low pulse when URC present. Open Drain output, 1M pull-up to VREF on modem. | VOL 0 to 0.1V | | VREF |
| 20 (J2-10) | ON_OFF | Input | Modem ON/OFF signal. Must be driven with an open-drain output and should never be driven high. Must be implemented. | VIL: GND to 0.45V | | 1.5V |

### 2.1.3  Module Pinout for Connectors J3, X1, X3

| Designator | Description | Connector Location |
|---|---|---|
| J3 | Micro SIM Connector | Bottom Side of Modem |
| X1 | Cellular Antenna Connection | Top Side of Modem |
| X3 | GPS/GNSS Satellite Receiver | Top Side of Modem |

## 2.1.4  Typical Power Consumption

The values contained in Section 2.1 .4 are provided as an example of typical current consumption behavior for NL-SW-LTE-QBG95 Skywires.

In customer applications, current consumption may vary, and is influenced by factors such as: signal quality, ambient temperature, battery/supply voltage, supply impedance, board capacity, and other factors.

| Test | RSRP (dBm) | RSRQ (dB) | Average Current (mA) | Average Peak Current (mA) | Average Charge (µAh) | Measurement Notes |
|------|-----------|-----------|---------------------|---------------------------|----------------------|-------------------|
| Socket Dial on LTE-M Network, 0 dB of Attenuation | -48 | -11 | 90.808 | 774.582 | 44.096 | **Supply Voltage:** 3.8V <br> **Number of Tests:** 5 <br> **Average Duration:** 1.709 s <br> **Notes:** Modem registered on the network prior to the test. Test consists of opening socket, HTTP POST, reading HTTP response, and closing socket. |
| Socket Dial on LTE-M Network, 20 dB of Attenuation | -71 | -13 | 92.761 | 905.747 | 46.015 | **Supply Voltage:** 3.8V <br> **Number of Tests:** 5 <br> **Average Duration:** 1.747 s <br> **Notes:** Same as previous test. |
| Socket Dial on LTE-M Network, 40 dB of Attenuation | -88 | -12 | 97.053 | 934.508 | 47.367 | **Supply Voltage:** 3.8V <br> **Number of Tests:** 5 <br> **Average Duration:** 1.757 s <br> **Notes:** Same as previous test. |
| Modem Boot | N/A | N/A | 60.360 | 117.695 | 46.520 | **Supply Voltage:** 3.8V <br> **Number of Tests:** 5 <br> **Average Duration:** 2.766 s <br> **Notes:** <br> Modem booted from powered-off state. Test concluded when "RDY" URC was received from modem. |
| Registered Idle | -40 | -17 | 23.830 | 827.983 | 1.992 (mAh) | **Supply Voltage:** 3.8V <br> **Number of Tests:** 1 <br> **Duration:** 300 s <br> **Notes:** Modem was booted and allowed to register on the network. 300 second measurement was taken while the modem was idling. |

| Test | RSRQ (dBm) | RSRP (dBm) | Average Current (mA) | Average Peak Current (mA) | Average Charge (µAh) | Measurement Notes |
|---|---|---|---|---|---|---|
| Unregistered Idle | N/A | N/A | 9.592 | 73.194 | 801.154 | **Supply Voltage:** 3.8V<br>**Number of Tests:** 1<br>**Duration:** 300 s<br>**Notes:** Modem booted and placed into "CFUN: 4" mode (unregistered state). 300 second measurement was taken while modem idled. |
| PSM | | | | | | *Coming Soon* |
| eDRx | | | | | | *Coming Soon* |
| Powered Off | N/A | N/A | 8.217 (uA) | 217.315 (uA) | 683.376 (nAh) | **Supply Voltage:** 3.8V<br>**Number of Tests:** 1<br>**Duration:** 300 s<br>**Notes:** Modem powered off using the "AT+QPOWD" command. 300 second measurement was taken while the modem was in a powered-down state. |
| GPS Cold Start | N/A | N/A | 76.954 | 700.975 | 813.136 | **Supply Voltage:** 3.8V<br>**Number of Tests:** 5<br>**Average TTFF:** 37.966 s<br>**Notes:** Modem booted, and idle in an unregistered state. Measurement was started, then GPS was enabled. Measurement concluded when modem obtained a fix. |
| GPS Hot Start | N/A | N/A | 77.817 | 122.300 | 1.622 | **Supply Voltage:** 3.8V<br>**Number of Tests:** 5<br>**Average Duration:** 0.094 s<br>**Notes:** Modem booted, and idle in an unregistered state. GPS enabled and allowed to obtain location fix. Measurement started, then the location was queried with the "AT+QGPSLOC?" command. Measurement concluded when the modem responded with GPS data. |

**2.1.5**

## 2.1.6 RF Specifications

| Parameter | Value | | |
|---|---|---|---|
| 4G LTE Technology | 4G Cat M1, 4G Cat NB2 | | |
| 4G LTE TX output power | 20dBm ± 2dB | | |
| 4G LTE RX Sensitivity | Band (LTE-FDD) | Cat M1/3GPP (dBm) | Cat NB2/3GPP (dBm) |
| | B1 | -104.6/-102.3 | -115/-107.5 |
| | B2 | -104.8/-100.3 | -115/-107.5 |
| | B3 | -103.9/-99.3 | -115/-107.5 |
| | B4 | -104.3/-102.3 | -115/-107.5 |
| | B5 | -104.4/-100.8 | -115/-107.5 |
| | B8 | -104.4/-99.8 | -115/-107.5 |
| | B12 | -104.7/-99.3 | -115/-107.5 |
| | B13 | -103.8/-99.3 | -115/-107.5 |
| | B14 | -104.4/-99.3 | Not Supported |
| | B18 | -104.4/-102.3 | -115/-107.5 |
| | B19 | -104.7/-102.3 | -115/-107.5 |
| | B20 | -104.4/-99.8 | -115/-107.5 |
| | B25 | -104.7/-100.3 | -114/-107.5 |
| | B26 | -104.4/-100.3 | -114/-107.5 |
| | B27 | -104.4/-100.8 | Not Supported |
| | B28 | -104.3/-100.8 | -115/-107.5 |
| | B66 | -104.4/-101.8 | -115/-107.5 |
| | B71 | Not Supported | -115/-107.5 |
| | B85 | -104.9/-99.3 | -115/-107.5 |
| GSM RX Sensitivity | GSM850/EGSM900 | -107/-102 | |
| | DCS1800/PCS1900 | -107/-102 | |
| Peak Uplink and Downlink Speeds | Connection Type | Downlink | Uplink |
| | 4G LTE Cat M1 | 300 Kbps | 375 Kbps |
| | 4G LTE Cat NB2 | 32 Kbps | 70 Kbps |
| | EGPRS | 296 Kbps | 236.8 Kbps |

### 2.1.7 Component Parameters

| Parameter | Value |
|---|---|
| Total Capacitance | 382uF ± 20% |
| Total Inductance | 1.65uH ± 20% |

## 2.2 Mechanical Specifications

### 2.2.1 Mechanical Characteristics

| Parameter | Typical | Unit |
|---|---|---|
| Dimensions (excluding pin height, for solder to board applications) | 1.334 x 1.140 x 0.243 [33.9 x 29.0 x 6.2] | inches [mm] |
| Dimensions (including pin height, for board to board connector applications) | 1.334 x 1.140 x 0.400 [33.9 x 29.0 x 10.2] | inches [mm] |
| Weight | 0.282 [8] | ounces [grams] |
| Connector Insertion/Removal | hundreds | Cycles |

### 2.2.2 Mechanical Drawing
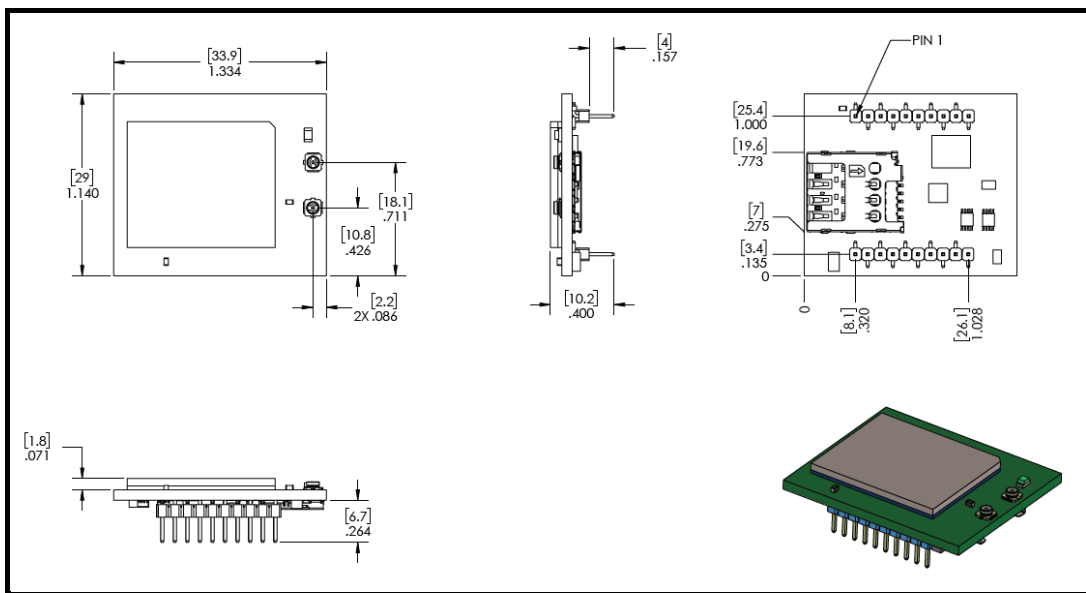


**Note:** Units are in inches and [mm].

### 2.2.3  Mating Connectors

| Connector Designator | Manufacturer | Populated on Modem | Recommended Mate | Mate Manufacturer |
|---|---|---|---|---|
| J1, J2 | Pinrex | 222-96-10GBE1 | 950510-6102-AR | 3M |
| | | | Acceptable Alternate: NPPN101BFCN-RC | Sullins Connector Solutions |
| J3 | Molex | 786463001 | Micro SIM 3FF Size | Micro SIM Card |
| X1, X3 | Hirose | U.FL-R-SMT(10) | CAB.011 | Taoglas |

### 2.2.4  Device Placement

⚠ **Make sure the Skywire is installed in the correct orientation in the host board. Failure to do so will damage the device and void the warranty.**

### 2.2.5  Environmental Specifications

| Parameter | Min | Typical | Max | Unit | Note |
|---|---|---|---|---|---|
| Operating Temperature | -40 | 25 | +85 | ˚C | |
| Storage Temperature | -40 | 25 | +90 | ˚C | |
| Operating Humidity | 20 | | 90 | % | Non-condensing |

# 3. Design Considerations

The following sections detail various design considerations that system designers should follow when designing the Skywire modem into their system. NimbeLink offers free schematic and layout design reviews for customers integrating a Skywire modem into their design. For more details please reach out to Nimbelink product support team at product.support@nimbelink.com.

## 3.1 Power Supply Requirements

NL-SW-LTE-QBG95 modems will regularly consume high amounts of current on their main power supply (Pin 1, VCC) input, up to 1.2A during LTE-M1 transmits and receives, 2G GSM connections will repeatedly hit 2A during transmissions.  In order to maintain compatibility with other 4G LTE Skywire modems, the baseboard power supply should be designed to support peak currents of at least 2 Amps. A 0.1 uF & 100uF low ESR ceramic capacitor should be placed on the baseboard near the VCC pin of the Skywire to ensure ample energy is available, with a low inductance path to the VCC pin.

| Parameter | Value |
|---|---|
| Nominal Supply Voltage | 3.8V |
| Operating Voltage Range | 3.4V to 4.3V |

NL-SW-LTE-QBG95 modems have an operating voltage range of 3.4V to 4.3V, with a recommended input voltage of 3.8V. Ensure that the voltage on the VCC pin never falls below 3.4V in order to prevent potential damage to the modem. The power supply must be able to handle the rigorous current demands of an LTE modem without falling outside of the operating voltage range.

If there is a voltage drop or overshoot that exceeds the limits of the operating voltage range, it may cause damage to the modem and void the modem's warranty.

### 3.1.1  Power Supply Design Guidelines

When designing the power supply for a Skywire modem it is recommended to adhere to the following design guidelines:

- For most applications, a switching power supply is recommended to supply power to the Skywire modem. This is because switching power supplies are able to rapidly respond to the sudden current demands of an LTE modem. To ensure compatibility with other Skywire modems, it is recommended to use a switching regulator capable of supporting up to 2A. Example designs using a switching DC/DC regulator can be found in the reference schematics below.

- To reduce EMI from the switching regulator, it is important to follow the design guidelines from the device manufacturer.

- Bypass ceramic capacitors (low ESR) with adequate capacity must be placed near the input to pin 1 (VCC) of the Skywire modem. It is recommended that the capacitor has a rated voltage of at least 2x the input voltage to the Skywire.

- A minimum of a 100 uF & 0.1uF capacitor is recommended for all Skywire modems. The 0.1uF capacitor should be placed as close as possible to pin 1 of the Skywire modem, followed by the 100 µF capacitor.

- The PCB traces from the power regulator and the bypass capacitors must be at least 80 mils to ensure that there is a low impedance power delivery circuit available to the modem. This ensures that no significant voltage drops occur. Try to keep the trace as short as possible.

- A dedicated ground plane must be used.

- The host board should have a method to power cycle the modem.

- Power supply input cables should be kept away from noise sensitive lines, such antennas.

NimbeLink offers multiple power supply reference designs in order to assist customers with their designs at no extra charge. Two of the designs are linked to below:

NL-AB-BBCL Reference Schematic

NL-SWDK Reference Schematic

Nimbelink highly recommends prototyping with a Skywire Development kit as opposed to a breadboard, which will not work with a Skywire modem. Please refer to the following application note, which explains this incompatibility in more detail:

Prototyping with Cellular Modems and Modules

## 3.2 Serial Communications

The NL-SW-LTE-QBG95 modem has two communication paths: serial (UART) and USB. The serial UART interface is targeted for applications using lower speed 8/16/32 bit microcontrollers that do not have a USB interface or easily available USB interface drivers. The USB interface for the modem is meant for use by higher end systems with a native USB interface controller or operating system (Single board computers, Linux/Windows).

For designs that are only using the serial UART interface, NimbeLink recommends designers include test points or a non-populated USB connector footprint in their designs. This allows access to the modem's USB interface to enable easy debugging and firmware updates.

### 3.2.1 Serial UART Interface

All Skywire modems support a serial UART interface with transmit and receive on pins 2 (DOUT) and 3 (DIN). On the NL-SW-LTE-QBG95 modem, the baud rate defaults to 115200 Baud 8N1. If a different baud rate is required, it can be changed with the **AT+IPR** command as defined in the AT command manual. The modem also supports RTS/CTS flow control on pins 12 (CTS) and 16 (RTS).

By default, the modem does have flow control enabled. To modify the flow control setting, please see the **AT+IFC** command in the AT command manual. It is recommended that any designs using the serial UART interface connect the RTS/CTS flow control lines to the host microcontroller and enable them in their application.

### 3.2.2 USB Interface

The NL-SW-LTE-QBG95 modem supports a USB 2.0 interface on pins 6 (VUSB), 7 (USB_P), and 8 (USB_N). Systems connecting to the modem's USB interface must observe proper design practices for connecting to a high speed USB device including, but not limited to, the following:

- The USB D± traces should be routed as  a 90 ohm impedance differential pair.
- The USB D± traces should be length matched as closely as possible.
- USB trace lengths should be minimized.
- USB differential pairs should be carefully routed to ensure they have a continuous return path beneath the traces.  Do not route differential pairs over splits in ground or power planes.
- If the USB signals will be used off-board, ESD protection should be implemented near the off-board connector.

Pin 6 is the VUSB detection pin that the modem uses to detect if a USB host controller has been connected to the modem. This pin has an internal pulldown and must have a voltage between 3.0V and 5.5V applied to it in order to activate the USB interface. The VUSB pin will draw less than 5mA when connected. VUSB must be disconnected or asserted to ground before activating Power Saving Mode.

## 3.3  VREF

The VREF signal drives the input voltage side of an onboard buffer which converts external I/O voltage from the  VREF range to the 1.8V range in order to drive the onboard Quectel BG95 module. System designers should connect the reference voltage of their system to this pin. The VREF signal will draw less than 1mA when the modem is powered.

To enable low power operation, system designers should include a method of removing the voltage from VREF when the system is in Power Save Mode (PSM). One such method would be to power VREF from a GPIO or to have a P-CH MOSFET in the VREF signal path.

## 3.4  nRESET Signal

In the event that the modem becomes unresponsive, pin 5 (nRESET) can be grounded to unconditionally reset the modem. When pin 5 is grounded, the modem will abruptly cease all ongoing operations, and shutdown.

Due to architecture changes to the chipset, the nRESET signal and the ON_OFF signal are internally tied together inside of the Quectel module used on the modem.

The modem will not detach itself from the network before shutting down when nRESET is asserted. Network providers request that a device gracefully detach from the network before shutting down. This functionality should only be used as an emergency, last resort, reset method when the modem is not responding to commands.

To unconditionally reset the modem with the nRESET signal, tie the pin low with an open collector for between 2000ms and 3800ms, and then release. The signal is internally pulled up to 1.5V inside of the module.
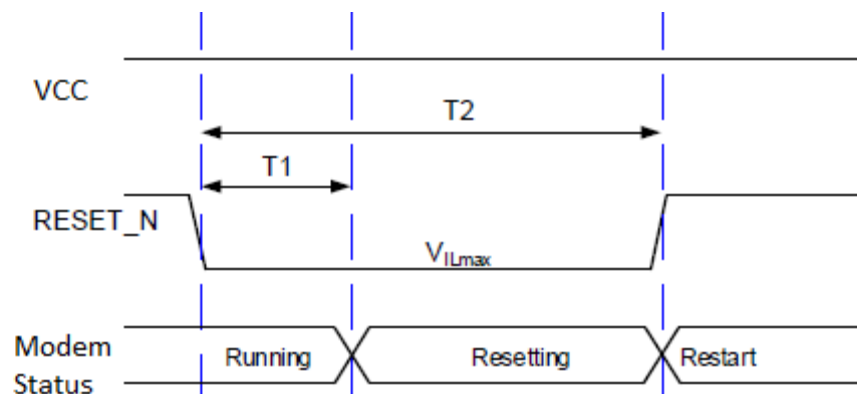


| Modem | $V_{IL, Max}$ | T1 | T2 |
|---|---|---|---|
| NL-SW-LTE-QBG95 | 0.45V | ≥ 2000 ms | ≤3800 ms |

If the signal is unused, it can be left floating, but it is highly recommended that the signal be connected to the host system. If the signal is used, it should be driven with an open collector output from the host system or a discrete open collector transistor.

In high noise (high EMI) environments, we recommend designers place a 0.01-0.1 uF capacitor on the nRESET line near the J1 connector.

# 3.5 Power Control

### 3.5.1 ON_OFF Signal

The ON_OFF signal on pin 20 is used to trigger the modem to turn on, and to turn the modem off.

To conserve power, the onboard cellular module does not automatically startup when power is applied.  Therefore, the baseboard design must supply a means to assert a logic-low level on the ON_OFF pin. To initiate the startup procedure, tie ON_OFF to ground for 500-1000 ms.
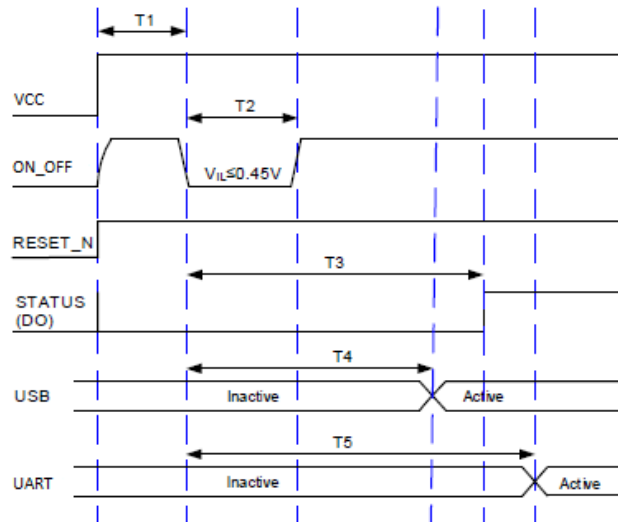


| Modem | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| NL-SW-LTE-QBG95 | ≥30 ms | 500 to 1000 ms | ≥2.1 s | ≥2.55 s | ≥2.5 s |

If the modem is currently running, the ON_OFF pin can be pulled low for 650-1500 ms to initiate a power-down sequence.
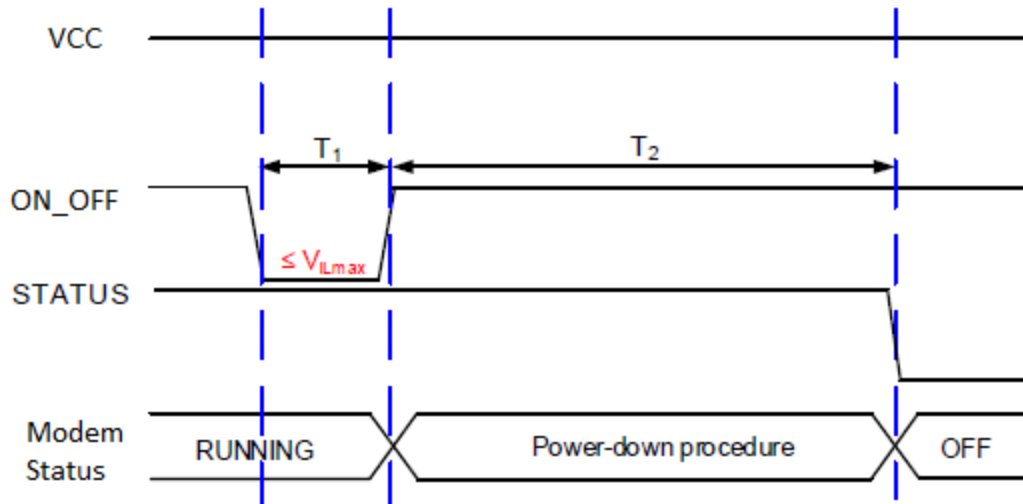


| Modem | $V_{IL, Max}$ | T1 | T2 |
|---|---|---|---|
| NL-SW-LTE-QBG95 | 0.45V | 650 to 1500 ms | ≥1300 ms |

Due to architecture changes to the chipset,  the nRESET signal and the ON_OFF signal are internally tied together inside of the Quectel module used on the modem. This pin should not be permanently attached to ground, nor should this pin be driven high or have a pull up resistor applied. The ON_OFF signal should be driven with an open collector output or with an open collector transistor. The signal is internally pulled up to 1.5V and should not be driven high, doing so may damage the modem.

### 3.5.2  Power Monitoring

Applications can check to see if the modem has powered up by reading the logic state on pin 13 (STATUS). When the Quectel BG95 module is powered up and running, pin 13 will be driven high to 1.8 V. When the module is not running, this pin will be logic level low. The STATUS pin will go high approximately 2.1 seconds after the ON_OFF pin is asserted.  Power should not be removed from the modem until the STATUS pin has gone low during the shutdown procedure.

### 3.5.3  Shutdown

The modem should be shut down in a controlled manner, so as to gracefully disconnect it from the network. Failure to do so violates carrier requirements. In rare events, failure to properly shut down the modem could render the modem inoperable due to firmware corruption.

To gracefully shut down the modem, the host system should do the following:

- Shut down the modem with the **AT+QPOWD=1** command. This command will gracefully disconnect the modem from the network and shut down the modem. This process will take no longer than a couple of seconds. After this command is issued, the host system should cease any communications with the modem.

- If power is to be cut from the modem, ensure that the host system is not back powering the modem through any of the modem's I/O lines.

- Users should monitor that the STATUS pin has gone low prior to removing power (as described in Section 3.5.2) to ensure the modem has powered down.

- Remove VREF (if VCC is being removed).

- Remove VCC.

In the event of power failure, the modem may need to be shut down faster than the **AT+QPOWD=1** command can manage. To immediately power down the modem in the event of power failure, the **AT+QPOWD=0** command can be used to force a fast shutdown.

## 3.6  Network Status Monitoring

In order to conserve power, the NL-SW-LTE-QBG95 does not have a status LED. It is recommended to monitor the modem's network status using AT commands and the serial interface.

## 3.7  Firmware Updates Over the Air (FOTA)

LTE networks are constantly being updated, improved, and enhanced with new features. As a result, carriers are making frequent network changes.  Most will not negatively affect devices connected to those networks, but occasionally an update will prevent an unprepared device from reconnecting to the network permanently.

To account for these future changes, FOTA (Firmware over the Air) capability is being added to cellular modules by each manufacturer. Accordingly, NimbeLink supports this functionality in the entire Skywire family of embedded modems. As such, it is highly recommended that designers implement provisions to accommodate FOTA processes.

Failure to accommodate FOTA processes may result in interruptions in cellular connectivity in the event of network changes. If a device can no longer access the network, FOTA cannot be used to remedy the problem. The only way to recover functionality is to physically update the device firmware.

FOTA Instructions are available by contacting NimbeLink's product support team at product.support@nimbelink.com.

## 3.8 SIM Selection

The NL-SW-LTE-QBG95 modem has the ability to select between a soldered-down SIM or a removable SIM inserted into the SIM card slot on the modem.

By default, the modem is configured to attempt to use the SIM card slot. However, users can select which SIM the modem is using by controlling the onboard SIM selection switch with AT commands. Whenever SIM selection is switched, the modem's RF system will need to be toggled with the AT+CFUN command.

To configure the modem to use the soldered down SIM issue the following commands to the modem in the order they appear below:

```
AT+CFUN=0
AT+QCFG="gpio",1,26,1,0,0,1
AT+QCFG="gpio",3,26,1,1
AT+CFUN=1
```

To configure the modem to use the SIM in the SIM card socket issue the following commands to the modem in the order they appear below:

```
AT+CFUN=0
AT+QCFG="gpio",1,26,1,0,0,1
AT+QCFG="gpio",3,26,0,1
AT+CFUN=1
```

**Note:** GPIO states will persist after reset, and the above AT commands will not need to be reissued each time the modem is powered on. Firmware updates may overwrite saved GPIO states, however.

To check what SIM is selected issue the following command:

```
AT+QCFG="gpio",2,26
```

The modem will respond with:

```
+QCFG: "gpio",x
```

```
OK
```

Where x is the value of the SIM interface GPIO control pin. If x == 1 then the solder down SIM is selected. If x==0 then the 3FF SIM socket is selected.

## 3.9  GNSS

The onboard Quectel BG95 module includes a fully integrated global navigation satellite system solution that supports Gen9 VT of Qualcomm (GPS, GLONASS, BeiDou/Compass, Galileo and QZSS). The BG95 has an embedded low-noise amplifier (LNA) that is utilized by the GNSS system. The modem supports both passive GNSS antennas and active antennas with a gain, at the modems RF connector, of <20dB.

Due to hardware limitations, the QGB95 can not use GPS and Cellular concurrently. By default, the QBG95 modem is configured into the GNSS priority mode, which can be switched to the WWAN priority mode with the command: **AT+QGPSCFG="priority",1,1** The command takes effect immediately. To revert back to GNSS priority mode use the command: **AT+QGPSCFG="priority",0,1** To query which system is prioritized use the command **AT+QGPSCFG="priority"**. For additional information on this command please refer to the BG95 GNSS AT command manual.

### 3.9.1  GNSS Antenna Requirements

| Item | Value |
|---|---|
| Frequency Range | 1559 − 1609 MHz |
| Impedance | 50 Ω |
| Polarization | RHCP or linear |
| VSWR | < 2 (Typ.) |
| Passive Antenna Gain | > 0 dBi |
| Active Antenna Noise Figure | < 1.5 dB |
| Active Antenna Gain | > 0 dBi |
| Active Antenna Embedded LNA Gain | < 17 dB |
| **Technology** | **Frequency** |
| GPS / QZSS | 1575.42 ± 1.023 MHz |
| GLONASS | 1597.5 − 1605.8 MHz |
| Galileo | 1575.42 ± 2.046 MHz |
| BeiDou | 1561.098 ± 2.046 MHz |

### 3.9.2 Active GNSS Antenna Control

A 3.3VDC, 100 mA source is available on the modem to bias the GPS line in order to power the modem. Control of the GNSS power source is done via GPIO64 on the modem. To conserve power, the GNSS power is off by default.

To turn on the DC power to the GNSS antenna, and save it in this state across power off, issue the following commands to the modem:

```
AT+QCFG="gpio",1,64,1,0,0,1

AT+QCFG="gpio",3,64,1,1
```

To turn off the DC power to the GNSS antenna, and save this state after power off, issue the following commands to the modem:

```
AT+QCFG="gpio",1,64,1,0,0,1

AT+QCFG="gpio",3,64,0,1
```

**Note:** GPIO states will persist after reset, and the above AT commands will not need to be reissued each time the modem is powered on. Firmware updates may overwrite saved GPIO states, however.

### 3.9.3 GNSS Antenna Placement

- The antenna must be installed according to the antenna manufacturer's instructions in order to obtain the maximum performance of the GNSS receiver.

- The antenna location must be evaluated carefully if operating in conjunction with any other antenna or transmitter.

- The antenna must not be installed inside metal cases or near any obstacle that may degrade features like antenna lobes and gain.

- Keep the antenna and the antenna cabling away from any power supply lines, noisy EM devices, and wireless RF lines.

### 3.9.4 Recommended Antennas

While Skywire modems will work with antennas from other manufacturers, the following antennas have been designed specifically to work with Skywire.

| Type | Manufacturer | Part Number |
|---|---|---|
| GPS/GALILEO Antenna, Internal[1] | Taoglas | AP.17E.07.0064A |
| GPS/GALILEO Antenna, External[1] | Taoglas | AA.108.301111 |

***Note 1:*** *U.FL to SMA adapter required.*

### 3.9.5 USB NMEA Port

The NL-SW-LTE-QBG95 has the ability to output location data to a dedicated GNSS NMEA port when connected over USB. By default, the modem will output location data via the USB NMEA port as soon as the GNSS receiver is turned on with **AT+QGPS=1**. However, it is possible to change the endpoint for the location data with the **AT+QGPSCFG** command.

To configure the modem to direct GNSS data to the USB NMEA port, send the following command. This command takes effect immediately, and its state is saved in memory:

> **AT+QGPSCFG="outport","usbnmea"**

### 3.9.6 GNSS UART (Pins 17 and 18)

The NL-SW-LTE-QBG95 Skywire has a fixed 1.8V referenced 2-pin UART brought out on Skywire pins 17 and 18. This UART can be used to output GNSS location data in the form of NMEA sentences.

| Pin | Name | Type | Description | Min | Typ. | Max |
|-----|------|------|-------------|-----|------|-----|
| 17 (J2-7) | GNSS_UART_RXD | Input | GPS UART RXD signal. Fixed 1.8V reference. Leave unconnected if unused. | VIL: -0.3V to 0.6V | | VIH: 1.2V to 2.0V |
| 18 (J2-8) | GNSS_UART_TXD | Output | GPS UART TXD signal. Used to transmit GPS data from the modem to the host. Fixed 1.8V reference. **Do not pull-up or drive this pin high during boot.** Leave unconnected if unused. | VOL: 0V to 0.45V | | VOH: 1.35V to 1.8V |

*Note: It is not possible to use this UART to send AT commands.*

By default, the modem will output GNSS location data via the USB NMEA port as soon as the GNSS receiver is turned on with **AT+QGPS=1**. However, this endpoint can be changed to select the GNSS UART with the **AT+QGPSCFG** command.

To configure the modem to direct GNSS data to the GNSS UART, send the following command. This command takes effect immediately, and its state is saved in memory:

> **AT+QGPSCFG="outport","uartnmea"**

*Note: The GNSS_UART_TXD signal is used as a boot configuration pin for the Quectel BG95 module, and must never be driven high or pulled-up during boot. Do not use a voltage-level translation IC that will cause this pin to be pulled high before/during boot. Failure to follow this guidance will prevent the modem from powering up normally.*

# 3.10  Cellular Antenna Requirements

NL-SW-LTE-QBG95 modems support one primary cellular antenna connection for RX & TX communication via the X1 connector on the top of the modem.  The X1 connector is a U.FL connector. Many antennas will require the use of a U.FL to SMA cable, such as the Taoglas CAB.011.

### 3.10.1 Primary Antenna Requirements

Depending on the frequency band(s) provided by the network operator, the customer shall use the most suitable antenna for that/those band(s):

| Band | Uplink (MHz) | Downlink (MHz) |
|---|---|---|
| B1 | 1920 – 1980 | 2110 – 2170 |
| B2, PCS1900 | 1850 – 1910 | 1930 – 1990 |
| B3, DCS1800 | 1710 – 1785 | 1805 – 1880 |
| B4 | 1710 – 1755 | 2110 – 2155 |
| B5, GSM850 | 824 – 849 | 869 – 894 |
| B8, EGSM900 | 880 – 915 | 925 – 960 |
| B12 | 699 – 716 | 729 – 746 |
| B13 | 777 – 787 | 746 – 756 |
| B14 | 788 – 798 | 758 – 768 |
| B18 | 815 – 830 | 860 – 875 |
| B19 | 830 – 845 | 875 – 890 |
| B20 | 832 – 862 | 791 – 821 |
| B25 | 1850 – 1915 | 1930 – 1995 |
| B26 | 814 – 849 | 859 – 894 |
| B27 | 807 – 824 | 852 – 869 |
| B28 | 703 – 748 | 758 – 803 |
| B66 | 1710 – 1780 | 2110 – 2180 |
| B71 | 663 – 698 | 617 – 652 |
| B85 | 698 – 716 | 728 – 746 |

*Note: B14 and B27 support LTE-M operation only. B71 supports LTE-NB2 only.*

| Specification | Value |
|---|---|
| VSWR | ≤ 2 (Typ.) |
| Efficiency | > 30% |
| Max Input Power | 50 W |
| Input Impedance | 50 Ω |
| Cable Insertion Loss<br>(B5, B8, B12, B13, B14, B18, B19, B20, B26, B27, B28,<br>B71, B85, GSM850, GSM900) | < 1 dB |
| Cable Insertion Loss<br>(B1, B2, B3, B4, B25, B66, DCS1800, PCS1900) | < 1.5 dB |

*Note:* *Any antennas used with the modem will need to comply with the Wireless Notice detailed in Section 5.7.*

### 3.10.2 Antenna Placement

The modem's cellular antenna placement will directly affect the modem's performance. It is vital that system designers carefully consider the placement of the antenna and follow all of the guidelines & specifications set by the antenna manufacturer. The following guidelines are general recommendations for antenna installation:

- Make sure the antenna has an impedance of 50 ohms.

- Keep the antenna cable as short as possible.

- The antenna must not be installed inside a metal enclosure, nor near metal objects unless specified by the antenna manufacturer.

- The antenna must be installed according to the manufacturer's instructions.

- Antenna gain must not exceed the values indicated in the regulatory requirements.

- Antenna integration should optimize antenna efficiency. Antennas are recommended to have >50% efficiency on all frequency bands.

- Additional FCC/IC testing may be required for applications where the antenna is located closer than 20 CM from the body.

- If the device antenna is located farther than 20cm from the human body and there are no co-located transmitter, the Quectel FCC/IC approvals can be re-used by the end product

- Antenna should not be mounted near noisy EM devices.

### 3.10.3 Recommended Antennas

**While Skywire modems will work with antennas from other manufacturers, the following antennas have been designed specifically to work with Skywire.**

| Type | Manufacturer | Part Number |
|---|---|---|
| Internal Cellular Antenna | Taoglas | FXUB65.07.0180C |
| External Cellular Antenna [1] | Taoglas | TG.30.8113 |

Note 1: U.FL to SMA adapter required.

## 3.11 Skywire Reference Design

NimbeLink offers free reference schematic and layout files as examples of how to integrate Skywire modems into various systems. Schematics, design files, gerber files, and tutorials for a variety of different systems can be found on the Skywire Development Tools webpage.

# 4. Mounting Guidelines

Skywire embedded cellular modems support multiple connection methods. The two primary methods are board-to-board connectors and soldering directly to the baseboard.

## 4.1 Board-to-Board Connectors Approach

The Skywire interface calls for two 10-pin, 2mm pitch, female receptacles spaced 22 mm apart. There are many connector manufacturers that can be used. Below is one readily available product:

**Manufacturer**: Sullins Connector Solutions, **Part Number**: NPPN101BFCN-RC

Typical part drawing and footprint information for the NPPN101BFCN-RC connector:
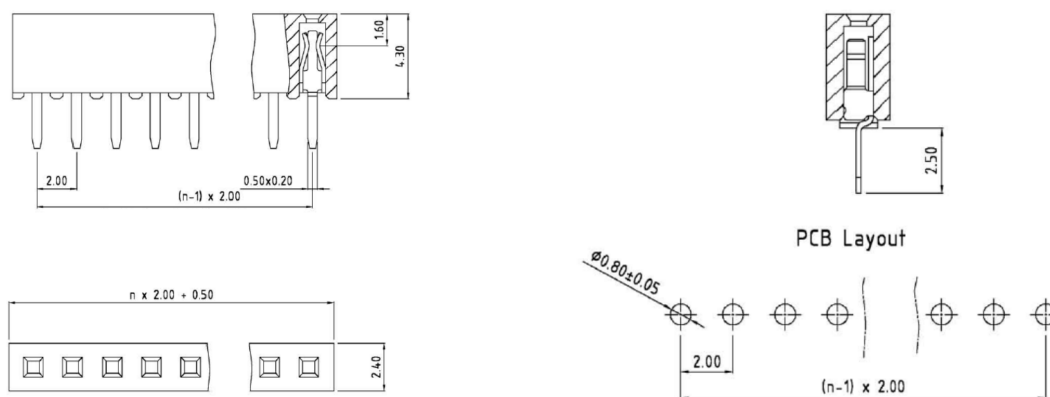
When using the recommended connector, ensure that any baseboard components placed under the Skywire (between the baseboard header pin connectors) are no taller than 4 mm. However, please note that the maximum component height may change based on the chosen baseboard connector.

### 4.1.1  Mechanical Retention

Certain applications where the modem is mounted on the host board using the connector approach detailed in section 4.1 may need to mechanically secure the Skywire modem & its SIM card in order to prevent the modem from vibrating out of the mating connectors. Skywire modems do not have any dedicated attachment points for securing to the host board, however it can easily be secured by one of the following methods:

- Zip ties
- Foam tape mounted on the Skywire to press against the enclosure
  - Note: User must ensure that foam tape does not compress the shielding can on the modem.
- Mechanical retention of the modem & SIM by the enclosure ([example](#))
- Solder the Skywire to the host board (as described in Section 4.2)

## 4.2  Solder to Board Connection

Alternatively, Skywires can be soldered directly to a PCB. The PCB should be designed with two rows of ten 0.8mm plated through holes spaced 2mm apart. See the figure below for the recommended footprint.
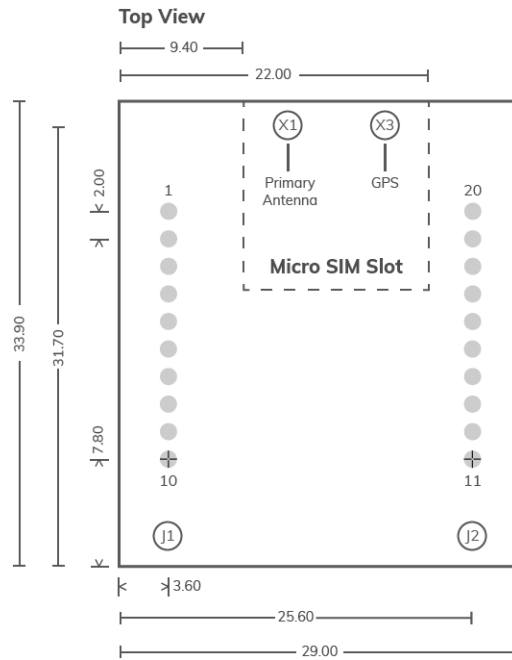
**Note:** All measurements are in millimeters. U.FL connectors X1 and X3 are on the top side of the board. Micro SIM card slot J3 is on the bottom of the board.

When using soldering directly to a PCB, ensure that any baseboard components placed under the Skywire (between the baseboard header pin connectors) are no taller than 0.5 mm.

# 5. Regulatory information

## 5.1 Carrier Specific Certifications

**NL-SW-LTE-QBG95:** Verizon ODI, PTCRB, AT&T, GCF **(In Progress)**, Telus **(In Progress)**, Orange **(In Progress)**

## 5.2 Export Control Classification Number (ECCN)

ECCNs are five character alphanumeric designations used on the Commerce Control List (CCL) to identify dual-use items for export control purposes.  An ECCN categorizes items based on the nature of the product, i.e. type of commodity, software, or technology and its respective technical parameters.

**ECCN for All Skywire Modems:** 5A992.c

## 5.3 Harmonized Tariff Schedule Code

**HTS Code:** 8517.62.0010

## 5.4  RoHS Compliance

The NL-SW-LTE-QBG95 modem family complies with the RoHS (Restriction of Hazardous Substances) directive of the European Union, EU Directive 2011/65/EU.

## 5.5  Interference statement

This device complies with Part 15 of the FCC Rules and Industry Canada licence-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interferences, and (2) this device must accept any interference received, including interference that may cause undesired operation.

## 5.6  FCC & IC Compliance

If the modem's antenna is located farther than 20cm from the human body and there are no adjacent transmitters, the FCC/IC approvals of the on-board Quectel BG95 cellular module can be reused by the end product.

Should the modems antenna be mounted closer than 20cm from the human body or if there are adjacent transmitters, additional FCC/IC testing may be required for the end product.

NL-SW-LTE-QBG95 modems make use of the on-board Quectel module's FCC & IC identification numbers.

| Orderable Device | FCC ID | IC ID |
|---|---|---|
| NL-SW-LTE-QBG95 | XMR201910BG95M3 | 10224A-2019BG95M3 |

The FCC certificate is available at the following link by searching for the FCCID listed above:

https://www.fcc.gov/oet/ea/fccid

The IC ID certificate is available at the following link by searching for the IC ID listed above:

https://sms-sgs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en

## 5.7  Wireless Notice

In order to maintain FCC/IC radiation exposure limits set forth for an uncontrolled environment alongside carrier specific certifications the antennas cannot exceed the maximum gain levels listed here:

| Band | Max Antenna Gain |
|---|---|
| GSM 850 | 8.571 dB |
| GSM 1900 | 10.030 dB |
| Band 2 | 11.000 dB |
| Band 4 | 8.000 dB |
| Band 5 | 12.541 dB |
| Band 12 | 11.798 dB |
| Band 13 | 12.214 dB |
| Band 14 | 12.272 dB |
| Band 25 | 11.000 dB |
| Band 26 | 12.541 dB |
| Band 66 | 8.000 dB |
| Band 71 | 11.687 dB |
| Band 85 | 11.798 dB |

## 5.8 Modification Statement

Nimbelink has not approved any changes or modifications to this device by the user. Any changes or modifications could void the user's authorization to operate the equipment.

## 5.9 End Product Labeling Requirements

End products utilizing NL-SW-LTE-QBG95 modems should be labeled with the following information:

Device Uses Approved Radio: NL-SW-LTE-QBG95

Contains FCC ID: XMR201910BG95M3

Contains IC: 10224A-2019BG95M3

This device complies with Part 15 of the FCC Rules and Industry Canada licence-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interferences, and (2) this device must accept any interference received, including interference that may cause undesired operation.

# 6. Document Version Information

| Revision | Description | Date |
|:---:|:---|:---:|
| 1 | - Initial document release. | 02/25/2020 |
| 2 | - Clarified pin IO for pins 17/18 | 07/31/2020 |
| 3 | - Removed notes regarding B26 and B66 being under development by the module manufacturer. | 08/25/2020 |
| 4 | - Added information on how to check which SIM is selected in section 3.8.<br>- Updated name of section 3.8 to "SIM Selection".<br>- Updated Table of Contents . | 09/22/2020 |
| 5 | - Added information on nRESET and ON_OFF internal connection.<br>- Added timing charts for nRESET and ON_OFF pins. | 10/02/2020 |
| 6 | - Updated Certification statuses. | 10/05/2020 |
| 7 | - Added NL-SW-LTE-QBG96-B PN.<br>- Updated power supply guidelines. | 02/12/2021 |
| 8 | - Added GNSS note to section 3.9 on GNSS/LTE usage limitations. | 02/17/2021 |
| 9 | - Updated antenna | 06/17/2021 |
| 10 | - Updated guidance for DIN pin termination when unused.<br>- Added a section for GNSS UART. | 07/09/2021 |