Airgain

SKYWIRE 4G LTE CAT 1 BIS EMBEDDED CELLULAR MODEM NORTH AMERICA

Datasheet

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1 Introduction

1.1 Scope

The aim of this document serves as a hardware reference datasheet for the NL-SW-LTE-TC1bisNAG Skywire® modem family. This document is updated often. Please be sure to download the latest version from Airgain's website.

1.2 Contact Information

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

1.3 Orderable Part Numbers

Orderable Device	Operating Temperature	4G LTE Bands	Fallback?	Applicable Networks
NL-SW-LTE-TC1bisNAG	-40 to +85°C	**LTE-FDD**: B2, B4, B5, B12, B13	**N/A**	AT&T, Bell, Rogers, Telus, Verizon

Note

Due to evolving PTCRB cellular certification requirements, additional device testing may be required. Please contact your cellular carrier for more information

1.4 Additional Resources

- Skywire® North American 4G LTE Cat 1 bis Embedded Modem Product Page
- Skywire® North American 4G LTE Cat 1 bis AT Command Manual
- Skywire NL-SWDK2 User Manual
- Skywire Hardware Design Developers Guide
- Skywire Hardware Design Checklist
- Skywire Software Developers Guide

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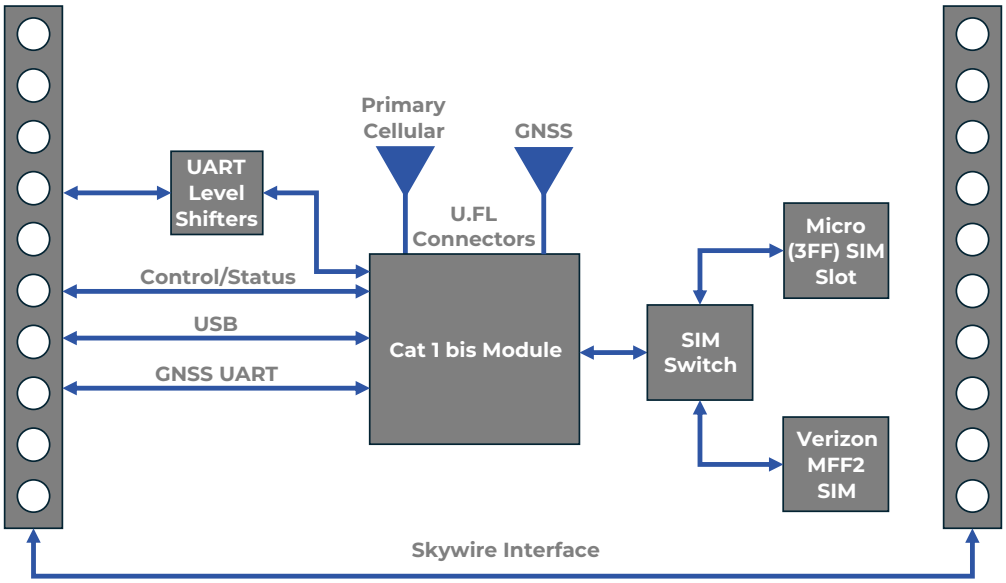
1.5 Product Overview

The Skywire® 4G LTE Cat 1 bis embedded modem for North America is purpose-designed for IoT applications, particularly those requiring location-based functionality. Based on the Telit LE910Q1-SNG 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 TC1bisNAG 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 1 bis modems have lower power requirements than Cat 1 or Cat 4 modems, 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



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2 Technical Specifications

2.1 Electrical Specifications

2.1.1 Absolute Maximum and Minimum Ratings

Parameter	Signal	Minimum Rating	Maximum Rating
Main Power Supply	VCC	3.4V	4.2V
I/O Voltage Reference	VREF	1.65V	5.5V
USB	VUSB, USB_P, USB_N	3V	5.5V
1.8V Referenced Signals	GPIO_02, GPIO_12, ON_OFF, nRESET, ON_nSLEEP	-0.3V	3.6V
VREF Referenced Signals	DIN, DOUT, DTR, RING, CTS, RTS	-0.5V	5.5V

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2.1.2 Typical Power Consumption

Mode	Avg. Current	Notes
Operating Mode		
Max transmit (23dBm)	600mA	Average current consumption with continuous LTE data transmission
Good signal condition (0dBm)	207mA	
Idle Mode (Standby, No call in progress, USB not connected)		
AT+CFUN=1	8.1mA	No PSM enabled
AT+CFUN=4	7mA	TX/RX disabled. Module is not registered on the network.
AT+CFUN=5	7.2mA	Power saving enabled. Paging cycle /#256 frames
AT+CFUN=14	280uA	Power saving mode with GPIO12 as wakeup. Paging cycle /#256 frames (2.56s DRx cycle)
Off		
Modem Powered Off	2.7uA	Module shut down but power applied.
PSM		
AT+CPSMS=1	32uA	PSM, external interfaces disconnected.
GNSS		
Before fix	24mA	
After fix	22mA	

2.1.3 Module Pinout for Connectors J1 and J2

The following table details the pinout of the NL-SW-LTE-TC1bisNAG Skywire modem, and recommended ratings for the Skywire interface on connectors J1 and J2. Further details and design requirements for these pins are documented in *Design Considerations*.

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#	Pin	Name	Direction	Description	Min	Typ.	Max	If not used
1	J1.1	VCC	Input	Main Power supply	3.4V	3.8V	4.2V	Must be implemented
2	J1.2	DOUT	Output	UART data out, I/O level tied to VREF	0V		VREF	Must be implemented if USB not used
3	J1.3	DIN	Input	UART data in, I/O level tied to VREF	0.8V [1]		2V [1]	Must be implemented if USB not used
4	J1.4	GND	Input	Ground Pin		0V		Must be implemented
5	J1.5	nRESET	Input	1.8V Reset signal for the module. Must be driven with an open drain or open collector signal.	VIL: GND to 0.5V			Must be implemented
6	J1.6	VUSB	Input	USB connection detection. This pin is disconnected internally and only present for compatibility purposes with other Skywire modules.	3.0V	5.0V	5.25V	No connection
7	J1.7	USB_P	I/O	USB differential data bus (+), Requires differential impedance of 90Ω.	Compliant with USB 2.0 standard specification.			No connection
8	J1.8	USB_N	I/O	USB differential data bus (-), Requires differential impedance of 90Ω.				No connection
9	J1.9	DTR	Input	Data terminal ready (sleep mode control), tied to internal reference voltage of 1.8V	VIL: GND to 0.63V		VIH: 1.17V to 5.5V	Tie to GND with 100k resistor
10	J1.10	GND	Input	Ground Pin		0V		Must be implemented
11	J2.1	GND	Input					
12	J2.2	CTS	Output	Clear to send	0V		VREF	No connection
13	J2.3	ON_nSLEEP	Output	Module status indicator	0V		1.8V	No connection
14	J2.4	VREF	Input	Voltage reference for offboard I/O signals.	0V	1.8V or 3.3V	5.5V	Must be implemented
15	J2.5	GND	Input	Ground Pin		0V		Must be implemented
16	J2.6	RTS	Input	Request to send, I/O level tied to VREF	0.8V [1]		2V [1]	No connection
17	J2.7	GPIO_12	I/O	General-purpose I/O	0V		1.8V	No connection
18	J2.8	GPIO_02	I/O	General-purpose I/O	0V		1.8V	No connection
19	J2.9	RING	Output	Modem ring indicator. Normally high. Open drain output with 1M internal pull-up.	VOL: 0 to 0.1V		VREF	No connection
20	J2.10	ON_OFF	Input	Modem On/Off signal. Must be driven with open drain signal.	VIL: 0V to 0.5V		2.3V	Must be implemented

[1] Assumes VREF of 3.3V. For other VREF ranges, see *Operating Voltage for VREF-Referenced Inputs*

Additional information on the Skywire pinout is available in *Design Considerations*.

2.1.4 Operating Voltage for VREF-Referenced Inputs

VREF Range	VIL	VIH
1.65V to 1.95V	VREF x 0.35V	VREF x 0.65V
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 0.7V

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2.1.5 Module Pinout for Connectors J3, X1, X3

Connector Designator	Description	Connector Location
J3	Micro (3FF) SIM Connector	Bottom Side of Modem
X1	Primary Cellular Antenna Connection	Top side of Modem
X3	GPS/GNSS Satellite Receiver	Bottom Side of Modem

2.2 RF Specifications

Parameter		Value	
4G LTE Technology		Cat 1 bis	
4G LTE TX output power		23dBm ± 2dB	
4G LTE RX Sensitivity (10 MHz Bandwidth)	Band	Primary/ 3GPP Minimum (dBm)	LTE Technology
	B2	-98.0/-91.3	FDD
	B4	-98.0/-93.3	FDD
	B5	-98.0/-91.8	FDD
	B12	-98.0/-90.3	FDD
	B13	-98.0/-90.3	FDD
	B66	-98.0/-92.8	FDD
Peak Uplink and Downlink Speeds	Connection Type	Downlink	Uplink
	LTE-FDD	10 Mbps	5 Mbps

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2.3 Mechanical Specifications

2.3.1 Mechanical Characteristics

Parameter	Typical	Unit
Dimensions (excluding pin height, for solder to board applications)	29.0 x 34.0 x 6.8	mm
Dimensions (including pin height, for board-to-board connector applications)	29.0 x 34.0 x 11.0	mm
Weight	8	Grams
Connector Insertion/Removal	hundreds	Cycles

2.3.2 Mechanical Drawing

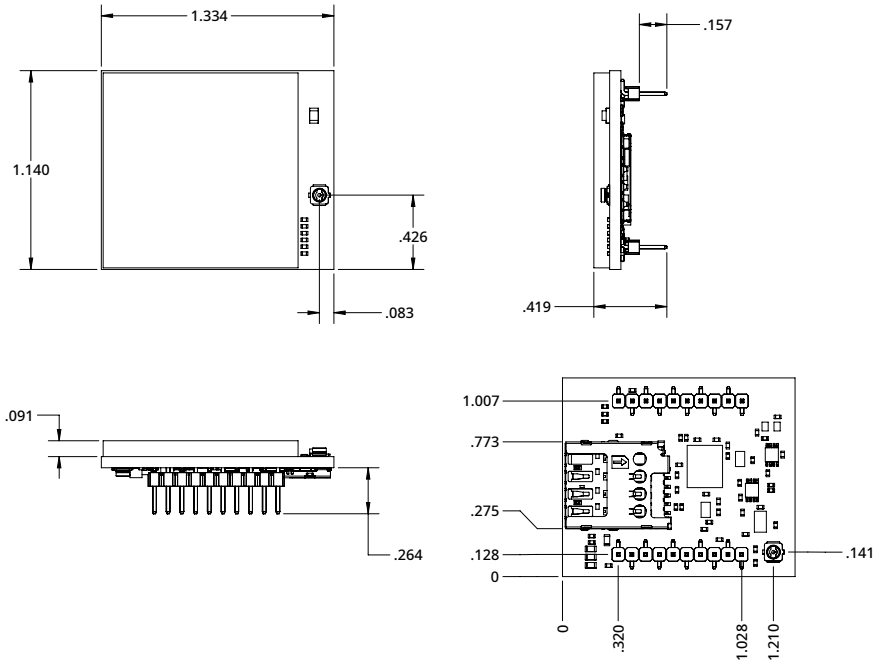

Fig. 1: Mechanical drawing (units in inches)

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2.4 Mating Connectors

Connector Designator	MFG	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)	MH113-MH1RP-01BJ1-0100	Samtec

Caution

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

2.5 Environmental Specifications

Parameter	Min	Typical	Max	Unit
Operating Temperature	-40	+25	+85	°C
Storage Temperature	-40	+25	+90	°C

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3 Design Considerations

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

To aid with customer design efforts, Airgain has released a Skywire Hardware Developers Guide and a Design Checklist. These supplemental documents contain design guidelines and suggestions for customers designing Skywire modems into their hardware platforms. Airgain strongly suggests reviewing your hardware platform against these documents to ensure proper modem integration.

- Skywire Hardware Developers Guide
- Skywire Hardware Design Checklist

3.1 Power Supply Requirements

NL-SW-LTE-TC1bisNAG modems will regularly consume high amounts of current on their Main Power Supply (Pin 1, VCC) input pins, up to 1.2A during LTE CAT1 transmits and receives. To maintain compatibility with other 4G Skywire modems, the baseboard power supply should be designed to support peak currents of at least 2 Amps. A 0.1uF & 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 4.2V

NL-SW-LTE-TC1bisNAG modems have a normal operating voltage range of 3.4V to 4.2V, with a recommended input voltage of 3.8V. Extreme care must be taken to ensure that the modem power supply stays within 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 strongly recommended to supply power to the Skywire modem. This is because switching power supplies can

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 have a rated voltage of at least 2x the input voltage to the Skywire. A minimum of a 100uF & 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 100uF 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 is recommended.
- Power supply input cables should be kept away from noise sensitive lines, such antennas.

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

- NL-AB-BBCL Reference Schematic
- NL-SWDK2 Reference Schematic

Airgain 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-TC1bisNAG 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, Airgain 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-TC1bisNAG 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-TC1bisNAG 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 length matched.
- 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. This pin is not used for USB detection on the NL-SW-LTE-TC1bisNAG since USB is automatically enabled. It can therefore be left disconnected while still using USB.

Optionally, to support drop-in compatibility with other Skywire modems if using USB, this pin should have a voltage between 3.0V and 5.25V (nominally 5V) applied to it to activate the USB interface.

3.3 VREF

The VREF signal is connected to onboard buffers that level shift the main Skywire UART signals (DOUT/DIN/CTS/RTS) to 1.8V, which is the logic level of the cellular module. Attach the host system's I/O reference voltage to the VREF pin to seamlessly enable UART communication with the Skywire at any voltage up to 5.5V. The VREF pin will draw less

than 1mA at 3.8V when the modem is powered. 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

If the modem becomes unresponsive, pin 5 (nRESET) can be grounded as an emergency reset system. When nRESET is grounded, the module resets the baseband and supply section. If reset for more than 5 seconds, the module completely discharges the internal power rails, performing the same functionality as an unconditional shutdown. Releasing this pin will initiate the power up procedure regardless of the state of the ON_OFF pin. Please note, the modem will not gracefully detach itself from the cellular network before resetting.

Network providers request that a device gracefully detach from the network before shutting down. Accordingly, this functionality should only be used as an emergency reset when the modem is not responding to commands.

It is necessary that this signal be connected to the host system. It should be driven with an open collector or open drain output from the host system or a discrete open collector transistor. To avoid damaging the modem, this signal must never be driven high with a push-pull I/O pin.

In high noise (high EMI) environments, it is recommended to place a 0.01-0.1uF 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. This signal is internally pulled high and must be driven by an open-drain or open-collector assertion. Do not drive this pin high nor apply a pullup resistor.

ON_OFF circuit reference design is an example for the turn-on circuit for the modem using either an open drain assertion with a N-Channel MOSFET or a button.

To conserve power, the onboard cellular module does not automatically start up when power is applied. 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 at least **10 ms**.

When the modem's UART interface is ready (Active) for AT commands the interface will

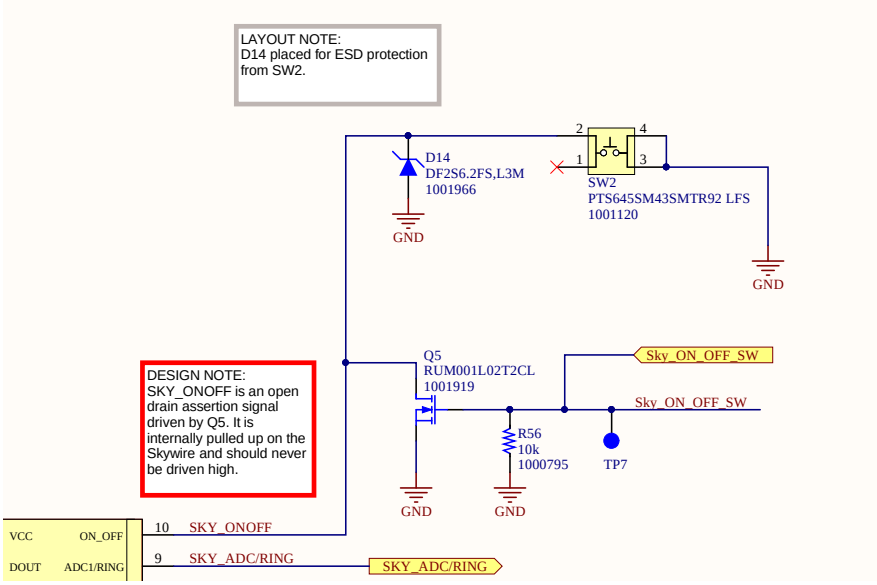

Fig. 2: ON_OFF circuit reference design

output a 'RDY' URC.

If the modem is currently running, the ON_OFF pin can be pulled low for at least **5 seconds** to initiate a power-down sequence.

3.5.2 Power Monitoring and LED Status

Applications can check to see if the modem has powered up by reading the logic state on pin 13 (ON/nSLEEP). This pin also dictates the on/off behavior of the green LED. By default, the ON/nSLEEP pin is programmed per the behavior table below. Power should not be removed from the modem until the pin has gone low during the shutdown procedure.

LED Status		Device Status
Permanently off		Device off
Blinking	Blinking 1s on and 2s off	Registered in idle mode
	Blinking time dependent on network status	Registered in idle with PSM
Permanently on		Not registered

Optionally, the default behavior of this pin can be reprogrammed via AT Commands. See **AT#GPIO** and **AT#SLED** commands in the AT Command manual.

3.5.3 Shutdown

The modem should be shut down in a controlled manner, 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#SHDN** command. This command will gracefully disconnect the modem from the network and shut down the modem. This process may take up to 25 seconds to complete. 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 the STATUS pin (as described in *Power Monitoring and LED Status*) 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 command can manage. To immediately power down the modem in the event of power failure, the **AT#FASTSHDN** command can be used to force a fast shutdown.

3.6 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.

The NL-SW-LTE-TC1bisNAG modem supports FOTA to account for future network changes and to allow for modem firmware to be updated remotely. Airgain highly recommends that system 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 Airgain's Product Support team at product.support@airgain.com.

3.7 SIM Selection

The NL-SW-LTE-TC1bisNAG modem can 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 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. When the 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#SIMSELECT=2
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#SIMSELECT=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#SIMSELECT?
```

The modem will respond with:

```
#SIMSELECT: x
OK
```

Where x is the value of the SIM interface GPIO control pin. If x=2 then the soldered down SIM is selected. If x=1 then the 3FF SIM socket is selected.

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3.8 GNSS

The onboard Telit LE910Q1-SNG module includes a fully integrated global navigation satellite system solution that supports GPS, GLONASS, Galileo, BDS and QZSS. The modem supports both passive GNSS antennas and active antennas with a gain at the modem's RF connector of > 0 dBi. The NL-SW-LTE-TC1bisNAG also has an onboard low-dropout regulator (LDO) that can be used to provide 3.3VDC power to the antenna connector when using an active GNSS antenna.

The requirements for the GNSS antenna are available in *GNSS Antenna Requirements*.

3.8.1 GNSS Performance

The following table shows the GNSS performance of the Telit LE910Q1-SNG module used on the NL-SW-LTE-TC1bisNAG modem.

Parameter	Description	Typ.	Unit
Sensitivity (GNSS)	Cold Start	-144	dBm
	Reacquisition	-156	dBm
	Tracking	-161	dBm
TTFF (GNSS)	Cold Start	33	seconds
	Hot Start	1	seconds
Accuracy (GNSS)	CEP-50	1.5	meter

3.8.2 GNSS Antenna Requirements

Item	Value
Frequency Range	1559 – 1609 MHz
Impedance	50 Ω
Polarization	RHCP or linear
VSWR	≤ 3:1 (recommended)
Active Antenna Noise Figure	< 1.5 dB
Active Antenna Embedded LNA Gain	< 17 dB
GNSS Frequency	**Frequency**
GPS	1575.42 ± 1.023 MHz (L1)
GLONASS	1597.5 – 1605.8 MHz (L1)
BDS	1561.098 ± 2.046 MHz (B1I)
QZSS	1575.42 ± 1.023 MHz (L1)
Galileo	1575.42 ± 2.046 (E1)

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3.8.3 Active GNSS Antenna Control

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

To turn on the DC power to the GNSS antenna and enable the GNSS controller, issue the following commands to the modem in order:

```
AT$GNSSMODE=1
AT#GPSP=1
```

To turn off the DC power to the GNSS antenna and disable the GNSS controller, issue the following commands in order:

```
AT$GPSP=0
AT$GNSSMODE=0
```

3.8.4 GNSS Antenna Placement

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

3.8.5 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	Airgain	CRJKS0010-LNA-G65U
GPS/GALILEO Antenna, External[1,2]	Airgain	CRJKS0009-LNA-LM5X3000SMA

[1] U.FL to SMA adapter required.

[2] To meet the maximum gain requirements of the modems GNSS interface an attenuator may be required for external two stage LNA GNSS antennas. Please consult an RF engineer for assistance.

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3.9 Cellular Antenna Requirements

NL-SW-LTE-TC1bisNAG 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 Samtec MH113-MH1RP-01BJ1-0100.

3.9.1 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):

Item		Value	
Frequency Range	Band	Uplink (MHz)	Downlink (MHz)
	LTE-FDD B2	1850 – 1910	1930 – 1990
	LTE-FDD B4	1710 – 1755	2110 – 2155
	LTE-FDD B5	824 – 849	869 – 894
	LTE-FDD B12	699 – 716	729 – 746
	LTE-FDD B13	777 – 787	746 – 756
	LTE-FDD B66	1710 – 1780	2110 – 2180
VSWR		≤ 2 (Typ.)	
Efficiency		> 30%	
Gain		1 dBi	
Max Input Power		50 W	
Input Impedance		50 Ω	
Cable Insertion Loss (<1 GHz)		< 1 dB	
Cable Insertion Loss (1 – 2.3 GHz)		< 1.5 dB	
Cable Insertion Loss (>2.3 GHz)		< 2 dB	

Note

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

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3.9.2 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 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 >30% efficiency on all frequency bands.
- Additional FCC/IC testing may be required for applications where the antenna is located closer than 20cm from the body.
- If the device antenna is located farther than 20cm from the human body and there is no co-located transmitter, the FCC/IC approvals can be re-used by the end-product
- Antenna should not be mounted near noisy EM devices.

3.9.3 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	Airgain	F47AGCHA-G150U
External Cellular Antenna [1]	Airgain	ET56AGBJA

[1] U.FL to SMA adapter required.

For Airgain's full line of compatible antennas, please refer to the following link: Airgain Antenna Listings.

3.10 Skywire Reference Design

Airgain 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.

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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:

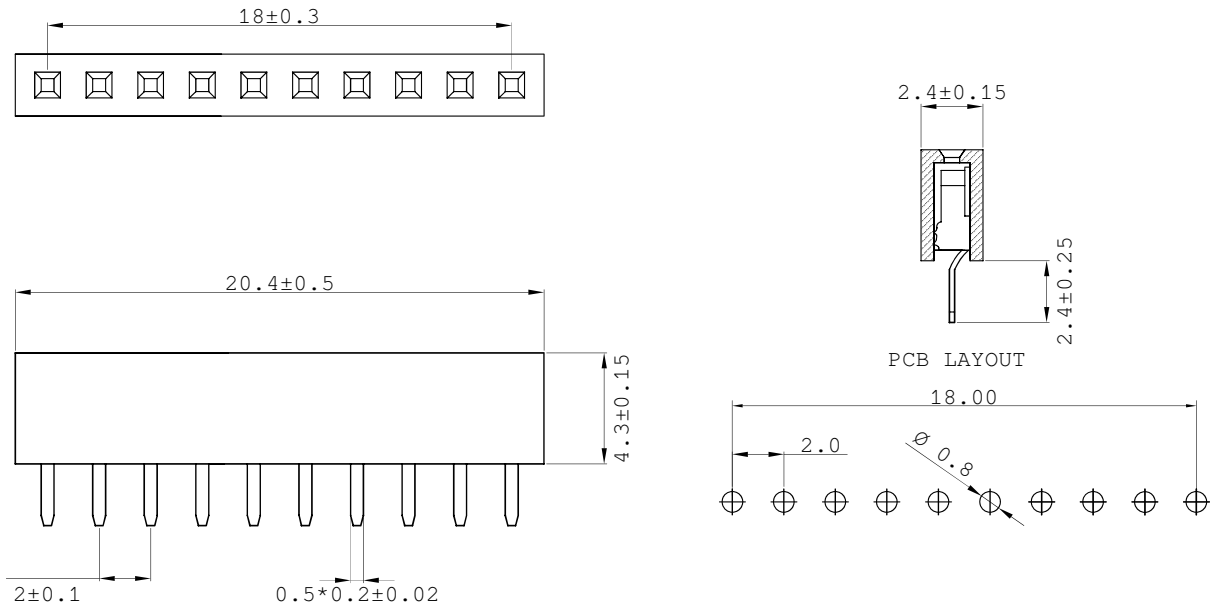


Fig. 3: Footprint of NPPN101BFCN-RC connector

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

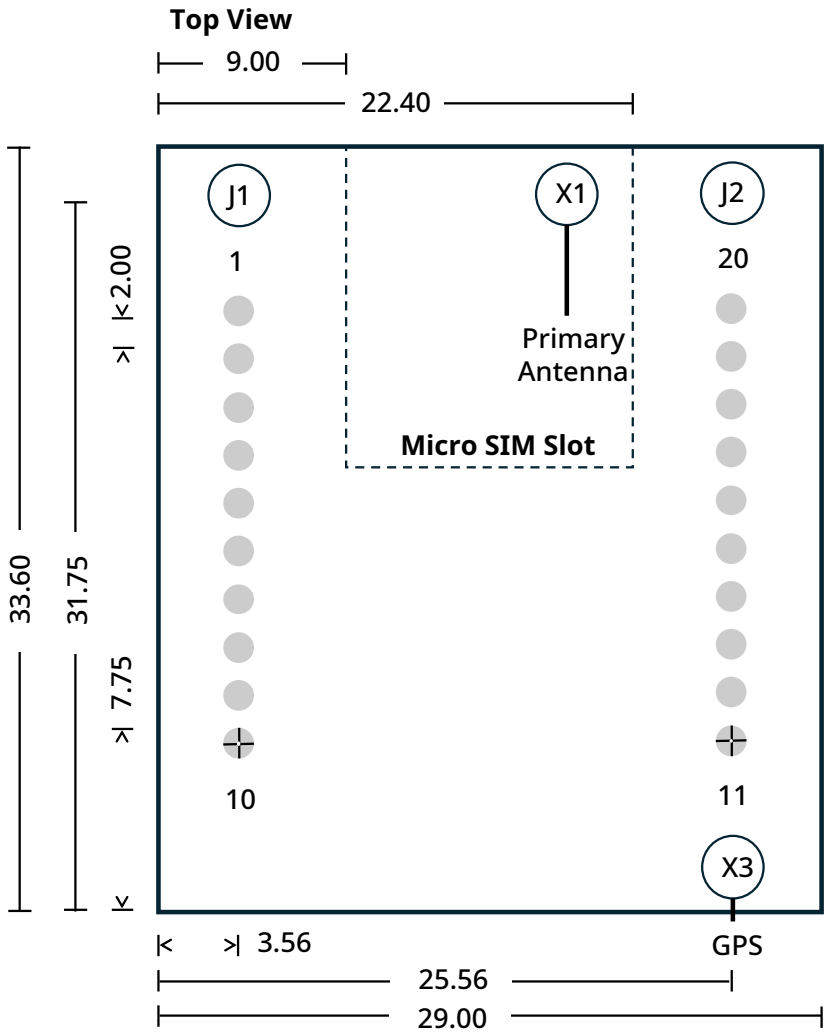
Certain applications where the modem is mounted on the host board using the connector approach detailed in *Board-to-Board Connectors Approach* may need to mechanically secure the Skywire modem & its SIM card to prevent the modem from vibrating out of the mating connectors. Skywire modems do not have 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
- Mechanical retention of the modem & SIM by the enclosure (example)
- Solder the Skywire to the host board (as described in *Solder to Board Connection*)

4.2 Solder to Board Connection

Alternatively, Skywire modems 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.



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> **Note**
>
> Units are in millimeters. U.FL connector X1 is on the top side of the board. Connector X3 and Micro SIM card slot J3 are 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 0.5mm.

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5 Regulatory information

5.1 Carrier Specific Certifications

NL-SW-LTE-TC1bisNAG: PTCRB, AT&T, Verizon

Note: Due to evolving PTCRB cellular certification requirements, additional device testing may be required. Please contact your cellular carrier for more information.

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 REACH/RoHS Compliance

The NL-SW-LTE-TC1bisNAG modem family complies with REACH and the RoHS (Restriction of Hazardous Substances) directive of the European Union, EU Directive 2015/863/EU.

5.5 Interference statement

This device complies with Part 15 of the FCC Rules and Industry Canada license-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, 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 Telit LE910Q1-SNG cellular module can be reused by the end-product.

Should the modem's 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-TC1bisNAG modems make use of the on-board Telit module's FCC & IC identification numbers.

Orderable Device	FCC ID	IC ID (certification number)
NL-SW-LTE-TC1bisNAG	RI7LE910Q1SN	5131A-LE910Q1SNG

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

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 (dBi)
LTE Band 2	8.0
LTE Band 4	5.0
LTE Band 5	9.4
LTE Band 12	8.7
LTE Band 13	9.2
LTE Band 66	5.0

5.8 Modification Statement

Airgain 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-TC1bisNAG modems should be labeled with the following information:

Device Uses Approved Radio: NL-SW-LTE-TC1bisNAG
Contains FCC ID: RI7LE910Q1SN
Contains IC: 5131A-LE910Q1SNG
This device complies with Part 15 of the FCC Rules and Industry Canada license-exempt RSS standards. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

6 Document Version Information

Revision	Description	Date
1.0	Initial Release	09/29/2025

Revision: October 3, 2025