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Modules

EM9291P / EM9293P

Hardware Integration Guide

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Semtech Corporation purchased Sierra Wireless in January 2023. The Sierra Wireless brand is gradually being phased out. During the phase-out period, references to both “Semtech” and “Sierra Wireless” may appear in product documentation.

Contact Information

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Revision History

Rev #	Release date	Changes
1	July 2025	Document created

Contents

1: Introduction

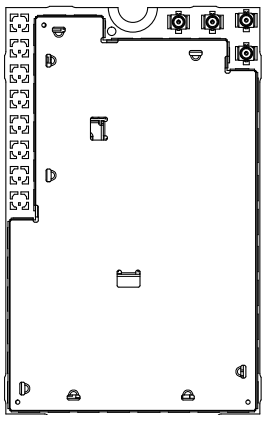
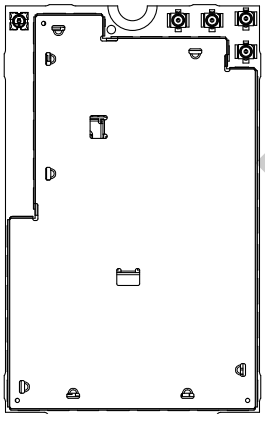
The Sierra Wireless EM929xP Embedded Module series (EM9291P, EM9293P) are FirstNet-ready (LTE B14) M.2 modules that provide 5G NR Sub-6 GHz, 4G LTE Advanced Pro, 3G (HSPA+, UMTS) and GNSS connectivity for a wide range of devices and purposes including business, personal, portable computing and communication devices, IoT devices, M2M applications and industrial use cases.

Note: In this document:

- *EM929xP refers to the EM9291P and EM9293P.*

EM929xP modules are available in region-specific and function-specific variants. Table 1-1 indicates RF capabilities supported by each variant.

Table 1-1: Module Variants

Variant	RF Capabilities (Supported RATs)		
	4G LTE	5G NR Sub-6 GHz	GNSS
EM9291P[a] 	Yes	Yes (SA, NSA EN-DC)[b]	Yes[c]
EM9293P 			Yes[d]

a. Note — EM9291P modules include unused solder masks (8) on the top left side of the PCB.
b. "SA" = "Standalone"; "NSA" = "Non-standalone"
c. GNSS supported via shared-path (ANT1)
d. GNSS supported via shared-path (ANT1) or dedicated GNSS (GNSS).

1.1 Accessories

A hardware development kit is available for Sierra Wireless M.2 modules. The kit contains hardware components for evaluating and developing with the module, including:

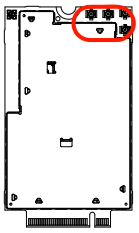
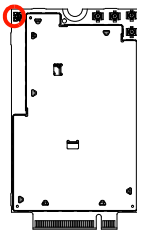
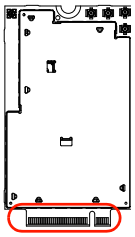
- Development board
- Cables
- Antennas
- Other accessories

Note: The development kit does not include an MHF 7S receptacle to access the EM9293P dedicated GNSS antenna (GNSS).

1.2 Required Connectors

Table 1-2 describes the connectors used to integrate the EM929xP Embedded Module into your host device.

Table 1-2: Required Host-Module Connectors[a]

Connector type	Module	Description
MHF 4 RF receptacles[b] — 5G NR Sub-6 GHz / LTE / GNSS (EM9293P shown) 	All EM929xP	▪ Four MHF 4 receptacles (mate with plugs, e.g., I-PEX 20448-001R-081 or equivalent) ▪ To avoid damage when attaching / detaching antenna cables to the receptacles, use an MHF 4 push / pull tool (I-PEX 90435-001 or equivalent). *Note: 5G NR Sub-6 GHz / LTE is supported on all four receptacles. Only the ANT1 receptacle can be also be used for shared GNSS.*
MHF 7S RF receptacle[b] — GNSS 	EM9293P only	▪ One MHF 7S receptacle (mate with plugs, e.g., I-PEX 20980-001R-13 or equivalent) ▪ To avoid damage when attaching / detaching an antenna cable to the receptacle, use an MHF 7S mating / unmating tool (I-PEX 91186-0001 or equivalent). *Note: Only the EM9293P includes the dedicated GNSS receptacle (GNSS). The EM9293P can also use ANT1 for shared 5G NR Sub-6 GHz / LTE / GNSS.*
M.2 (Slot B-compatible) 67-pin edge connector (EM9293P shown) 	All EM929xP	▪ Slot B compatible — Per the M.2 standard (*PCI Express M.2™ Specification Revision 4.0, Version 1.1*), a generic M.2 Slot B-compatible edge connector on the motherboard uses a mechanical key to mate with the 67-pin notched module connector. ▪ Manufacturers include LOTES, Kyocera, JAE, TE Connectivity, and Longwell.

a. Manufacturers/part numbers are for reference only and are subject to change. Choose connectors that are appropriate for your own design.
b. MHF 4 and MHF 7S RF receptacles (PCB connectors) are mounted on EM929xP modules. The host must mate these with corresponding RF plugs (cable connectors).

2: Power

2.1 Power Supply

The host provides power to the EM929xP module through multiple power and ground pins as summarized in Table 2-1.

The host must provide safe and continuous power (via battery or a regulated power supply) at all times; the module does not have an independent power supply, or protection circuits to guard against electrical issues.

Table 2-1: Power Supply Requirements[a]

Name	Pins	Specification	Min	Typ	Max	Units
VCC (3.3V)	2, 4, 24, 38, 68, 70, 72, 74	Voltage range	3.135	3.3	4.4	V
		Ripple voltage	—	—	100	mV_{pp}
		Peak current	—	—	4.75	A
		Continuous current	—	—	2.8	A
GND	3, 5, 11, 27, 33, 39, 45, 51, 57, 71, 73		—	0	—	V

a. Preliminary values, subject to change.

2.2 Module Power States

The module has five power states, as described in Table 2-2.

Table 2-2: Module Power States

State	Details	Host is powered	Host interface active	RF enabled
Normal (Default state)	▪ Module is active ▪ Default state. Occurs when VCC is first applied, Full_Card_Power_Off_N is deasserted (pulled high), and W_DISABLE_N is deasserted ▪ Module is capable of placing/receiving calls, or establishing data connections on the wireless network ▪ Current consumption is affected by several factors, including: · Radio band being used · Transmit power · Receive gain settings · Data rate	✔	✔	✔

Table 2-2: Module Power States (Continued)

State	Details	Host is powered	Host interface active	RF enabled
Low power (Airplane mode)	▪ Module is active ▪ Module enters this state: · Under host interface control: · Host issues AT+CFUN=0, or · Host asserts W_DISABLE_N, after AT!PCOFFEN=0 has been issued. · Automatically, when critical temperature or voltage threshold limits are reached.	✔	✔	✘
Sleep	▪ Normal state of module between calls or data connections ▪ Module cycles between wake (polling the network) and sleep, at network provider-determined interval.	✔	✘	✘
Off	▪ Host keeps module powered off by asserting Full_Card_Power_Off_N (signal pulled low or left floating) ▪ Module draws minimal current	✔	✘	✘
Disconnected	▪ Host power source is disconnected from the module and all voltages associated with the module are at 0 V.	✘	✘	✘

3: RF Specifications

3.1 Antenna Receptacles

EM929xP modules include 5G NR Sub-6 GHz/LTE/WCDMA/GNSS Receptacles and (EM9293P only) a dedicated GNSS receptacle for use with host-supplied antennas:

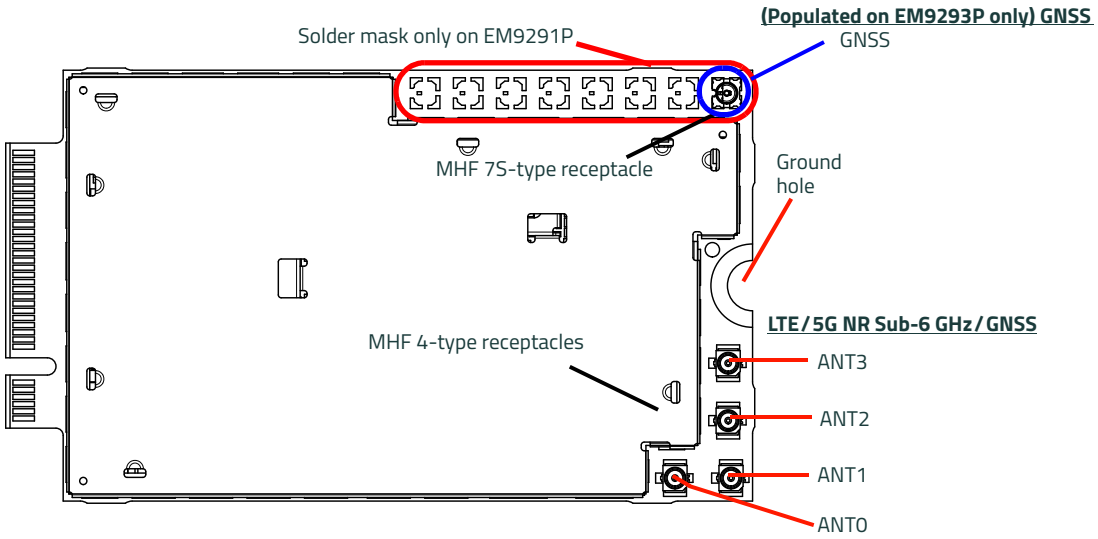


Figure 3-1: EM929xP Module RF Receptacles

3.1.1 5G NR Sub-6 GHz/LTE/WCDMA/GNSS Receptacles

The number of 5G NR Sub-6 GHz/LTE/WCDMA/GNSS receptacles is module-dependent.

Table 3-1: 5G NR Sub-6 GHz/LTE/WCDMA/GNSS Receptacles

Module	Receptacles		RATs[a]	Receptacle type[b]
	Qty	Designators		
EM9291P	4	ANT0–ANT3	▪ 5G NR Sub-6 GHz/LTE/WCDMA on all receptacles ▪ ANT1 also supports GNSS	MHF 4
EM9293P	4	ANT0–ANT3	▪ 5G NR Sub-6 GHz/LTE/WCDMA on all receptacles ▪ ANT1 also supports GNSS	MHF 4
	1	GNSS	Dedicated GNSS	MHF 7S

a. Refer to Table 3-2 for specific Antenna assignments.
b. To avoid damage when attaching/detaching antenna cables, make sure to use the correct tool for the specific receptacle type (different tools are used for MHF 4 and MHF 7S receptacles).

Note: Systems connected to a live network must have all four MHF 4 antennas (ANT0–ANT3) connected. (The dedicated GNSS antenna is only required if the dedicated GNSS antenna path is configured.)

Table 3-2 details the Tx and Rx antenna assignments for 5G NR Sub-6 GHz / LTE/WCDMA / GNSS bands. (Note — The listed Tx antenna assignments are for SA mode.)

Table 3-2: 5G NR Sub-6 GHz / LTE/WCDMA / GNSS Antenna Receptacles — RF Technology Support

RAT[a]	Bands	Tx Antennas[b,c,d,e]		Rx Antennas				GNSS Antenna
		Default	Alternate Path[f]	ANT0	ANT1	ANT2	ANT3	(EM9293P only) GNSS
5G NR Sub-6 GHz	29[h]	—	—	Y	—	Y	—	—
	38, 41	ANT2	ANT0	Y	Y	Y	Y	—
	48	ANT3	ANT1	Y	Y	Y	Y	—
	75[h], 76[h]	—	—	Y	Y	Y	Y	—
	77, 78	ANT3	ANT1, ANT2	Y	Y	Y	Y	—
	79	ANT3	ANT1	Y	Y	Y	Y	—
LB LTE / 5G NR Sub-6 GHz	5, 8, 12, 13, 14, 17, 18, 19, 20, 26, 28, 71, 106	ANT0	—	Y	—	Y	—	—
MB/HB LTE / 5G NR Sub-6 GHz	1, 2, 3, 4, 7, 25, 30[g], 39, 40, 66, 70	ANT0	—	Y	Y	Y	Y	—
LTE	29[h]	—	—	Y	—	Y	—	—
	34[i]	ANT0	—	Y	—	Y	—	—
	46[h]	—	—	Y	—	—	Y	—
	32[h]	—	—	Y	Y	Y	Y	—
	38, 41	ANT0	—	Y	Y	Y	Y	—
	42, 43	ANT3	—	Y	Y	Y	Y	—
	48	ANT3	ANT1	Y	Y	Y	Y	—
WCDMA	1, 2, 4, 5, 8, 19	ANT0	—	Y	—	Y	—	—
GNSS	L1[j]/L5	—	—	—	L1[j]/L5	—	—	L1[j]

a. LB=Low Band (<1 GHz), MB=Mid Band (1–6 GHz), HB=High Band (>6 GHz)
b. The indicated Tx antenna is used to carry the Tx PUSCH channel.
c. SRS antenna switching is supported on certain bands (see Table 3-3 on page 15).
d. Tx antenna assignments are for SA mode. For NSA mode, the antenna depends on the RAT, bands and resource allocation, and the device firmware dynamically assigns the antenna based on those factors.
e. In NSA and ULCA / MIMO modes, a maximum of two Tx antennas can transmit at the same time.
f. Alternate Tx path is used only in ENDC and CA modes. For ENDC and CA, the module firmware chooses the Tx chain (antenna) based on resource allocation.
g. B30 DL only; n30 DL/UL
h. DL only band
i. B34 is restricted to 2x2 by FW (not HW)
j. GNSS is populated on EM9293P only — the EM9293P can use either ANT1 or GNSS (software-selectable, ANT1 by default). Note that GNSS is used for GNSS L1 only.

3.2 RF Connections

When attaching antennas to the module:

- LTE/5G NR Sub-6 GHz/GNSS receptacles (ANT0–ANT3):
  - Use RF plugs that are compatible with I-PEX (20449-001E (MHF 4)) RF receptacles.
  - Match coaxial connections between the module and the antenna to 50 Ω.
  - Minimize RF cable losses to the antenna; the recommended maximum cable loss for antenna cabling is 0.5 dB.
- (EM9293P only) Dedicated GNSS receptacle (GNSS):
  - Use only an RF plug connector that is compatible with I-PEX (20981-001E-02 (MHF 7S)) RF receptacles.
- To ensure best thermal performance, use the ground hole (if possible) to attach (ground) the device to a metal chassis.

Important: *Systems connected to a live network must have all four MHF 4 antennas (ANT0–ANT3) connected. (The dedicated GNSS antenna (GNSS) is only required if the dedicated GNSS antenna path is configured.)*

Note: If an antenna connection is shorted or open, the modem will not sustain permanent damage.

3.2.1 5G NR Sub-6 GHz/GNSS Antennas and Cabling

When selecting 5G NR Sub-6 GHz/GNSS antennas and cables, it is critical to RF performance to match antenna gain and cable loss.

Note: There is no explicit list of antennas required in the host platform. The PWB-6-60-RSMAP Wide Band 4G/5G Terminal Paddle Antenna has been verified as a reference. For detailed electrical performance criteria, see *Antenna Specification on page 20**.*

3.2.1.1 Choosing the Correct 5G NR Sub-6 GHz/GNSS Antenna and Cabling

When matching antennas and cabling:

- The antenna (and associated circuitry) should have a nominal impedance of 50 Ω with a return loss of better than 10 dB across each frequency band of operation.
- The system gain value affects both radiated power and regulatory (FCC, IC, CE, etc.) test results.

3.2.1.2 Determining the 5G NR Sub-6 GHz/GNSS Antenna's Location

When deciding where to put the antennas:

- Antenna location may affect RF performance. Although the module is shielded to prevent interference in most host platforms, the placement of the antenna is still very important — if the host platform is insufficiently shielded, high levels of broadband or spurious noise can degrade the module's performance.
- Connecting cables between the module and the antenna must have 50 Ω impedance. If the impedance of the module is mismatched, RF performance is reduced significantly.
- Antenna cables should be routed, if possible, away from noise sources (switching power supplies, LCD assemblies, etc.). If the cables are near the noise sources, the noise may be coupled into the RF cable and into the antenna. See Interference from Other Wireless Devices on page 14.

3.2.1.3 Disabling the Diversity Antenna

Certification testing of a device with an integrated EM929xP module may require the module's main and diversity antennas to be tested separately.

Note: For WCDMA, the diversity antenna is ANT2. For LTE and 5G, the diversity antenna will be ANT0–ANT3, dependent on the band combination. For example, some combinations may use ANT0, some may use ANT1, etc.

To facilitate this testing, receive diversity can be enabled / disabled using the following AT command:

- !RXDEN — Used to enable / disable diversity for single-cell call (no carrier aggregation).

Important: *Systems connected to a live network must have all four MHF 4 antennas (ANT0–ANT3) connected. (The dedicated GNSS antenna (GNSS) is only required if the dedicated GNSS antenna path is configured.)*

Note: A diversity antenna is used to improve connection quality and reliability through redundancy. Because two antennas may experience difference interference effects (signal distortion, delay, etc.), when one antenna receives a degraded signal, the other may not be similarly affected.

3.3 Shielding

The module is fully shielded to protect against EMI. The shield must not be removed.

3.4 Ground Connection

When connecting the module to system ground:

- Prevent noise leakage by establishing a very good ground connection to the module through the host connector.
- Connect to system ground using the ground hole shown in Figure 3-1 on page 10.
- Minimize ground noise leakage into the RF.
  Depending on the host board design, noise could potentially be coupled to the module from the host board. This is mainly an issue for host designs that have signals traveling along the length of the module, or circuitry operating at both ends of the module interconnects.

3.5 Interference and Sensitivity

Several interference sources can affect the module's RF performance (RF desense). Common sources include power supply noise and device-generated RF.

RF desense can be addressed through a combination of mitigation techniques (Methods to Mitigate Decreased Rx Performance on page 14) and radiated sensitivity measurement (Radiated Sensitivity Measurement on page 15).

3.5.1 Interference from Other Wireless Devices

Wireless devices operating inside the host device can cause interference that affects the module.

To determine the most suitable locations for antennas on your host device, evaluate each wireless device's radio system, considering the following:

- Any harmonics, sub-harmonics, or cross-products of signals generated by wireless devices that fall in the module's Rx range may cause spurious response, resulting in decreased Rx performance.
- The Tx power and corresponding broadband noise of other wireless devices may overload or increase the noise floor of the module's receiver, resulting in Rx desense.

The severity of this interference depends on the closeness of the other antennas to the module's antenna. To determine suitable locations for each wireless device's antenna, thoroughly evaluate your host device's design.

3.5.2 Host-generated RF Interference

All electronic computing devices generate RF interference that can negatively affect the receive sensitivity of the module.

Proximity of host electronics to the antenna in wireless devices can contribute to decreased Rx performance. Components that are most likely to cause this include:

- Microprocessor and memory
- Display panel and display drivers
- Switching-mode power supplies

3.5.3 Device-generated RF Interference

The module can cause interference with other devices. Wireless devices such as Sierra Wireless embedded modules transmit in bursts (pulse transients) for set durations (RF burst frequencies). Hearing aids and speakers convert these burst frequencies into audible frequencies, resulting in audible noise.

3.5.4 Methods to Mitigate Decreased Rx Performance

It is important to investigate sources of localized interference early in the design cycle. To reduce the effect of device-generated RF on Rx performance:

- Put the antenna as far as possible from sources of interference. The drawback is that the module may be less convenient to use.
- Shield the host device. The module itself is well shielded to avoid external interference. However, the antenna cannot be shielded for obvious reasons. In most instances, it is necessary to employ shielding on the components of the host device (such as the main processor and parallel bus) that have the highest RF emissions.
- Filter out unwanted high-order harmonic energy by using discrete filtering on low frequency lines.
- Form shielding layers around high-speed clock traces by using multi-layer PCBs.
- Route antenna cables away from noise sources.

3.5.5 Radiated Spurious Emissions (RSE)

When designing an antenna for use with Sierra Wireless embedded modules, the host device with an Sierra Wireless embedded module must satisfy any applicable standards / local regulatory bodies for radiated spurious emission (RSE) for receive-only mode and for transmit mode (transmitter is operating).

Note that antenna impedance affects radiated emissions, which must be compared against the conducted 50 Ω emissions baseline. (Sierra Wireless embedded modules meet the 50 Ω conducted emissions requirement.)

3.5.6 Radiated Sensitivity Measurement

A wireless host device contains many noise sources that contribute to a reduction in Rx performance.

Over-the-air (OTA) or radiated testing is done to determine the extent of any receiver performance desensitization due to self-generated noise in the host device. Receiver desensitization can show up as lower than expected radiated resistivity measurements.

3.5.7 Sensitivity vs. Frequency

Sensitivity definitions for supported RATs:

- UMTS bands — Sensitivity is defined as the input power level in dBm that produces a BER (Bit Error Rate) of 0.1%. Sensitivity should be measured at all UMTS frequencies across each band.
- LTE bands — Sensitivity is defined as the RF level at which throughput is 95% of maximum.
- 5G NR Sub-6 GHz bands — Sensitivity is defined as the RF level at which throughput is 95% of maximum.

3.6 Sounding Reference Signal

The EM929xP implements a Sounding Reference Signal (SRS) on specific 5G NR Sub-6 GHz bands (Table 3-3).

An SRS is an uplink reference signal that the UE transmits to the base station. This signal provides channel 'sounding' information (details about the uplink signal) that the base station uses to estimate the combined effect on uplink channel quality, including multipath fading, scattering, Doppler, and power loss.

Based on the channel quality, the base station can manage resource scheduling, beam management, and signal power control.

SRS can also implement antenna switching on the EM929xP by sending sequential SRS bursts on different device antennas. The base station analyzes the bursts, then indicates to the module which antennas are providing the best channel quality, and system performance is adjusted appropriately.

Table 3-3: SRS 5G NR Sub-6 GHz Band Support

	Band						
SRS type	n38	n40	n41	n48	n77	n78	n79
SRS_T1_R4[a]	Y	Y	Y	Y	Y	Y	Y
SRS_T2_R4[b]	—	—	Y	Y	Y	Y	Y

a. 1 Tx + 4 Rx
b. 2 Tx + 4 Rx

3.7 Supported RATs

The EM929xP module supports:

- 5G:
  - Multiple-band 5G — See Table 3-4 (supported bands) and Table 3-6 (5G NR bandwidth support).
  - 5G NR Carrier aggregation:
    - 5G NR Sub-6 GHz DLCA — For comprehensive details, refer to *EM9 Carrier Aggregations and EN-DC (Doc# 2174317)*.

- LTE:
  - Multiple-band LTE — See Table 3-4 (supported bands) and Table 3-5 on page 17 (LTE bandwidth support).
  - LTE Advanced carrier aggregation:
    - Intra-band contiguous and non-contiguous ULCA
    - Inter-band ULCA — Low band and mid-high band combinations.
    - For comprehensive details, refer to *EM9 Carrier Aggregations and EN-DC (Doc# 2174317)*.
- WCDMA:
  - Multiple-band WCDMA/HSPA/HSPA+/DC-HSPA+ — See Table 3-4.
  - Multiple-band WCDMA receive diversity
- inter-RAT and inter-frequency cell reselection and handover between supported frequency bands
- GNSS:
  - GPS, GLONASS, BeiDou, Galileo, QZSS, NavIC

3.7.1 Supported Bands

Table 3-4: Supported Frequency Bands, by RAT (5G NR/LTE/3G)

Band#	Mode	5G (n<band#)	LTE (B<band#>)	3G (Band<band#)	Frequency (Tx)	Frequency (Rx)
1	FDD	Y	Y	Y	1920–1980 MHz	2110–2170 MHz
2	FDD	Y	Y	Y	1850–1910 MHz	1930–1990 MHz
3	FDD	Y	Y	—	1710–1785 MHz	1805–1880 MHz
4	FDD	—	Y	Y	1710–1755 MHz	2110–2155 MHz
5	FDD	Y	Y	Y	824–849 MHz	869–894 MHz
7	FDD	Y	Y	—	2500–2570 MHz	2620–2690 MHz
8	FDD	Y	Y	Y	880–915 MHz	925–960 MHz
12	FDD	Y	Y	—	699–716 MHz	729–746 MHz
13	FDD	Y	Y	—	777–787 MHz	746–756 MHz
14	FDD	Y	Y	—	788–798 MHz	758–768 MHz
17	FDD	—	Y	—	704–716 MHz	734–746 MHz
18	FDD	Y	Y	—	815–830 MHz	860–875 MHz
19	FDD	—	Y	Y	830–845 MHz	875–890 MHz
20	FDD	Y	Y	—	832–862 MHz	791–821 MHz
25	FDD	Y	Y	—	1850–1915 MHz	1930–1995 MHz
26	FDD	Y	Y	—	814–849 MHz	859–894 MHz
28	FDD	Y	Y	—	703–748 MHz	758–803 MHz
29[d]	FDD	Y	Y	—	n/a	717–728 MHz
30	FDD	Y	Y	—	n30: 2305–2315 MHz B30: n/a[a]	2350–2360 MHz
32[b]	FDD	—	Y	—	n/a	1452–1496 MHz
34	TDD	—	Y	—	2010–2025 MHz (TDD)	

Table 3-4: Supported Frequency Bands, by RAT (5G NR / LTE / 3G) (Continued)

Band#	Mode	5G (n<band#)	LTE (B<band#>)	3G (Band<band#)	Frequency (Tx)	Frequency (Rx)
38	TDD	Y	Y	—	2570–2620 MHz (TDD)	
39	TDD	—	Y	—	1880–1920 MHz (TDD)	
40	TDD	Y	Y	—	2300–2400 MHz (TDD)	
41	TDD	Y	Y	—	2496–2690 MHz (TDD)	
42	TDD	—	Y	—	3400–3600 MHz (TDD)	
43	TDD	—	Y	—	3600–3800 MHz (TDD)	
46[c]	TDD	—	Y	—	n/a	5150–5925 MHz (TDD)
48	TDD	Y	Y	—	3550–3700 MHz (TDD)	
66	FDD	Y	Y	—	1710–1780 MHz	2110–2200 MHz
70	FDD	Y	—	—	1695–1710 MHz	1995–2020 MHz
71	FDD	Y	Y	—	663–698 MHz	617–652 MHz
75[d]	FDD	Y	—	—	n/a	1432–1517 MHz
76[d]	FDD	Y	—	—	n/a	1427–1432 MHz
77	TDD	Y	—	—	3300–4200 MHz (TDD)	
78	TDD	Y	—	—	3300–3800 MHz (TDD)	
79	TDD	Y	—	—	4400–5000 MHz (TDD)	
106	FDD	—	Y	—	896–901 MHz	935–940 MHz

a. LTE B30 downlink only
b. Downlink only
c. LTE-LAA B46 (downlink only)
d. SDL (Supplementary Downlink) only, for 5G SA only

Table 3-5: LTE Bandwidth Support[ab]

Band	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
B1	—	—	Y	Y	Y	Y
B2	Y	Y	Y	Y	Y[c]	Y[c]
B3	Y	Y	Y	Y	Y[c]	Y[c]
B4	Y	Y	Y	Y	Y	Y
B5	Y	Y	Y	Y[c]	—	—
B7	—	—	Y	Y	Y[d]	Y[c,d]
B8	Y	Y	Y	Y[c]	—	—
B12	Y	Y	Y[c]	Y[c]	—	—
B13	—	—	Y[c]	Y[c]	—	—
B14	—	—	Y[c]	Y[c]	—	—
B17	—	—	Y[c]	Y[c]	—	—

Table 3-5: LTE Bandwidth Support[ab] (Continued)

Band	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
B18	—	—	Y	Y[c]	Y[c]	—
B19	—	—	Y	Y[c]	Y[c]	—
B20	—	—	Y	Y[c]	Y[c]	Y[c]
B25	Y	Y	Y	Y	Y[c]	Y[c]
B26	Y	Y	Y	Y[c]	Y[c]	—
B28	—	Y	Y	Y[c]	Y[c]	Y[c,e]
B29	—	Y	Y	Y[c]	—	—
B30[f]	—	—	Y	Y[c]	—	—
B32	—	—	Y	Y	Y	Y
B34	—	—	Y	Y	Y	—
B38	—	—	Y	Y	Y[d]	Y[d]
B39	—	—	Y	Y	Y[d]	Y[d]
B40	—	—	Y	Y	Y	Y
B41	—	—	Y	Y	Y	Y
B42	—	—	Y	Y	Y	Y
B43	—	—	Y	Y	Y	Y
B46[g]	—	—	—	Y	—	Y
B48	—	—	Y	Y	Y	Y
B66	Y	Y	Y	Y	Y	Y
B71	—	—	Y	Y[c]	Y[c]	Y[c,h]
B106	Y	Y	—	—	—	—

a. Support provided by module hardware/firmware. Carrier PRI configurations and regulatory body requirements may limit the supported bandwidths in customer applications.
b. Table contents are derived from 3GPP TS 36.521-1 v15.5.0, table 5.4.2.1-1.
c. Bandwidth for which a relaxation of the specified UE receiver sensitivity requirement (Clause 7.3 of 3GPP TS 36.521-1 v15.5.0) is allowed.
d. Bandwidth for which uplink transmission bandwidth can be restricted by the network for some channel assignments in FDD/TDD co-existence scenarios in order to meet unwanted emissions requirements (Clause 6.6.3.2 of 3GPP TS 36.521-1 v15.5.0).
e. For the 20 MHz bandwidth, the minimum requirements are specified for EUTRA UL carrier frequencies confined to either 713–723 MHz or 728–738 MHz.
f. DL only
g. LTE-LAA B46 (downlink only), used only in LTE CA
h. For the 20 MHz bandwidth, the minimum requirements are specified for EUTRA UL carrier frequencies confined to either 673–678 MHz or 683–688 MHz.

Table 3-6: 5G NR Bandwidth and 5G Architecture Support

Band	SCS	Bandwidth (MHz) (Default architecture support: N — Non-Standalone; S — Standalone; B — Both (N+S))													
		5	10	15	20	25	30	35	40	50	60	70	80	90	100
n1	15	B	B	B	B	B	B	—	B	—	—	—	—	—	—

Table 3-6: 5G NR Bandwidth and 5G Architecture Support (Continued)

Band	SCS	Bandwidth (MHz) (Default architecture support: N — Non-Standalone; S — Standalone; B — Both (N+S))													
		5	10	15	20	25	30	35	40	50	60	70	80	90	100
n2	15	B	B	B	B	—	—	—	—	—	—	—	—	—	—
n3	15	B	B	B	B	B	B	—	B[a]	—	—	—	—	—	—
n5	15	B	B	B	B	B[b]	—	—	—	—	—	—	—	—	—
n7	15	B	B	B	B	B	B	—	B	—	—	—	—	—	—
n8	15	B	B	B	B	—	—	B[b]	—	—	—	—	—	—	—
n12	15	B	B	B	—	—	—	—	—	—	—	—	—	—	—
n13	15	S	S	—	—	—	—	—	—	—	—	—	—	—	—
n14	15	B	B	—	—	—	—	—	—	—	—	—	—	—	—
n18	15	S	S	S	—	—	—	—	—	—	—	—	—	—	—
n20	15	B	B	B	B	—	—	—	—	—	—	—	—	—	—
n25	15	B	B	B	B	B	B	—	B	—	—	—	—	—	—
n26	15	S	S	S	S	—	—	—	—	—	—	—	—	—	—
n28	15	B	B	B	B	—	B	—	—	—	—	—	—	—	—
n29	15	B[b]	B[b]	—	—	—	—	—	—	—	—	—	—	—	—
n30	15	B	B	—	—	—	—	—	—	—	—	—	—	—	—
n38	30	—	B	B	B	—	B	—	B	—	—	—	—	—	—
n40	30	—	B	B	B	—	B	—	B	B	B	—	B	B[b]	B[b]
n41[c]	30	—	B	B	B	—	B	—	B	▪ S ▪ N[d]	▪ S ▪ N[d]	—	▪ S ▪ N[d]	▪ S ▪ N[d]	▪ S ▪ N[d]
n48	30	—	B	B	B	—	B	—	B	B[b]	B[b]	—	B[b]	B[b]	B[b]
n66	15	B	B	B	B	B	B	—	B	—	—	—	—	—	—
n70	15	S	S	S	S[b]	S[b]	—	—	—	—	—	—	—	—	—
n71	15	B	B	B	B	B[b]	B[b]	B[b]	—	—	—	—	—	—	—
n75	15	B[b]	B[b]	B[b]	B[b]	B[b,a]	B[b,a]	—	—	—	—	—	—	—	—
n76	15	B[b]	—	—	—	—	—	—	—	—	—	—	—	—	—
n77	30	—	B	B	B	—	B	—	B	B	B	B	B	B	B
n78	30	—	B	B	B	—	B	—	B	B	B	B	B	B	B
n79	30	—	—	—	—	—	—	—	B	B	B	—	B	—	B

a. non-3GPP BW (3GPP TS 38.521-1 V17.4.0 (2022-03)
b. DL only
c. n41 BW support:
   - UL — Up to 40 MHz (ENDC/UL MIMO mode) or 100 MHz (5G NR SA mode)
   - DL — Up to 100 MHz
d. DL only in ENDC/UL MIMO mode

3.8 Antenna Specification

This section describes recommended electrical performance criteria for Sub-6G and GNSS antennas used with Sierra Wireless embedded modules.

The performance specifications described in this section are valid while antennas are mounted in the host device with antenna feed cables routed in their final application configuration.

*Note: Antennas should be designed **before** the industrial design is finished to make sure that the best antennas can be developed.*

3.8.1 Recommended WWAN Antenna Specifications

Important: *Specifications included in Table 3-7 are DRAFT, and are intended **only** to identify the general parameters that will be fully defined in subsequent revisions of this document.*

Table 3-7: Antenna Requirements[ab]

Parameter	Requirements	Comments
Antenna system	▪ NR/LTE: External multi-band 4×4 DL MIMO antenna system — ANT0, ANT1, ANT2, ANT3 ▪ 3G: External multi-band antenna system with diversity — ANT0, ANT2	If an antenna includes GNSS, it must also satisfy requirements in Table 3-8 on page 22.
Antenna frequency ranges	▪ ANT0 — 617–5925 MHz ▪ ANT1 — 1164–5000 MHz ▪ ANT2 — 617–5000 MHz ▪ ANT3 — 1427–5925 MHz	
VSWR	▪ ANT0, ANT1, ANT2, ANT3: · < 2:1 (recommended) · < 3:1 (worst case)	On all bands including band edges
Total radiated efficiency	> 50% on all bands	▪ Measured at the RF receptacle. ▪ Includes mismatch losses, losses in the matching circuit, and antenna losses, excluding cable loss. ▪ Sierra Wireless recommends using antenna efficiency as the primary parameter for evaluating the antenna system. ▪ Peak gain is not a good indication of antenna performance when integrated with a host device (the antenna does not provide omni-directional gain patterns). Peak gain can be affected by antenna size, location, design type, etc. — the antenna gain patterns remain fixed unless one or more of these parameters change.
Radiation patterns	Nominally omni-directional radiation pattern in azimuth plane.	

Table 3-7: Antenna Requirements[ab] (Continued)

Parameter	Requirements	Comments
Envelope correlation coefficient	Between receiving antennas: ▪ < 0.5 on Rx bands below 960 MHz ▪ < 0.2 on Rx bands above 1.4 GHz	To identify the receiving antennas for any band, refer to Table 3-2 on page 11.
Mean Effective Gain (MEG)	Receiving antennas: ▪ ≥ -3 dBi	To identify the receiving antennas for any band, refer to Table 3-2 on page 11.
Mean Effective Gain Imbalance $\left\lvert\frac{MEGx}{MEGy}\right\rvert$	Between any two antennas: ▪ < 2 dB for MIMO operation ▪ < 6 dB for diversity operation	
Maximum antenna gain	Must not exceed antenna gains due to RF exposure and ERP/EIRP limits, as listed in the module's FCC grant.	See Important Compliance Information for the United States on page 23.
Isolation	▪ B41: >20 dB between transmitting antennas ▪ UL MIMO: >20 dB (PC1.5, PC2, PC3) between transmitting antennas to avoid potential ACLR and EVM issues ▪ All antennas for all other bands/ scenarios: >10 dB	▪ To identify the transmitting antennas for any band, refer to Table 3-2 on page 11. ▪ If antennas can be moved, test all positions for both antennas. ▪ Make sure all other wireless devices (Bluetooth or WLAN antennas, etc.) are turned OFF to avoid interference.
Maximum input power at antenna port	▪ ANT0 — 10 dBm ▪ ANT1 — 10 dBm (*0 dBm — see Comment) ▪ ANT2 — 10 dBm ▪ ANT3 — 10 dBm ▪ GNSS — 10 dBm	***Important:** GPS inband signal on ANT1 must be < 0 dBm to avoid damaging LNA.
Power handling	▪ > 1 W	▪ Measure power endurance over 4 hours (estimated talk time) using a 1 W CW signal — set the CW test signal frequency to the middle of each supporting Tx band. ▪ Visually inspect device to ensure there is no damage to the antenna structure and matching components. ▪ VSWR/TIS/TRP measurements taken before and after this test must show similar results.

a. Preliminary values, subject to change.
b. These worst-case VSWR figures for the transmitter bands may not guarantee RSE levels to be within regulatory limits. The device alone meets all regulatory emissions limits when tested into a cabled (conducted) 50 Ω system. With antenna designs with up to 2.5:1 VSWR or worse, the radiated emissions could exceed limits. The antenna system may need to be tuned in order to meet the RSE limits as the complex match between the module and antenna can cause unwanted levels of emissions. Tuning may include antenna pattern changes, phase/delay adjustment, and passive component matching. Examples of the application test limits would be included in FCC Part 22, Part 24 and Part 27,test case 4.2.2 for WCDMA (ETSI EN 301 908-1), where applicable.

3.8.2 Recommended GNSS Antenna Specifications

Table 3-8: GNSS Antenna Requirements

Parameter	Requirements	Comments
Frequency range	▪ GNSS L1: 1563–1587 MHz ▪ GNSS L5: 1164–1189 MHz ▪ GPS/QZSS L1: 1575.42 MHz ±2 MHz ▪ GPS/QZSS L5: 1176 MHz ±2 MHz ▪ Galileo E1: 1559–1591 MHz ▪ Galileo E5a: 1164–1189 MHz ▪ BeiDou B1I: 1559–1563 MHz ▪ BeiDou B1C: 1559–1591 MHz ▪ BeiDou B2a: 1166–1186 MHz ▪ GLONASS G1: 1593–1610 MHz ▪ NavIC L5: 1164–1189 MHz	These ranges include a buffer zone to ensure coverage of the GNSS frequencies.
Field of view (FOV)	▪ Omni-directional in azimuth ▪ -45° to +90° in elevation	
Polarization (average Gv/Gh)	> 0 dB	Vertical linear polarization is sufficient.
Free space average gain (Gv+Gh) over FOV	> -6 dBi (preferably > -3 dBi)	Gv and Gh are measured and averaged over -45° to +90° in elevation, and ±180° in azimuth.
Gain	▪ Maximum gain and uniform coverage in the high elevation angle and zenith. ▪ Gain in azimuth plane is not desired.	
Average 3D gain	> -5 dBi	
Isolation between GNSS and transmitting antennas	> 15 dB in all uplink bands and GNSS Rx bands	
Typical VSWR	< 2.5:1	
Polarization	Any other than LHCP (left-hand circular polarized) is acceptable.	
Active GNSS antenna	▪ EM929xP: Active antenna must not be used on shared path (ANT1). ▪ EM9293P: Active antenna can be used on dedicated path (GNSS).	**Important:** *Do not connect an active antenna/DC presence to **any** of the shared antennas (ANT0–ANT3). Doing so will damage the module.*

4: Regulatory Compliance and Industry Certifications

This chapter describes the current certification status of the EM9291P and EM9293P (hereinafter collectively referred to as "EM929xP") modules. Certifications in other countries may be attained upon customer request—contact your Sierra Wireless account representative for details.

Additional testing and certification may be required for the host product with an embedded EM929xP module and are the responsibility of the host product manufacturer. Sierra Wireless offers professional services-based assistance to host product manufacturers with the testing and certification process, if required.

4.1 Regulatory Compliance

The EM929xP module, upon commercial release, will meet the requirements of the following regulatory bodies and regulations, where applicable:

- Federal Communications Commission (FCC) of the United States
- Innovation, Science and Economic Development Canada (ISED)
- Radio Equipment Directive (RED) and RoHS Directive of the European Union
- Japan Ministry of Internal Affairs and Communications (MIC)
- The National Communications Commission (NCC) of Taiwan, Republic of China

4.1.1 Important Compliance Information for the United States

The EM929xP module has been granted modular approval for mobile applications under:

- FCC ID: N7NEM92P

Integrators may use the EM929xP module in their host products without additional FCC certification if they meet the following conditions. Otherwise, additional FCC approvals must be obtained.

1. At least 20 cm separation distance between the antenna and the user's body must be maintained at all times.
2. To comply with FCC regulations limiting both maximum RF output power and human exposure to RF radiation, the maximum antenna gain including cable loss in a mobile-only exposure condition must not exceed the limits stipulated in Table 4-1.
3. The EM929xP module may transmit simultaneously with other collocated radio transmitters within a host product, provided the following conditions are met:
   - Each collocated radio transmitter has been certified by FCC for mobile application.
   - At least 20 cm separation distance between the antennas of the collocated transmitters and the user's body must be maintained at all times.
   - The radiated power of a collocated transmitter must not exceed the EIRP limit stipulated in Table 4-1.

Table 4-1: FCC Antenna Gain and Collocated Radio Transmitter Specifications

	Operating mode	Tx Freq Range (MHz)		Antenna Gain Limit (dBi)	
				Standalone	Collocated
EM929xP	WCDMA Band 2	1850	1910	7.5	7.5
	WCDMA Band 4	1710	1755	4.5	4.5
	WCDMA Band 5	824	849	8.5	8.0

Table 4-1: FCC Antenna Gain and Collocated Radio Transmitter Specifications (Continued)

	Operating mode	Tx Freq Range (MHz)		Antenna Gain Limit (dBi)	
				Standalone	Collocated
	LTE B2	1850	1910	7.5	7.5
	LTE B4	1710	1755	4.5	4.5
	LTE B5	824	849	8.5	8.0
	LTE B7	2500	2570	5.5	5.5
	LTE B12	699	716	8.0	7.5
	LTE B13	777	787	8.5	8.0
	LTE B14	788	798	8.5	8.0
	LTE B17	704	716	9.5	8.0
	LTE B25	1850	1915	7.5	7.5
	LTE B26	814	849	8.5	8.0
	LTE B41_PC3	2496	2690	5.5	5.5
	LTE B41_PC2	2496	2690	5.5	5.5
	LTE B42_PC3	3450	3550	4.0	4.0
	LTE B42_PC2	3450	3550	4.0	4.0
	LTE B48**	3550	3700	-1.0	-1.0
	LTE B66	1710	1780	4.5	4.5
	LTE B71	663	698	7.5	7.5
	LTE B106	897.5	900.5	10.0	10.0
	5G NR n2	1850	1910	7.5	7.5
	5G NR n5	824	849	8.5	7.5
	5G NR n7	2500	2570	5.5	5.5
	5G NR n12	699	716	8.0	7.5
	5G NR n13	777	787	8.5	8.0
	5G NR n14	788	798	8.5	8.0
	5G NR n25	1850	1915	7.5	7.5
	5G NR n26	814	849	8.5	8.0
	5G NR n30*	2305	2315	-1.5	-1.5
	5G NR n41_PC3	2496	2690	5.5	5.5
	5G NR n41_PC2	2496	2690	5.5	5.5
	5G NR n41_PC1.5	2496	2690	2.5	2.5
	5G NR n48**	3550	3700	-2.5	-2.5

Table 4-1: FCC Antenna Gain and Collocated Radio Transmitter Specifications (Continued)

	Operating mode	Tx Freq Range (MHz)		Antenna Gain Limit (dBi)	
				Standalone	Collocated
	5G NR n66	1710	1780	4.5	4.5
	5G NR n70	1695	1710	4.5	4.5
	5G NR n71	663	698	7.5	7.5
	5G NR n77_PC3	3450	3550	2.5	2.5
	5G NR n77_PC2	3450	3550	2.5	2.5
	5G NR n77_PC1.5	3450	3550	-0.5	-0.5
	5G NR n78_PC3	3450	3550	2.5	2.5
	5G NR n78_PC2	3450	3550	2.5	2.5
	5G NR n78_PC1.5	3450	3550	-0.5	-0.5
Collocated transmitters				Maximum EIRP (dBm)	
	WLAN 2.4 GHz	2400	2500	25.0	
	WLAN 5 GHz	5150	5850	25.0	
	WLAN 6 GHz	5925	7125	25.0	
	Bluetooth	2400	2500	20.0	

***Important:** *The FCC has a strict EIRP limit in band n30 for mobile and portable stations in order to protect adjacent satellite radio, aeronautical mobile telemetry, and deep space network operations. Mobile and portable stations must not have antenna gain exceeding -1.5 dBi in band n30. Additionally, the FCC prohibits the use of external vehicle-mounted antennas for mobile and portable stations in this band.*

Fixed stations may often use antennas with higher gain due to increased EIRP limits. For example in band n30, EM929xP modules used as fixed customer premises equipment (CPE) stations in the United States may have an antenna gain up to 7.5 dBi in band n30, subject to other operating conditions stipulated in FCC Part 27.

Mobile carriers often have limits on total radiated power (TRP), which requires an efficient antenna. The host product with an embedded module must output sufficient power to meet the TRP requirement but not too much to exceed FCC's EIRP limit. If you need assistance in meeting this requirement, please contact Sierra Wireless.

****Important:** *Airborne operations in LTE Band 48 / 5G NR n48 are prohibited.*

4. A label must be affixed to the outside of the host product into which the EM929xP module is incorporated, with a statement similar to the following:
   - **This device contains FCC ID: N7NEM92P.**
5. A user manual with the host product must clearly indicate the operating requirements and conditions that must be observed to ensure compliance with current FCC RF exposure guidelines.

Note: Host product manufacturers are responsible for the overall compliance of the host products including, where applicable, all additional equipment authorization and testing not covered by the modular approval (e.g., unintentional radiator FCC Part 15 Subpart B requirements, and RF exposure requirements for host products intended for use within 20 cm of the user's body.)

4.2 Industry Certifications

The EM929xP module complies with the mandatory requirements described in the following standards. The exact set of requirements supported is network operator-dependent.

Table 4-2: Standards Compliance

RAT	Standards
5G NR Sub-6 GHz	▪ 3GPP Release 16
LTE	▪ 3GPP Release 16
UMTS	▪ 3GPP Release 9

The following industry certifications have been obtained, where applicable:

- GCF
- PTCRB

A: Abbreviations

Table A-1: Abbreviations and Definitions

Abbreviation or Term	Definition
3GPP	3rd Generation Partnership Project
ACLR	Adjacent channel leakage ratio
BDS	See BeiDou
BeiDou	BeiDou Navigation Satellite System A Chinese system that uses a series of satellites in geostationary orbit and Medium Earth Orbit (MEO) to provide navigational data.
BER	Bit Error Rate — A measure of receive sensitivity
BLER	Block Error Rate
Bluetooth	Wireless protocol for data exchange over short distances
CPE	Customer-Premises Equipment
CW	Continuous waveform
dB	Decibel = 10 x $\log_{10}$ (P1 / P2) *P1 is calculated power; P2 is reference power* Decibel = 20 x $\log_{10}$ (V1 / V2) *V1 is calculated voltage, V2 is reference voltage*
dBm	A logarithmic (base 10) measure of relative power (dB for decibels); relative to milliwatts (m). A dBm value will be 30 units (1000 times) larger (less negative) than a dBW value, because of the difference in scale (milliwatts vs. watts).
DC-HSPA+	Dual Carrier HSPA+
DL	Downlink (network to mobile)
EIRP	Effective (or Equivalent) Isotropic Radiated Power
EMC	Electromagnetic Compatibility
ENDC	E-UTRAN New Radio — Dual Connectivity
ERP	Effective Radiated Power
ESD	Electrostatic Discharge
EVM	Error vector magnitude
FCC	Federal Communications Commission The U.S. federal agency that is responsible for interstate and foreign communications. The FCC regulates commercial and private radio spectrum management, sets rates for communications services, determines standards for equipment, and controls broadcast licensing. Consult www.fcc.gov.
FDD	Frequency Division Duplexing (Spectrum usage technique where uplink and downlink are carried on different frequencies)

Table A-1: Abbreviations and Definitions (Continued)

Abbreviation or Term	Definition
firmware	Software stored in ROM or EEPROM; essential programs that remain even when the system is turned off. Firmware is easier to change than hardware but more permanent than software stored on disk.
FOV	Field Of View
Galileo	A European system that uses a series of satellites in Medium Earth Orbit (MEO) to provide navigational data.
GCF	Global Certification Forum
GLONASS	Global Navigation Satellite System — A Russian system that uses a series of 24+ satellites in Medium Earth Orbit (MEO) to provide navigational data.
GNSS	Global Navigation Satellite Systems (GPS, QZXX, GLONASS, BeiDou, and Galileo)
GPS	Global Positioning System An American system that uses a series of 24–32 satellites in Medium Earth Orbit (MEO) to provide navigational data.
HB	High Band
Host	The device into which an embedded module is integrated
HSDPA	High Speed Downlink Packet Access
HSPA+	Enhanced HSPA, as defined in 3GPP Release 7 and beyond
HSUPA	High Speed Uplink Packet Access
Hz	Hertz = 1 cycle/second
IC	Industry Canada
IF	Intermediate Frequency
inrush current	Peak current drawn when a device is connected or powered on
inter-RAT	Radio Access Technology
IOT	Interoperability Testing
IS	Interim Standard. After receiving industry consensus, the TIA forwards the standard to ANSI for approval.
ISED	Innovation, Science and Economic Development Canada (formerly Industry Canada (IC))
LAA	Licensed Assisted Access
LB	Low Band
LED	Light Emitting Diode. A semiconductor diode that emits visible or infrared light.
LHCP	Left-Hand Circular Polarized
LNA	Low Noise Amplifier
LTE	Long Term Evolution—a high-performance air interface for cellular mobile communication systems.

Table A-1: Abbreviations and Definitions (Continued)

Abbreviation or Term	Definition
MB	Mid Band
MEO	Medium Earth Orbit
MHz	Megahertz = 10e6 Hz
MIMO	Multiple Input Multiple Output—wireless antenna technology that uses multiple antennas at both transmitter and receiver side. This improves performance.
MSAS	Multi-functional Satellite Augmentation System (SBAS for GPS)
NAS/AS	Network Access Server
NC	No Connect
NMEA	National Marine Electronics Association
NSA	5G Non-standalone architecture
OTA	'Over the air' (or radiated through the antenna)
PA	Power Amplifier
packet	A short, fixed-length block of data, including a header, that is transmitted as a unit in a communications network.
PC	Power Class
PCB	Printed Circuit Board
PCS	Personal Communication System A cellular communication infrastructure that uses the 1.9 GHz radio spectrum.
PTCRB	PCS Type Certification Review Board
QZSS	Quasi-Zenith Satellite System — Japanese system for satellite-based augmentation of GPS.
RAT	Radio Access Technology
RF	Radio Frequency
RI	Ring Indicator
roaming	A cellular subscriber is in an area where service is obtained from a cellular service provider that is not the subscriber's provider.
RSE	Radiated Spurious Emissions
RSSI	Received Signal Strength Indication
S/N	Signal-to-noise (ratio)
SA	5G Standalone architecture
SAR	Specific Absorption Rate
SBAS	Satellite-based Augmentation System
SCC	Secondary Component Carrier

Table A-1: Abbreviations and Definitions (Continued)

Abbreviation or Term	Definition
SCS	Subcarrier Spacing
SDK	Software Development Kit
SDL	Supplementary Downlink (Downlink-only frequency band providing additional carrier aggregation capacity)
SED	Smart Error Detection
Sensitivity (Audio)	Measure of lowest power signal that the receiver can measure.
Sensitivity (RF)	Measure of lowest power signal at the receiver input that can provide a prescribed BER/BLER/SNR value at the receiver output.
SG	An LTE signaling interface for SMS ("SMS over SGs")
SIB	System Information Block
SIM	Subscriber Identity Module. Also referred to as USIM or UICC.
SIMO	Single Input Multiple Output—smart antenna technology that uses a single antenna at the transmitter side and multiple antennas at the receiver side. This improves performance and security.
SISO	Single Input Single Output—antenna technology that uses a single antenna at both the transmitter side and the receiver side.
SKU	Stock Keeping Unit—identifies an inventory item: a unique code, consisting of numbers or letters and numbers, assigned to a product by a retailer for purposes of identification and inventory control.
SMS	Short Message Service. A feature that allows users of a wireless device on a wireless network to receive or transmit short electronic alphanumeric messages (up to 160 characters, depending on the service provider).
SNR	Signal-to-Noise Ratio
SOF	Start of Frame — A USB function.
SRB	Signaling Radio Bearer
SSS	Secondary synchronization signal.
SUPL	Secure User Plane Location
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TDD	Time Division Duplexing (Spectrum usage technique where single frequency is used for alternating uplink and downlink)
TIA/EIA	Telecommunications Industry Association / Electronics Industry Association. A standards setting trade organization, whose members provide communications and information technology products, systems, distribution services and professional services in the United States and around the world. Consult www.tiaonline.org.
TIS	Total Isotropic Sensitivity
TRP	Total Radiated Power
TRX	Transceiver Transmits and receives signals

Table A-1: Abbreviations and Definitions (Continued)

Abbreviation or Term	Definition
UDK	Universal Development Kit (for PCI Express Mini Cards)
UE	User Equipment
UHB	Ultra-High Band
UICC	Universal Integrated Circuit Card (Also referred to as a SIM card.)
UL	Uplink (mobile to network)
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
USIM	Universal Subscriber Identity Module (UMTS)
VCC	Supply voltage
VDC	Volts DC
VSWR	Voltage Standing Wave Ratio
WAAS	Wide Area Augmentation System (SBAS for GPS)
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access (also referred to as UMTS)
WLAN	Wireless Local Area Network
ZIF	Zero Intermediate Frequency
ZUC	ZUC stream cypher