



# EM919X/EM7690

## Product Technical Specification



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## Revision History

Revision number	Release date	Changes
0.1-Draft	October 17, 2019	Preliminary release
0.2-Draft	November 15, 2019	Updated pinouts, RF and connectors, mechanical drawings, and thermal notes, some power consumptions changed to TBD
0.3-Draft	November 29, 2019	Cleaned up a few pinout descriptions, updated module control signals, added notes for optional signals, removed band of n8, updated 5G UL modulation, added preliminary CA and EN-DC tables
0.4-Draft	March 6, 2020	Updated M.2 pinout to have both USB3.1 and PCIe signals, added PCIE_DIS for interface selection, updated M.2 port configuration, added 3 VCC pins, added ANT_CTRLx pins, changed to use MHF7S connectors, added figures of USB3, specified maximum sink current for WWAN_LED#, updated supported NR bands and bandwidth in 4.6, updated typical conducted Rx sensitivities in 4.7, updated 5G NR data rates, updated MIMO support descriptions, added notes for CA/EN-DC, updated power state transition trigger levels, removed GNSS features of 10Hz and SBAS, added production testing with reference document.

Revision number	Release date	Changes
0.5-Draft	May 12, 2020	Corrected some data rates in Table 1-1, updated system block diagram, added VCC peak and continuous current spec, updated RESET# timing, updated PCIe/USB descriptions and power on/off timing diagrams and parameters, updated mmWave IF ports assignment, updated GNSS specifications, updated power consumption data, updated MHF7S part numbers, added mmWave guidelines reference document, removed intra-band EN-DC on n41.
0.6-Draft	June 24, 2020	Changed to EM919X/EM7690 to include EM9190, EM9191 and EM7690. Updated power consumption, updated RESET timing, added ESDC compliance, updated RF sensitivity, updated DPR of SAR backoff control, updated mechanical drawings, added weight information, updated antenna gain and collocated radio transmitter specifications, updated FCC ID and IC, added FCC compliance standards.
0.7-Draft	July 31, 2020	Added variants information, specified EM9191 data rate, added bands n7, n8, n12, n20, n25, n38, n40, n48 and B43 support in future release, clarified RF power class and B41 standalone HPUE, updated bandwidth support for some bands, updated some NR conducted Rx sensitivity, added some notes for PCIe interface, added non-sleep mode standby power consumption, updated mechanical and environmental specifications, updated mechanical drawings, updated CA and EN-DC tables, added a few reference documents.
0.8-Draft	August 27, 2020	Updated EM9191 variant information, updated EM9191 DL throughput, updated n41 DL MIMO, added 42C for Intra-band ULCA, updated B71 bandwidth support, added a note for B46 Conducted Rx Sensitivity, updated Tx Power Control and moved to section 3.7, updated power supply/consumption spec for EM9190, EM9191 and EM7690 respectively, updated CA and EN-DC tables based on updated EM9191 capability, updated a few reference documents.
1	October 30, 2020	Removed USB2.0 backward-compatible references Updated resistor value - Figure 3-7 Recommended Wireless Disable Connection Updated 3.6.6 PCIe_DIS - Interface Selection Updated Table 5-1 Averaged Standby DC Power Consumption Added test data footnote - Table 5-2 Averaged Call Mode DC Power Consumption Added footnote - Table 5-5 Power State Transition Trigger Levels Updated PLA_S2# signal details - Figure 5-2 Power On/Off Timing for PCIe Port, and Table 5-6 PCIe Timing
2	November 04, 2020	Updated Table 5-1 Averaged Standby DC Power Consumption Updated Figure 7-5 Unit Product Marking Example

Revision number	Release date	Changes
3	July, 2021	<p>B42/B48 enabled</p> <p>Updated <a href="#">Table 1-1, Module Variants</a>, on page 14</p> <p>Updated <a href="#">Table 1-2, RF Band Support</a>, on page 15</p> <p>Updated <a href="#">Table 1-3, Required Host-Module Connectors</a>, on page 20</p> <p>Updated <a href="#">Host Interface Features</a> on page 17</p> <p>Updated <a href="#">Modem Features</a> on page 17</p> <p>Updated <a href="#">5G Features</a> on page 18</p> <p>Updated <a href="#">LTE Features</a> on page 18</p> <p>Updated <a href="#">USB Interface</a> on page 30 (USB 2.0 operation note)</p> <p>Updated <a href="#">Table 3-1, Host Interface (75-pin) Connections—Module View</a>, on page 25 (removed Coexistence)</p> <p>Updated <a href="#">Table 3-2, Power Supply Requirements</a>, on page 30 (removed VCC footnote)</p> <p>Updated <a href="#">PCIE_PEWAKE_N</a> on page 33</p> <p>Updated <a href="#">Table 4-1, Antenna Connectors—RF Technology Support</a>, on page 43</p> <p>Updated <a href="#">RF Connections</a> on page 45 (mmWave connector part number)</p> <p>Updated <a href="#">Table 4-4, Supported Frequency Bands, by RAT (5G/LTE/3G)</a>, on page 49</p> <p>Updated <a href="#">Table 4-6, EM919x NR Bandwidth and 5G Architecture Support</a>, on page 52</p> <p>Updated <a href="#">Table 4-9, Typical Conducted Rx Sensitivity—NR Bands</a>, on page 54</p> <p>Updated <a href="#">Table 4-10, Typical Conducted Rx (Receive) Sensitivity—LTE Bands at 10 MHz BW</a>, on page 55</p> <p>Updated <a href="#">Table 4-12, Conducted Maximum Tx (Transmit) Power Tolerances</a>, on page 57</p> <p>Updated <a href="#">Table 5-2, Averaged Call Mode DC Power Consumption</a>, on page 60</p> <p>Updated <a href="#">Power On/Off Timing for PCIe Port</a> on page 64</p> <p>Updated <a href="#">Table 5-6, PCIe Timing</a>, on page 65</p> <p>Updated <a href="#">Required Shutdown Sequence</a> on page 66</p> <p>Updated <a href="#">Software</a> on page 68</p> <p>Updated <a href="#">Table 8-1, Antenna Gain and Collocated Radio Transmitter Specifications</a>, on page 79</p> <p>Updated <a href="#">Table A-3, Low Power/High Power mmWave Antenna Comparison</a>, on page 84 (EIRP value)</p> <p>Updated <a href="#">Low Power mmWave Antenna Modules</a> on page 84</p> <p>Updated <a href="#">High Power mmWave Antenna Modules</a> on page 85</p> <p>Updated <a href="#">Table E-1, Hardware Integration Design Considerations</a>, on page 89 (removed Host/Modem Communication)</p>
4	October 2021	<p>Updated <a href="#">Table 1-1</a>—consolidated content</p> <p>Updated <a href="#">Table 1-2</a>—consolidated content</p> <p>Renamed Supported Frequencies section to <a href="#">Supported RATs</a>, added subsection headings</p> <p>Updated <a href="#">Table 4-9</a>—corrected n40 worst case sensitivity requirement</p> <p>Updated <a href="#">Table 4-12</a>—corrected typo (replaced LTE B38 with LTE B3), added single-cell detail for same row</p> <p>Updated <a href="#">Table 8-1</a>—removed LTE B38</p> <p>Updated reference doc number and availability—[15] EM9 Carrier Aggregations and EN-DC (Doc# 2174317)</p> <p>Updated <a href="#">Table A-1</a>—added max input power at antenna ports</p>

Revision number	Release date	Changes
5	March 2022	<p>Removed references to WCDMA B3 (<a href="#">Table 1-2</a>, <a href="#">Table 4-4</a>, <a href="#">Table 4-11</a>)</p> <p>Renamed section 3.9 mmWave Antenna Power Control</p> <p>Added 3.10 Antenna Control</p> <p>Updated <a href="#">Table 4-6</a>—supported architectures</p> <p>Updated 4.6 Supported RATs—removed 48C from LTE Advanced carrier aggregation list</p> <p>Updated <a href="#">Table 4-12</a>—updated 5G section; updated LTE band groups; removed single-cell detail in LTE row erroneously added in rev4</p>
6	October 2022	<p>Updated internal SIM references to indicate internal SIM is optional/SKU-dependent</p> <p>Updated <a href="#">Table 1-2</a> (Removed incorrect FR1 UL MIMO entry; added link to QTM band support; updated 5G NR FR1 content)</p> <p>Marked ANT_CTRL1–3 as reserved (<a href="#">Table 3-1</a>; <a href="#">Antenna Control</a>)</p> <p>Added <a href="#">Table 4-1</a> (5G NR band support by QTM type)</p> <p>Removed 4.5.1 Sierra Wireless' Sensitivity Testing and Desensitization Investigation</p> <p>Updated <a href="#">Table 4-9</a> (worst case n8/n12/n20/n25)</p> <p>Updated 5.3.2.4 Required Shutdown Sequence—power off timing note</p> <p>Updated <a href="#">Figure 7-7</a> (added debugging test points)</p> <p>Updated 7.4 Thermal Considerations (added debugging test points)</p> <p>Removed LTE B30 from <a href="#">Table 8-1</a></p>
7	November 2022	<p>Rephrased MIMO support in 5G Features and LTE Features</p> <p>Updated <a href="#">Table 3-2</a> (EM7690 Continuous current)</p> <p>Reorganized 4 RF Specifications</p> <p>Updated <a href="#">Table A-1</a>, <a href="#">Table A-2</a> (antenna name references)</p>
8	May 2023	<p>Updated <a href="#">Table 3-1</a> footnote on pins 24/38/68 to apply only to EM7690</p> <p>Updated <a href="#">Table 4-1</a> (Reformat; clarified B32)</p> <p>Updated <a href="#">Table 4-11</a> (Band 1,2,4,5,8,19 sensitivity values)</p> <p>Updated <a href="#">Table 5-1</a> (Removed footnote from Standby and LPM sections; updated current for LPM with Host interface suspended)</p> <p>Updated 5.3.2.4 Required Shutdown Sequence—reverted power off timing note</p>

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# >> 1: Introduction

The Sierra Wireless EM91 Embedded Module series (EM9190, EM9191, EM7690) are FirstNet-ready (B14 LTE) M.2 modules that provide 5G NR Sub-6G, 5G NR mmWave, 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:*

- *EM91 refers to the EM91 module series, which includes EM9190, EM9191, and EM7690.*
- *EM919x refers to EM9190 and EM9191.*

EM91 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	LTE Only	LTE+FR1 NSA EN-DC/FR1 SA	LTE+FR2 NSA EN-DC
EM9190	Supported	Supported	Supported
EM9191	Supported	Supported	Not supported
EM7690	Supported	Not supported	Not supported

## 1.1 Supported RF bands

The modem supports data operation on 5G NR, 4G LTE and 3G networks over the bands described in [Table 1-2](#).

For additional RF details, see [Supported RATs on page 49](#).

Table 1-2: RF Band Support

RAT	Bands	Capabilities <sup>a</sup>
5G NR	<u>FR2 (mmWave)<sup>b</sup></u> n257, n258, n260, n261  (For antenna module-specific band support, see <a href="#">Table 4-2 on page 44.</a> )	Downlink (DL): <ul style="list-style-type: none"> <li>LTE 7CC (20 layers max) + 5G NR FR2 4CC (400 MHz BW max)</li> <li>LTE 7CC (8 layers max) + 5G NR FR2 8CC (800 MHz BW max)</li> <li>64QAM, 2x2 MIMO</li> </ul> Uplink (UL): <ul style="list-style-type: none"> <li>LTE 1CC + 5G NR FR2 2CC (200 MHz BW max)</li> <li>64QAM, 2x2 MIMO</li> </ul>
	<u>FR1 (sub-6GHz)<sup>c</sup></u> n1 <sup>d</sup> , n2 <sup>d</sup> , n3 <sup>d</sup> , n5, n7 <sup>e</sup> , n8 <sup>e</sup> , n12 <sup>e</sup> , n20 <sup>e</sup> , n25 <sup>e</sup> , n28 <sup>d</sup> , n38 <sup>e</sup> , n40 <sup>e</sup> , n41 <sup>d</sup> , n48 <sup>e</sup> , n66 <sup>d</sup> , n71 <sup>d</sup> , n77 <sup>d</sup> , n78, n79	NSA (ENDC)  EM9190 Downlink (DL): <ul style="list-style-type: none"> <li>LTE 7CC (20 layers max) + 5G NR FR1 TDD 1CC (100 MHz BW max)</li> <li>LTE 4CC (8 layers max) + 5G NR FR1 TDD 2CC (200 MHz BW max)</li> <li>LTE 7CC (20 layers max) + 5G NR FR1 FDD 1CC (40 MHz BW max)</li> <li>256QAM, 4x4 or 2x2 MIMO</li> </ul> EM9191 Downlink (DL): <ul style="list-style-type: none"> <li>LTE 7CC (12 layers max) + 5G NR FR1 TDD 1CC (100 MHz BW max)</li> <li>LTE 7CC (16 layers max) + 5G NR FR1 FDD 1CC (40 MHz BW max)</li> <li>256QAM, 4x4 or 2x2 MIMO</li> </ul> Uplink (UL): <ul style="list-style-type: none"> <li>LTE 1CC + 5G NR FR1 TDD 1CC (100 MHz BW max)</li> <li>LTE 1CC + 5G NR FR1 FDD 1CC (40 MHz BW max)</li> <li>256QAM, SISO</li> </ul>
		SA  Downlink: <ul style="list-style-type: none"> <li>5G NR FR1 TDD 2CC (up to 200 MHz aggregate BW max) (Note: Older firmware releases limited to 5G NR FR1 TDD 1CC (100 MHz BW max))</li> <li>5G NR FR1 FDD 1CC (40 MHz BW max) (Note: Older firmware releases limited to 5G NR FR1 FDD 1CC (20 MHz BW max))</li> <li>256QAM, 4x4 or 2x2 MIMO</li> </ul> Uplink: <ul style="list-style-type: none"> <li>5G NR FR1 TDD 1CC (100 MHz BW max)</li> <li>5G NR FR1 FDD 1CC (40 MHz BW max) (Note: Older firmware releases limited to 5G NR FR1 FDD 1CC (20 MHz BW max))</li> <li>256QAM, SISO</li> </ul>
LTE	LTE B1, B2, B3, B4, B5, B7, B8, B12, B13, B14, B17, B18, B19, B20, B25, B26, B28, B29, B30 <sup>f</sup> , B32, B34, B38, B39, B40, B41, B42, B43 <sup>e</sup> , B46 <sup>g</sup> , B48, B66, B71	<ul style="list-style-type: none"> <li>DL Cat 20:               <ul style="list-style-type: none"> <li>7CC (20 layers max)</li> <li>256QAM, 4x4 or 2x2 MIMO</li> </ul> </li> <li>UL Cat 18:               <ul style="list-style-type: none"> <li>2CC (2 layers max) intra-band contiguous and inter-band</li> <li>256QAM, SISO</li> </ul> </li> <li>Supported CC BW up to 20 MHz, per 3GPP specs for supported bands</li> </ul>
3G	<u>HSPA+/WCDMA</u> Bands 1, 2, 4, 5, 6, 8, 9, 19	<ul style="list-style-type: none"> <li>DC-HSPA+—Rel 10</li> <li>WCDMA—R99</li> </ul>

**Table 1-2: RF Band Support (Continued)**

RAT	Bands	Capabilities <sup>a</sup>
GNSS	L1 GPS/QZSS L1, GLONASS G1, Galileo E1, BeiDou B1i	Standalone and assisted GNSS
	L5 <sup>h</sup> GPS L5, GAL E5a, QSZZ L5, BDS B2a	

- a. For theoretical peak data rate with minimal overhead and maximal TDD ratio, refer to [7] EM919X 5G NR Peak Throughput (Doc# 2174277).
- b. EM9190 only. The EM9190 supports 5G NR mmWave only when used in combination with optional Qualcomm mmWave antenna hardware—the QTM525 low power and QTM527 high power mmWave antenna modules include their own active antenna arrays, dedicated power management, integrated frequency up-converters, and power amplifiers. Note that mmWave is supported only in NSA mode.
- c. EM919x only, not supported in EM7690
- d. Band is supported in NSA mode. Band support in SA mode is firmware and SKU dependent.
- e. Band support is firmware and SKU dependent.
- f. To assist OEMs to meet FCC and PTCRB rules, LTE band 30 is set to downlink only by default.
- g. LTE-LAA B46 (downlink only)
- h. The L1 signal is required for decoding the L5 signal.

## 1.2 Mechanical Features

- M.2 form factor:
  - WWAN Type 3042-S3-B (in WWAN—PCIe and USB3 Port Configuration 2) with length of 52 mm, as specified in [20] *PCI Express M.2™ Specification Revision 3.0, Version 1.2*.
  - Conforms to M.2 form factor width specification. For complete dimensions, see [Figure 7-2](#).
  - Input voltage per M.2 specification

*Note: Any variations from the M.2 specification are detailed in this document.*

- Ambient operating temperature range with appropriate heatsinking:
  - Class A (3GPP compliant): -30°C to +70°C
  - Class B (operational, non-3GPP compliant): -40°C to +85°C (reduced operating parameters required)

**Important:** *The internal module temperature (reported by AT!PCTEMP?) must be kept below 115°C. For best performance, the internal module temperature should be kept below 100°C. Proper mounting, heat sinks, and active cooling may be required—refer to [3] EM9190 Thermal Application Note (Doc# 2174257) for details. Refer also to [4] EM919x/EM7690 Thermal Mitigation Application Note (Doc# 2174267).*



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## 1.3 Host Interface Features

EM91 modules support PCIe and USB physical host interfaces, with the following features:

- Operating system support:
  - Windows, Linux, Android
  - Mobile Broadband packages for each system (MBPW, MBPL, MBPA)
  - SDK with rich set of APIs and sample applications
- PCIe:
  - Gen 3, Single lane
  - Typical PCIe topology:
    - Module configured as a PCIe End Point (EP)
    - Host is the PCIe root complex (RC) node
- USB:
  - USB3.1
  - Configurable USB composite interface—Enable/disable specific interfaces via AT command
- AT command interface and proprietary extended AT commands. For details, refer to [1] *Sierra Wireless EM919X AT Command Reference (Doc# 41113480)*.

For additional details, refer to [13] *Software Integration and Development Guide for Linux USB Platforms (Doc# 41114212)* and [14] *Software Integration and Development Guide for Linux Platforms (Doc# 41113764)*.

## 1.4 Modem Features

- 5G NR mmWave (EM9190), 5G NR Sub-6G (EM919x), 4G LTE, 3G (DC-HSPA+/HSPA+/HSPA/WCDMA) operation
- Multiple (up to 16) cellular packet data profiles
- Traditional modem COM port support for AT commands
- Host interface (USB, PCIe) support for USB Selective Suspend (USB SS) and PCIe power management to minimize idle power draw
- QoS QCI
- Static and Dynamic IP address. The network may assign a fixed IP address or dynamically assign one using DHCP (Dynamic Host Configuration Protocol).
- PDP context type (IPv4, IPv6, or IPv4v6)
- RFC1144 TCP/IP header compression
- Public Safety 3GPP Features—3GPP R15 (per 3GPP TS 23.203, TS 29.212): QCI values 65, 66, 69, and 70

## 1.5 5G Features

*Note: 5G features are supported on EM919x only, and mmWave features are supported on EM9190 only.*

- Supported frequency range: FR1 (Sub-6G) and FR2 (mmWave)
- Network options:
  - SA (Option 2):
    - TDD: n38<sup>1</sup>, n40<sup>1</sup>, n41, n48<sup>1</sup>, n77, n78, n79
    - FDD: n1, n2, n3, n5, n7<sup>1</sup>, n8<sup>1</sup>, n12<sup>1</sup>, n20<sup>1</sup>, n25<sup>1</sup>, n28, n66, n71
  - NSA (Options 3a/3x)
    - Supports EN-DC for all NR bands—See [CA/EN-DC Support](#).
- Modulation:
  - UL modulation: FR1 (256QAM), FR2 (64QAM)
  - DL modulation: FR1 (256QAM), FR2 (64QAM)
- 5G MIMO support:

MIMO	Uplink (UL)		Downlink (DL)	
	FR1 (Sub-6G)	FR2 (mmW)	FR1 (Sub-6G)	FR2 (mmW)
2x2	n/a	Yes	Supported on all bands <ul style="list-style-type: none"> <li>• Band n41 uses MIMO1 and MIMO2 antennas.</li> <li>• All other bands use MAIN (PRx) and AUX (DRx) antennas.</li> </ul>	Yes
4x4	n/a	n/a	Supported on bands n1/2/3/7 <sup>a</sup> /25 <sup>a</sup> /38 <sup>a</sup> /40 <sup>a</sup> /41/48 <sup>a</sup> /66/77/78/79	n/a

a. Band support is firmware and SKU dependent

- SCS:
  - FR1: FDD (15 KHz); TDD (30 KHz)
  - FR2: Data and sync channels (120 KHz); Sync channels only (240 KHz)
- BW per CC:
  - FR1: Up to 100 MHz
  - FR2: 50 MHz, 100 MHz

## 1.6 LTE Features

- Carrier aggregation:
  - DL: Up to 7CC
  - UL: 2CC intra-band continuous and inter-band CA

1. Band support is firmware and SKU dependent.

- LTE MIMO support:

MIMO	Uplink (UL)	Downlink (DL)
2x2	n/a	Supported on all bands. All bands use MAIN (PRx) and AUX (DRx) antennas.
4x4	n/a	Supported on bands B1/2/3/4/7/25/30/32/34/38/39/40/41/42/43 <sup>a</sup> /48/66

a. Band support is firmware and SKU dependent

- HPUE: B41 standalone mode
- LAA: supported by B46
- Modulation:
  - DL modulation: Up to 256QAM
  - UL modulation: Up to 256QAM
- CSG support (LTE Femto)
- LTE Advanced receivers (NLIC, eICIC, feICIC)
- Basic cell selection and system acquisition
  - PSS/SSS/MIB decode
  - SIB1–SIB16 decoding
- NAS/AS security procedures
  - Snow 3G/AES/ZUC security
- CQI/RI/PMI reporting
- Paging procedures
  - Paging in Idle and Connected mode
- Dedicated bearer
  - Network-initiated dedicated bearer
  - UE-initiated dedicated bearer
- Multiple PDN connections (IPv4 and IPv6 combinations), subject to operating system support.
- Connected mode intra-LTE mobility
- Idle mode intra-LTE mobility
- iRAT between LTE/3G for idle and connection release with redirection
- Detach procedure
  - Network-initiated detach with reattach required
  - Network-initiated detach followed by connection release

## 1.7 Short Message Service (SMS) Features

- Mobile-originated and mobile-terminated SMS over [IMS](#)
- Mobile-originated and mobile-terminated SMS over SGs

## 1.8 Position Location (GNSS)

- High-precision GNSS with L1+L5 (optional)
- Customizable tracking session
- Automatic tracking session on startup
- Concurrent standalone GNSS (GPS, GLONASS, Galileo, BeiDou, QZSS)

- Simultaneous fixes from two GNSS systems (e.g. GPS and GLONASS)
- Assisted GPS (A-GPS)/GLONASS SUPL2.0 with configurable aiding refresh rate
- gpsOneXTRA 2.0/3.1

## 1.9 Accessories

A hardware development kit (part #6001349) 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

For details, refer to [2] Sierra Wireless EM919x/EM7690 Development Kit User Guide (Doc# 41113875).

## 1.10 Required Connectors

[Table 1-3](#) describes the connectors used to integrate the EM91 Embedded Module into your host device.

**Table 1-3: Required Host-Module Connectors<sup>a</sup>**

Connector type	Description
RF cables— 5G NR Sub-6G/LTE/GNSS	<ul style="list-style-type: none"> <li>• Mate with M.2-spec connectors</li> <li>• Four connector jacks (mate with I-PEX 20448-001R-081 or equivalent)</li> </ul>
RF cables—5G NR mmWave <sup>b</sup>	<ul style="list-style-type: none"> <li>• Eight connector jacks (mate with I-PEX 20955-001R-13 or equivalent)</li> <li>• Two cables for each mmWave antenna module (up to 8 cables in total)</li> </ul>
M.2 (Slot B-compatible) 67-pin edge connector	<ul style="list-style-type: none"> <li>• Slot B compatible—Per the M.2 standard (<i>[20] PCI Express M.2™ Specification Revision 3.0, Version 1.2</i>), 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.</li> <li>• Manufacturers include LOTES (part #APCI0018-P001A01), Kyocera, JAE, Tyco, and Longwell.</li> </ul>

a. Manufacturers/part numbers are for reference only and are subject to change. Choose connectors that are appropriate for your own design.

b. EM9190 only

## 1.11 Integration Guidance

When integrating the EM91 Embedded Module, the following items, if applicable, must be considered:

- **Mounting**—Effect on temperature, shock, and vibration performance
- **Power supply**—Impact on battery drain and possible [RF](#) interference
- **Antenna location and type**—Impact on RF performance
- **Regulatory approvals**—As discussed in [Regulatory Compliance and Industry Certifications on page 77](#).

- **Service provisioning**—Manufacturing process
- **Software**—As discussed in [Software on page 68](#).
- **Host interface**—Compliance with interface voltage levels

## >> 2: Standards Compliance

EM91 modules comply with the mandatory requirements described in the following standards. The exact set of requirements supported is network operator-dependent.

**Table 2-1: Standards Compliance**

<b>RAT</b>	<b>Standards</b>
<b>5G<sup>a</sup></b>	<ul style="list-style-type: none"><li>• 3GPP Release 15</li></ul>
<b>LTE</b>	<ul style="list-style-type: none"><li>• 3GPP Release 15</li></ul>
<b>UMTS</b>	<ul style="list-style-type: none"><li>• 3GPP Release 9</li></ul>

a. EM919x only

## >> 3: Electrical Specifications

The system block diagram in [Figure 3-1](#) represents the EM91 module integrated into a host system. The module includes the following interfaces to the host:

- Full\_Card\_Power\_Off#—Active-low input from the host—Low turns the module off, high turns the module on.
- W\_DISABLE#—Active low input from the host—Low disables the main RF radio.
- GPS\_DISABLE#—Active low input from the host—Low disables the GNSS radio receiver.
- WAKE\_ON\_WAN#—Active low output to the host—Low wakes the host when specific events occur.
- RESET#—Active low input from the host—Low resets the module.
- Antenna—Four LTE/Sub-6G [RF](#) connectors and eight mmWave IF connectors (EM9190 only) to support up to four mmWave antennas. For details, see [RF Specifications on page 43](#).
- Dynamic power control (DPR)—Signal used to adjust Tx power to meet FCC SAR requirements. For details, see [Tx Power Control on page 41](#).
- SIMs:
  - External SIM—The SIM Holder/tray is mounted on the host platform.
  - Internal SIM—A SIM may be mounted/embedded internal to the module (SKU-dependent).
  - Either the external or internal SIM can be active—the active SIM can be specified through configuration or software control.
- SIM detect—Internal pull-up on the module detects whether a SIM is present or not:
  - If a SIM is not inserted, the pin must be shorted to ground.
  - If a SIM is present, the pin will be an open circuit.
- USB—USB 3.1 Gen2 interface to the host for data, control, debug and status information. (USB 2.0 backward-compatible. Note—USB 2.0 operation is not officially tested or commercially supported.)
- PCIe:
  - PCIe—PCIe3.0 interface to the host for data, control, debug and status information. (PCIe2.0 backward-compatible)
  - PCIE\_DIS—Host interface selection, high for USB, low or Hi-Z for PCIe

The EM91 module has three main interface areas—the host I/O connector, the LTE/Sub-6G [RF](#) connectors, and the mmWave IF (EM9190 only) connectors. Details of these interfaces are described in the sections that follow.

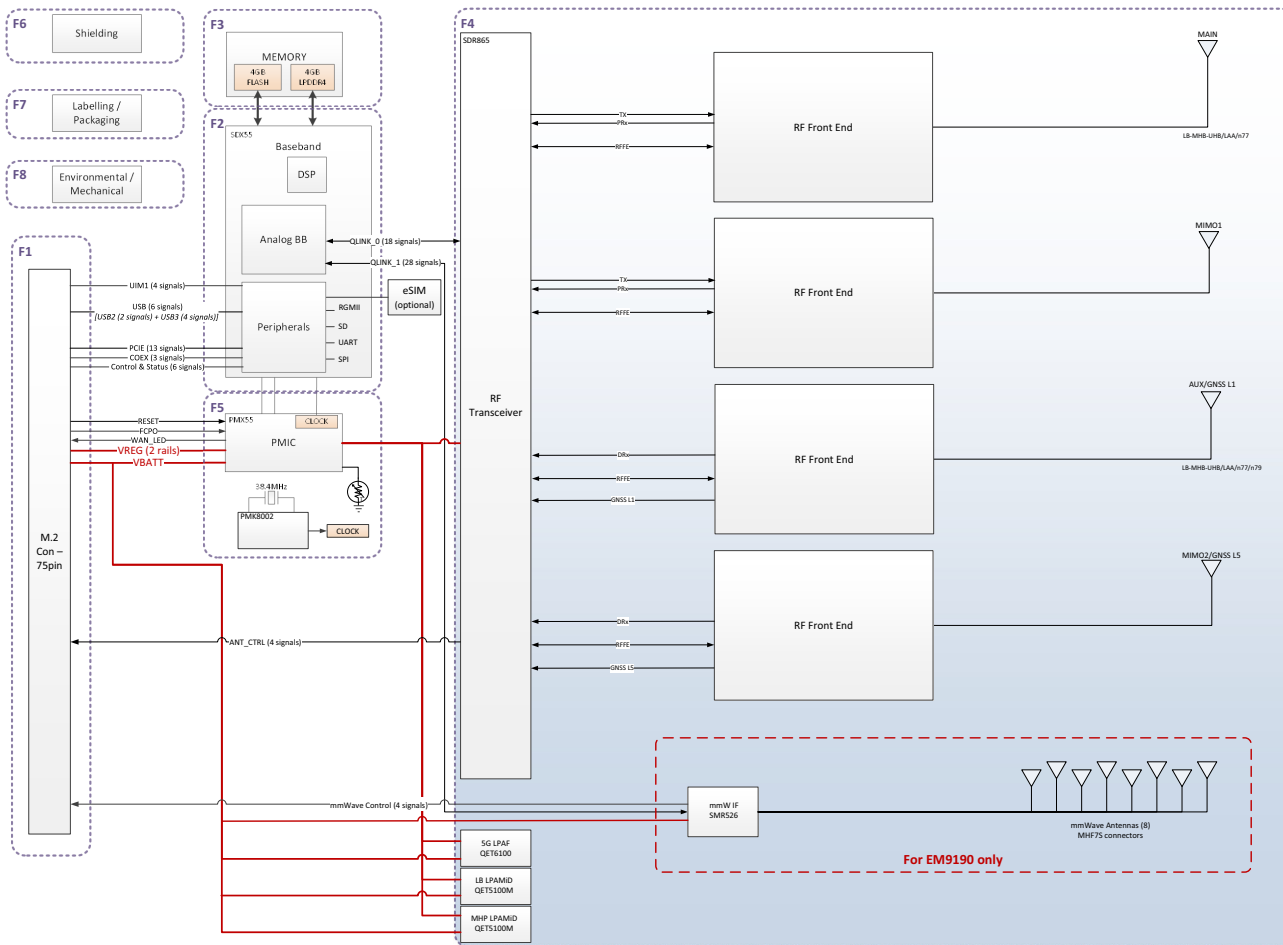


Figure 3-1: System Block Diagram

### 3.1 M.2 (Host) Interface Pin Assignments

The EM91 module’s host I/O connector provides pins for power, serial communications, and control. Pin assignments are listed in [Table 3-1](#).

Refer to the following tables for pin details based on interface types:

- [Table 3-2, Power Supply Requirements](#), on page 30
- [Table 3-3, USB Interface](#), on page 30
- [Table 3-4, PCIe Interface](#), on page 32
- [Table 3-5, SIM Interface Signals](#), on page 34
- [Table 3-6, Module Control Signals](#), on page 37
- [Table 3-7, W\\_DISABLE#/GPS\\_DISABLE# Usage](#), on page 38
- [Table 3-8, Full\\_Card\\_Power\\_Off# and RESET# Usage](#), on page 39
- [Table 3-10, mmWave Antenna Power Control Signals](#), on page 42



*Note: Unless indicated otherwise, leave unused inputs and outputs as no-connects.*

*Note: The host must not drive any signals to the module until >100 ms from the start of the power-on sequence.*

**Table 3-1: Host Interface (75-pin) Connections — Module View**

Pin	Signal name	Pin type <sup>a</sup>	Description	Direction <sup>b</sup>	Active state	Voltage levels (V)		
						Min	Typ	Max
1	CONFIG_3 (NC in default module configuration)		Reserved—Host must not repurpose this pin.			–	–	–
2	VCC	V	Power source	Input	Power	3.135	3.3	4.4
3	GND	V	Ground	Input	Power	–	0	–
4	VCC	V	Power source	Input	Power	3.135	3.3	4.4
5	GND	V	Ground	Input	Power	–	0	–
6	Full_Card_Power_Off#	PD	Turn modem on	Input	High	1.0	–	4.4
			Turn modem off	Input	Low	-0.3	–	0.5
7	USB_D+	-	USB data positive	Input/Output	Differential	–	–	–
8	W_DISABLE#	PU	Wireless Disable (WWAN radio)	Input	Low	–	–	0.4
				Input	High	0.7	–	4.4
9	USB_D-	-	USB data negative	Input/Output	Differential	–	–	–
10	WWAN_LED#	OC	LED Driver	Output	Low	0	–	0.15
11	GND	V	Ground	Input	Power	–	0	–
12	Key	Notch location						
13	Key	Notch location						
14	Key	Notch location						
15	Key	Notch location						

**Table 3-1: Host Interface (75-pin) Connections—Module View (Continued)**

Pin	Signal name	Pin type <sup>a</sup>	Description	Direction <sup>b</sup>	Active state	Voltage levels (V)		
						Min	Typ	Max
16	Key		Notch location					
17	Key		Notch location					
18	Key		Notch location					
19	Key		Notch location					
20	PCIE_DIS	PD	Host interface selection	Input	High	1.35	1.80	2.10
				Input	Low	-0.3	–	0.5
21	CONFIG_0 (GND in default configuration)	V	Reserved—Host must not repurpose this pin.	Output	–		0	
22	VBUS_SENSE	PD	USB Detection	Input	High	1.6	–	5.25
23	WAKE_ON_WAN#	OC	Wake Host	Output	Low	0	–	0.1
24 <sup>c</sup>	VCC	V	Power source	Input	Power	3.135	3.3	4.4
25	DPR	-	Dynamic power control	Input	High	1.17	1.80	2.10
				Input	Low	-0.3	–	0.63
26	GPS_DISABLE#	PU	Wireless disable (GNSS radio)	Input	Low	–	–	0.4
				Input	High	0.7	–	4.4
27	GND	V	Ground	Input	Power	–	0	–
28	PLA_S2#	O	Power loss acknowledge	Output	High	1.17	1.80	2.10
					Low	-0.3	–	0.63
29	USB3_TXM		USB3 Negative Transmit Data	Output	Differential	–	–	–
30	UIM1_RESET	O	SIM Reset	Output	Low	0	–	0.45
					High	2.55 (3V SIM) 1.35 (1.8V SIM)	3.00 (3V SIM) 1.80 (1.8V SIM)	3.10 (3V SIM) 1.90 (1.8V SIM)
31	USB3_TXP		USB3 Positive Transmit Data	Output	Differential	–	–	–

Table 3-1: Host Interface (75-pin) Connections—Module View (Continued)

Pin	Signal name	Pin type <sup>a</sup>	Description	Direction <sup>b</sup>	Active state	Voltage levels (V)		
						Min	Typ	Max
32	UIM1_CLK	O	SIM Clock	Output	Low	0	–	0.45
					High	2.55 (3V SIM) 1.35 (1.8V SIM)	3.00 (3V SIM) 1.80 (1.8V SIM)	3.10 (3V SIM) 1.90 (1.8V SIM)
33	GND	V	Ground	Input	Power	–	0	–
34	UIM1_DATA	-	SIM I/O pin	Input	Low	-0.30 (3V SIM) -0.30 (1.8V SIM)	–	0.60 (3V SIM) 0.35 (1.8V SIM)
					High	2.10 (3V SIM) 1.17 (1.8V SIM)	3.00 (3V SIM) 1.80 (1.8V SIM)	3.30 (3V SIM) 2.10 (1.8V SIM)
				Output	Low	0	–	0.40
					High	2.55 (3V SIM) 1.35 (1.8V SIM)	3.00 (3V SIM) 1.80 (1.8V SIM)	3.10 (3V SIM) 1.90 (1.8V SIM)
35	USB3_RXM		USB3 Negative Receive Data	Input	Differential	–	–	–
36	UIM1_PWR	V	SIM VCC supply	Output	Power	2.90 (3V SIM) 1.75 (1.8V SIM)	3.00 (3V SIM) 1.80 (1.8V SIM)	3.10 (3V SIM) 1.85 (1.8V SIM)
37	USB3_RXP		USB3 Positive Receive Data	Input	Differential	–	–	–
38 <sup>c</sup>	VCC	V	Power source	Input	Power	3.135	3.3	4.4
39	GND	V	Ground	Input	Power	–	0	–
40	QTM0_PON <sup>d</sup>	O	mmWave antenna module Power On signal (from EM9190)	Output	High	1.35	–	1.8
					Low	0	–	0.45
41	PCIE_TXM0		PCIe Negative Transmit Data	Output	Differential	–	–	–
42	QTM1_PON <sup>d</sup>	O	mmWave antenna module Power On signal (from EM9190)	Output	High	1.35	–	1.8
					Low	0	–	0.45
43	PCIE_TXP0		PCIe Positive Transmit Data0	Output	Differential	–	–	–

Table 3-1: Host Interface (75-pin) Connections—Module View (Continued)

Pin	Signal name	Pin type <sup>a</sup>	Description	Direction <sup>b</sup>	Active state	Voltage levels (V)		
						Min	Typ	Max
44	QTM2_PON <sup>d</sup>	O	mmWave antenna module Power On signal (from EM9190)	Output	High	1.35	–	1.8
					Low	0	–	0.45
45	GND	V	Ground	Input	Power	–	0	–
46	QTM3_PON <sup>d</sup>	O	mmWave antenna module Power On signal (from EM9190)	Output	High	1.35	–	1.8
					Low	0	–	0.45
47	PCIE_RXM0		PCIe Negative Receive Data0	Input	Differential	–	–	–
48	QTM_IO_1.9V <sup>d</sup>	V	1.904 V power supply	Output	Power	1.8	1.904	2
49	PCIE_RXP0		PCIe Positive Receive Data0	Input	Differential	–	–	–
50	PCIE_PERST_N		PCIe Reset	Input	Low	0	–	0.7
				Input	High	1.5	–	VCC
51	GND	V	Ground	Input	Power	–	0	–
52	PCIE_CLKREQ_N	OC	PCIe Clock Request	Output	Low	0	–	0.35
53	PCIE_REFCLKM		PCIe Negative Reference Clock	Input	Differential	–	–	–
54	PCIE_PEWAKE_N	OC	PCIe Wake	Output	Low	0	–	0.35
55	PCIE_REFCLKP		PCIe Positive Reference Clock	Input	Differential	–	–	–
56	NC		Reserved—Host must not repurpose this pin.					
57	GND	V	Ground	Input	Power	–	0	–
58	NC		Reserved—Host must not repurpose this pin.					
59	ANT_CTRL0		External antenna tuner control	Output	High	1.35	–	1.8
				Output	Low	0	–	0.45
60	Reserved		Reserved—Host must not repurpose this pin.					

**Table 3-1: Host Interface (75-pin) Connections—Module View (Continued)**

Pin	Signal name	Pin type <sup>a</sup>	Description	Direction <sup>b</sup>	Active state	Voltage levels (V)		
						Min	Typ	Max
61	ANT_CTRL1		Reserved for EM92xx compatibility	Output	High	1.35	–	1.80
				Output	Low	0	–	0.45
62	Reserved		Reserved—Host must not repurpose this pin.					
63	ANT_CTRL2		Reserved for EM92xx compatibility	Output	High	1.35	–	1.80
				Output	Low	0	–	0.45
64	Reserved		Reserved—Host must not repurpose this pin.					
65	ANT_CTRL3		Reserved for EM92xx compatibility	Output	High	1.35	–	1.80
				Output	Low	0	–	0.45
66	SIM1_DETECT	PU	SIM indication	Input		0 V—SIM not present Open circuit—SIM present		
67	RESET#	PU	Reset module	Input	Low	-0.3	–	0.63
68 <sup>c</sup>	VCC	V	Power source	Input	Power	3.135	3.3	4.4
69	CONFIG_1 (GND in default configuration)		Reserved—Host must not repurpose this pin.	Output	–		0	
70	VCC	V	Power source	Input	Power	3.135	3.3	4.4
71	GND	V	Ground	Input	Power	–	0	–
72	VCC	V	Power source	Input	Power	3.135	3.3	4.4
73	GND	V	Ground	Input	Power	–	0	–
74	VCC	V	Power source	Input	Power	3.135	3.3	4.4
75	CONFIG_2 (NC in default module configuration)	V	Reserved—Host must not repurpose this pin.		–	–		–

- a. I—Input; O—Digital output; OC—Open Collector output; PU—Digital input (internal pull-up); PD—Digital input (internal pull-down); V—Power or ground
- b. Signal directions are from module's point of view (e.g. 'Output' from module to host, 'Input' to module from host.)
- c. VCC pins 24/38/68—Optional to leave NC for EM7690.
- d. These pins are NC for EM9191/EM7690.

## 3.2 Power Supply

The host provides power to the EM91 module through multiple power and ground pins as summarized in [Table 3-2](#).

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 3-2: Power Supply Requirements**

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 <sub>pp</sub>	
		Peak current	EM9190 with mmWave	-	-	5000	mA
			EM9190 without mmWave	-	-	3000	
			EM9191	-	-	2700	
			EM7690	-	-	2300	
		Continuous current	EM9190 with mmWave	-	-	4000	mA
			EM9190 without mmWave	-	-	2300	
EM9191	-		-	2000			
EM7690	-		-	1600			
GND	3, 5, 11, 27, 33, 39, 45, 51, 57, 71, 73	-	-	0	-	V	

## 3.3 USB Interface

**Important:** Host support for USB 3.1 signals is required when USB is selected as the host interface.

The EM91 module supports a USB 3.1 Gen2 interface for communication between the host and module. (USB 2.0 backward-compatible. Note—USB 2.0 operation is not officially tested or commercially supported.)

The USB interface complies with the [21] *Universal Serial Bus Specification, Rev 2.0* and [22] *Universal Serial Bus Specification, Rev 3.1* (subject to limitations described below), and the host platform must be designed to the same standards.

**Table 3-3: USB Interface**

Name	Pin	Description
USB_D+	7	(USB 2 High speed) Data positive
USB_D-	9	(USB 2 High speed) Data negative

**Table 3-3: USB Interface (Continued)**

Name	Pin	Description
VBUS_SENSE	22	USB detection
USB3_TXM <sup>a</sup>	29	(USB 3 Superspeed) Transmit data negative
USB3_TXP <sup>a</sup>	31	(USB 3 Superspeed) Transmit data positive
USB3_RXM <sup>a</sup>	35	(USB 3 Superspeed) Receive data negative
USB3_RXP <sup>a</sup>	37	(USB 3 Superspeed) Receive data positive

a. Signal directions (Tx/Rx) are from the module's point of view.

*Note: USB cannot be identified until VBUS\_SENSE is connected.*

### 3.3.1 Host-side Recommendation

Series capacitors are recommended on the host-side USB3 Rx signals (no capacitors required for the Tx signals), as shown below.

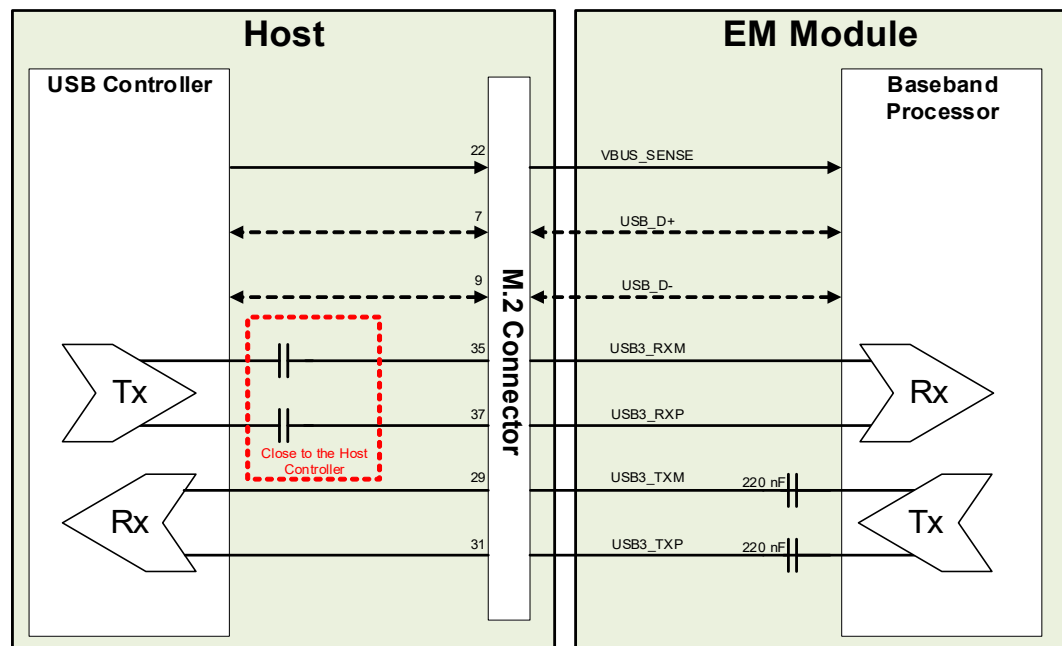


Figure 3-2: Recommended Schematic for USB Signals

### 3.4 PCIe Interface

**Important:** *Host support for PCIe 3.0 signals is required (for performance purposes) when PCIe is selected as host interface.*

The EM91 module supports a PCIe interface for communication between the host and module.

The PCIe interface complies with the PCI Express<sup>®</sup> Card Electromechanical Specification Revision 3.0 (2.0 backward-compatible), and the host platform must be designed to the same standards.

**Table 3-4: PCIe Interface**

	Name	Pin	Description
PCIe	PCIE_TXM0 <sup>a</sup>	41	PCIe Negative Transmit Data0
	PCIE_TXP0 <sup>a</sup>	43	PCIe Positive Transmit Data0
	PCIE_RXM0 <sup>a</sup>	47	PCIe Negative Receive Data0
	PCIE_RXP0 <sup>a</sup>	49	PCIe Positive Receive Data0
	PCIE_PERST_N	50	PCIe Reset
	PCIE_CLKREQ_N	52	PCIe Clock Request
	PCIE_REFCLKM	53	PCIe Negative Reference Clock
	PCIE_PEWAKE_N	54	PCIe Wake
	PCIE_REFCLKP	55	PCIe Positive Reference Clock

a. Signal directions (Tx/Rx) are from the module's point of view.

*Note: EM91 modules support Active State Power Management (ASPM) L1 and L0s (PCIE\_CLKREQ\_N is required to support Clock Power Management in ASPM L1).*

*Note: EM91 modules do not have Optimized Buffer Flush/Fill (OBFF) support.*



### 3.4.1 Host-side Recommendation

Series capacitors are recommended on the host-side PCIe Rx signals (no capacitors required for the Tx signals). Also, pull-ups are recommended on the PCIE\_PEWAKE\_N and PCIE\_CLKREQ\_N signals, as shown below.

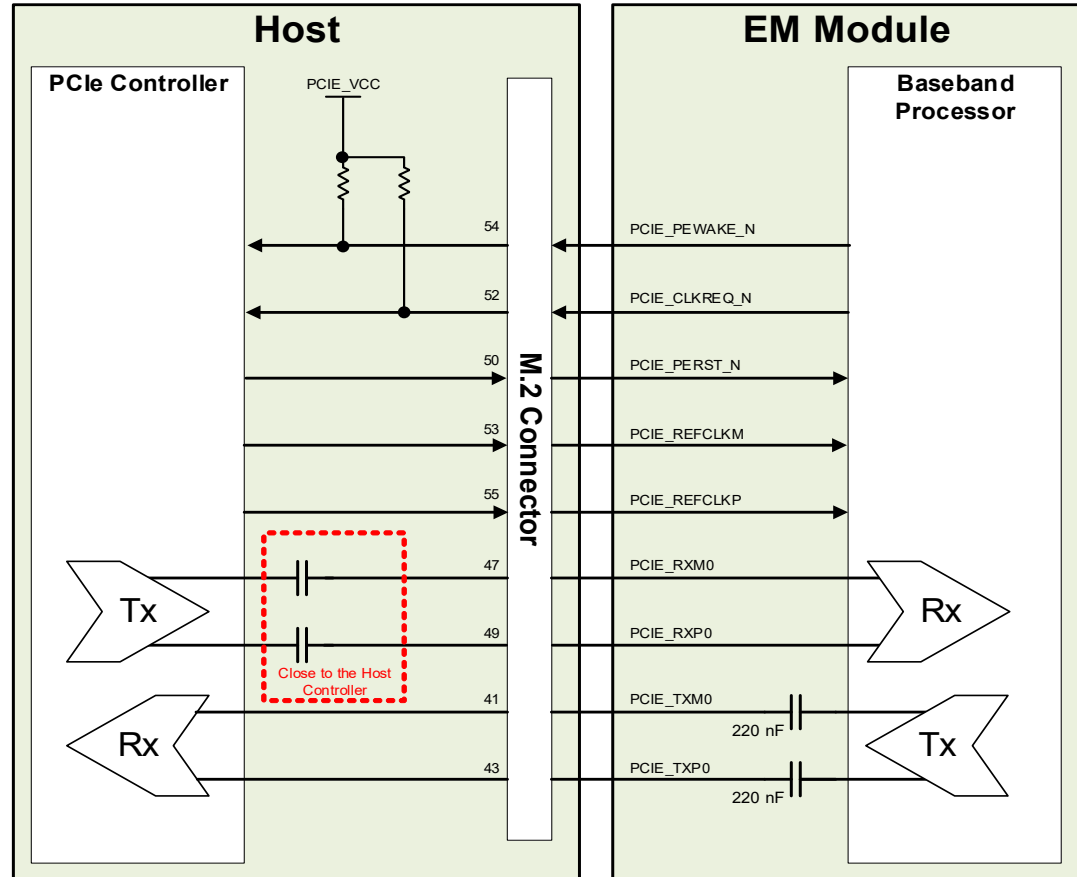


Figure 3-3: Recommended Schematic for PCIe Signals

### 3.4.2 PCIE\_PEWAKE\_N

Depending on the host platform's configuration, PCIE\_PEWAKE\_N can be used by the module to wake the host when the PCIe link is in a power saving state.

For details, refer to [12] EM919x/EM7690 PCIe Integration Guide (Doc# 41114276).

## 3.5 SIM Interface

*Note: Host support for SIM interface signals is required.*

The module supports one external SIM (Subscriber Identity Module) (1.8 V or 3 V). The SIM holds information for a unique account, enabling the customer to use the account on multiple devices.

The module may also include an M2M- or consumer-eUICC embedded SIM (SKU-dependent)

The **SIM** pins (Table 3-5 on page 34) provide the connections necessary to interface to SIM sockets located on the host platform as shown in Figure 3-4 on page 35. Voltage levels over this interface comply with 3GPP standards.

The SIM connector types used depend on how the host platform exposes the SIM sockets.

**Table 3-5: SIM Interface Signals**

<b>SIM</b>	<b>Name</b>	<b>Pin</b>	<b>Description</b>	<b>SIM contact<sup>a</sup></b>	<b>Notes</b>
Primary	UIM1_RESET	30	Reset	2	Active low SIM reset
	UIM1_CLK	32	Serial clock	3	Serial clock for SIM data
	UIM1_DATA	34	Data I/O	7	Bi-directional SIM data line
	UIM1_PWR	36	SIM voltage	1	Power supply for SIM
	SIM_DETECT	66	SIM indication	–	Input from host indicating whether SIM is present or not <ul style="list-style-type: none"> <li>• Grounded if no SIM is present</li> <li>• No-connect (floating) if SIM is inserted</li> </ul>
	UIM_GND		Ground	5	Ground reference UIM_GND is common to module ground

a. See Figure 3-5 on page 35 for SIM card contacts.

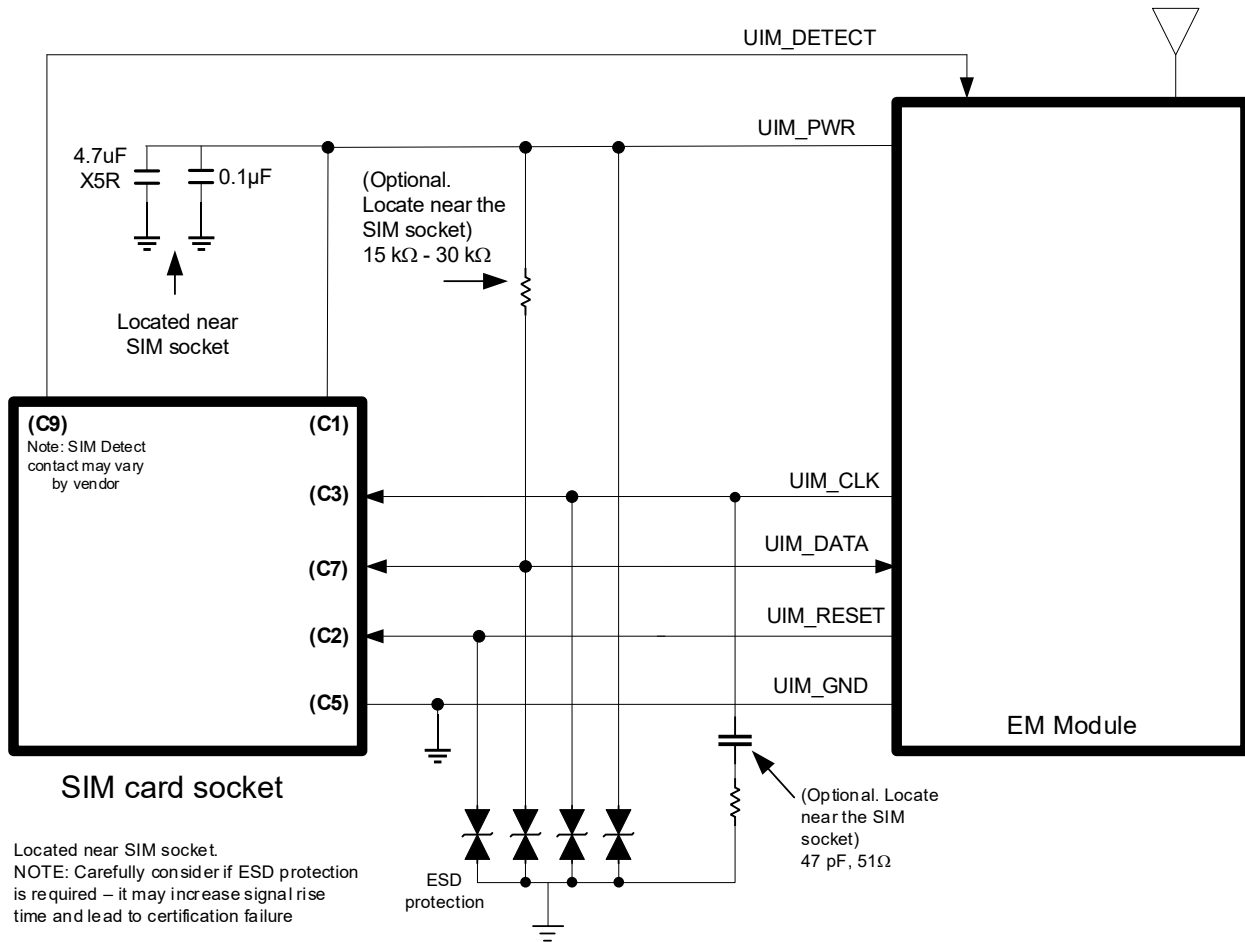


Figure 3-4: SIM Application Interface

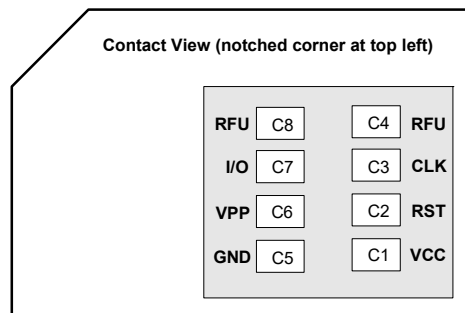


Figure 3-5: SIM Card Contacts (Contact View)

### 3.5.1 SIM Implementation

Note: For interface design requirements, refer to ETSI TS 102 230 V5.5.0, section 5.2.

When designing the remote SIM interface, you must make sure that SIM signal integrity is not compromised.

Some design recommendations include:

- Total impedance of the VCC and GND connections to the SIM, measured at the module connector, should be less than 1  $\Omega$  to minimize voltage drop (includes any trace impedance and lumped element components—inductors, filters, etc.).
- Position the SIM connector  $\leq 10$  cm from the module. If a longer distance is required because of the host platform design, use a shielded wire assembly—connect one end as close as possible to the SIM connector and the other end as close as possible to the module connector. The shielded assembly may help shield the SIM interface from system noise.
- Avoid routing the clock and data lines (UIM1\_CLK, UIM1\_DATA) in parallel over distances  $> 2$  cm—cross-coupling of a clock and data line pair can cause failures.
- 3GPP has stringent requirements for I/O rise time ( $< 1$   $\mu$ s), signal level limits, and noise immunity—consider this carefully when developing your PCB layout.
  - Keep signal rise time  $< 1$   $\mu$ s—keep SIM signals as short as possible, and keep very low capacitance traces on the data and clock signals (UIM1\_CLK, UIM1\_DATA). High capacitance increases signal rise time, potentially causing your device to fail certification tests.
- Add external pull-up resistors (15 k $\Omega$ –30 k $\Omega$ ), if required, between the data and power lines (UIM1\_DATA, UIM1\_PWR) to optimize the signal rise time.
- VCC line should be decoupled close to the SIM socket.
- Make sure that placement and routing of SIM signals and connectors supports SIM clock rates up to 5 MHz (per 3GPP specification).
- You must decide whether additional ESD protection is required for your product, as it is dependent on the platform, mechanical enclosure, and SIM connector design. The SIM pins will require additional ESD protection if they are exposed to high ESD levels (i.e. can be touched by a user).
- Putting optional decoupling capacitors on the SIM power line (UIM1\_PWR) near the SIM socket is recommended—the longer the trace length (impedance) from the socket to the module, the greater the capacitance requirement to meet compliance tests.
- Putting an optional series capacitor and resistor termination (to ground) on the clock line (UIM1\_CLK) at the SIM socket to reduce EMI and increase signal integrity is recommended if the trace length between the SIM socket and module is long—a 47 pF capacitor and 50  $\Omega$  resistor are recommended.
- Test your first prototype host hardware with a Comprion IT<sup>3</sup> SIM test device at a suitable testing facility.

## 3.6 Control Interface (Signals)

The EM91 module provides signals for:

- Waking the host when specific events occur
- Host platform control of the module's radios
- Host platform control of module power
- Module status indication to host
- Host interface selection (i.e. PCIe, USB)

---

*Note: Host support for Full\_Card\_Power\_Off# is required, and support for other signals in [Table 3-6](#) is optional.*

---

These signals are summarized in [Table 3-6](#) and paragraphs that follow.

**Table 3-6: Module Control Signals**

Name	Pin	Description	Type <sup>a</sup>
Full_Card_Power_Off#	6	On/off control	PD
W_DISABLE#	8	Wireless disable (Main RF)	PU
WWAN_LED#	10	LED driver	OC
PCIE_DIS	20	Host interface selection	PD
WAKE_ON_WAN#	23	Wake host	O
GPS_DISABLE#	26	Wireless disable (GNSS)	PU
PLA_S2#	28	Power loss acknowledge	O
RESET#	67	Reset module	PU

a. O—Digital pin Output; OC—Open Collector output; PD—Digital pin Input, internal pull-down; PU—Digital pin Input, internal pull-up

### 3.6.1 WAKE\_ON\_WAN# — Wake Host

*Note: Host support for WAKE\_ON\_WAN# is optional.*

The EM91 module uses WAKE\_ON\_WAN# to wake the host when specific events occur.

The host must provide a 5–100 k $\Omega$  pull-up resistor that considers total line capacitance (including parasitic capacitance) such that when WAKE\_ON\_WAN# is deasserted, the line will rise to 3.3 V (Host power rail) in < 100 ns.

See [Figure 3-6 on page 37](#) for a recommended implementation.

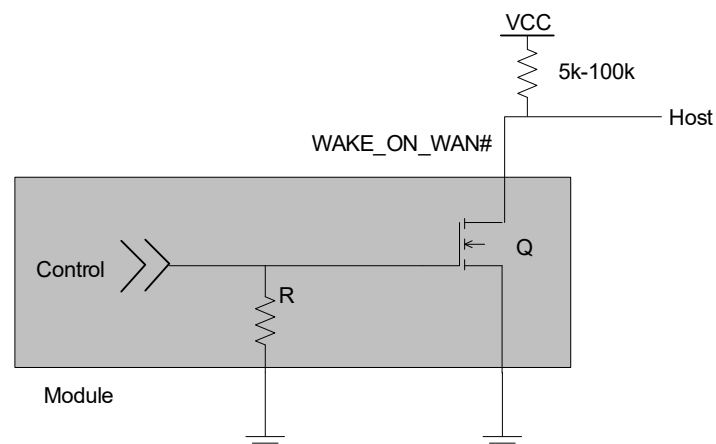


Figure 3-6: Recommended WAKE\_ON\_WAN# Connection

### 3.6.2 W\_DISABLE# (WWAN Disable) and GPS\_DISABLE# (GNSS Disable)

*Note: Host support for WWAN/GNSS disable signals is optional.*

The host platform uses W\_DISABLE# to enable/disable the WWAN or radio modem, and GPS\_DISABLE# to enable/disable GNSS functionality.

Letting these signals float high allows the module to operate normally. These pins have 100 kΩ pull-up resistors. See [Figure 3-7 on page 38](#) for a recommended implementation.

When integrating with your host platform, keep the following in mind:

- The signal is an input to the module and should be driven LOW to turn the radio off, or HIGH or floating to keep it on.
- If the host never needs to assert this power state control to the module, leave this signal unconnected from the host interface.

**Table 3-7: W\_DISABLE#/GPS\_DISABLE# Usage**

Name	Pin	Description/notes
<b>W_DISABLE#</b>	8	Enable/disable the WWAN or radio modem <sup>a</sup> . When disabled, the modem cannot transmit or receive. <ul style="list-style-type: none"> <li>• Keep modem always on—Leave as not connected or drive HIGH.</li> <li>• Turn modem off—Drive LOW.</li> </ul>
<b>GPS_DISABLE#</b>	26	Enable/disable GNSS functionality <sup>a</sup> <ul style="list-style-type: none"> <li>• Enable GNSS functionality—Leave as not connected or drive HIGH.</li> <li>• Disable GNSS functionality—Drive LOW.</li> <li>• For details on enabling/disabling GNSS functionality, refer to the AT!CUSTOM="GPSENABLE" command in [1] <i>Sierra Wireless EM919X AT Command Reference (Doc# 41113480)</i>.</li> </ul>

a. Sierra Wireless recommends that the host implement an open collector driver where a Low signal turns off the modem or disables GNSS functionality, and a high signal turns on the modem or enables GNSS functionality.

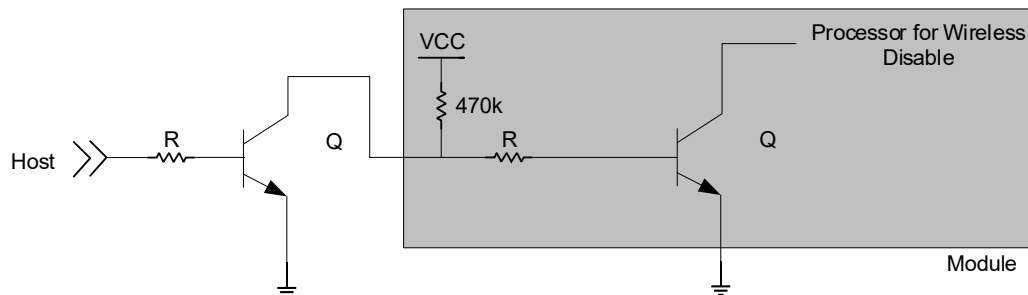


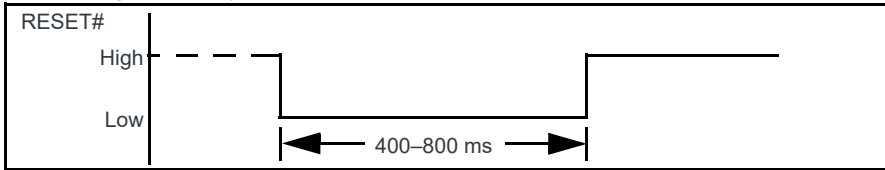
Figure 3-7: Recommended Wireless Disable Connection

### 3.6.3 Full\_Card\_Power\_Off# and RESET#

*Note: Host support for Full\_Card\_Power\_Off# is required, and support for RESET# is optional.*

Full\_Card\_Power\_Off# and RESET# are inputs to the module that the host uses as described in [Table 3-8](#).

**Table 3-8: Full\_Card\_Power\_Off# and RESET# Usage**

Name	Pin	Description/notes
Full_Card_Power_Off#	6	<p>Powers the module on/off</p> <ul style="list-style-type: none"> <li>Signal is required.</li> <li>Pull HIGH to keep the module on. To keep the module always on: <ul style="list-style-type: none"> <li>Tie the pin directly to a host GPIO (1.8V), or</li> <li>Use an external pull-up to pull signal high (10k–20 kΩ for 1.8V, 75–100 kΩ for VCC rail). Note that a larger-value resistor will reduce leakage current.</li> </ul> </li> <li>To power off the module, see <a href="#">Required Shutdown Sequence on page 66</a>.</li> </ul>
RESET#	67	<p>Resets the module</p> <ul style="list-style-type: none"> <li>Signal is optional. The module will operate correctly if the pin is left disconnected on the host.</li> <li>This is a 'hard' reset, which should be used only if the host cannot communicate with the module via the PCIe or USB port. (If the port is not working, the module may have locked up or crashed.)</li> <li>To reset the module, pulse the RESET# pin with a logic low signal for 400–800 ms—if the signal is held low for more than 800 ms, the reset cycle restarts, and if it is held low through several cycles, the module will not fully boot. Otherwise, leave the signal floating or high impedance (the module will remain operational because the module has a pull-up resistor to an internal reference 1.8V voltage in place).</li> </ul>  <ul style="list-style-type: none"> <li>The signal requires an open collector input from the host.</li> </ul> <p><b>Caution:</b> RESET# should not be driven or pulled to a logic high level by the host, as this may cause damage to the module.</p>

### 3.6.4 PLA\_S2# (Power Loss Acknowledge)

*Note: Host support for PLA\_S2# is optional but highly recommended.*

The PLA signal is asserted by the module when it has completed its power down operation. Once asserted, the host can safely remove power to the module.

For timing details, refer to [Timing on page 64](#).

### 3.6.5 WWAN\_LED#—LED Output

*Note: Host support for WWAN\_LED# is optional.*

The configuration for the LED shown in Figure 3-8 is customizable. WWAN\_LED# supports up to 10 mA current sink. Contact your Sierra Wireless account representative for details.

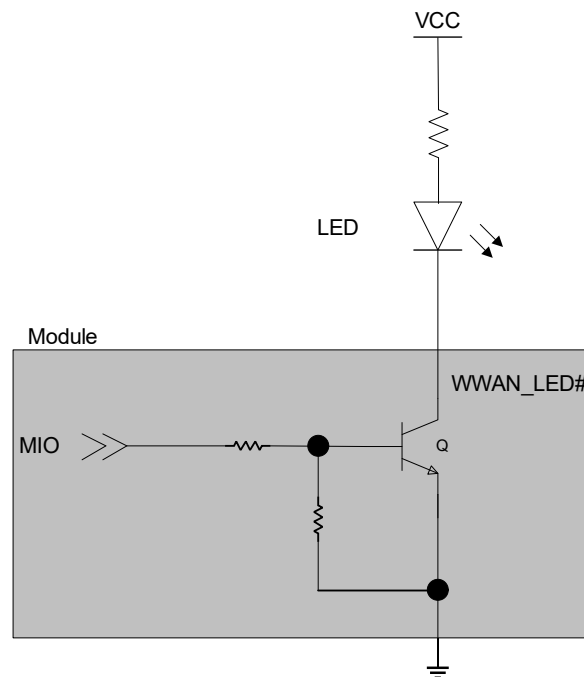


Figure 3-8: Recommended LED Connection

### 3.7 PCIE\_DIS—Interface Selection

*Note: Host support for PCIE\_DIS is optional.*

The PCIE\_DIS signal is provided for host interface selection:

- PCIe single lane interface—Leave signal unconnected or tie to GND
- USB interface—Drive signal high (1.8V)

#### Switching Interfaces

Typically, a host platform will configure the module for use with only one of these interfaces (i.e. the platform will be designed to use either PCIe or USB, but not both).

However, if a platform must be able to switch between interfaces (e.g. a development kit that will be used to test both interfaces), the module must be power-cycled or reset to do the switch, because the interfaces are mutually-exclusive.



For example, if PCIE\_DIS is high when the module boots, the USB interface will be active.

To switch from USB to PCIe interface:

1. While the module is on, set PCIE\_DIS low.  
At this point, the module continues to use the USB interface.
2. While keeping PCIE\_DIS low, power cycle the module.  
When the module boots, it will use the PCIe interface.

(Follow the same basic process to switch from PCIe to USB—drive PCIE\_DIS high, then power cycle the module.)

## 3.8 Tx Power Control

The module's SAR backoff state may be controlled using either SAR backoff AT commands (refer to [1] *Sierra Wireless EM919X AT Command Reference (Doc# 41113480)*), or the DPR (Dynamic Power Control) signal.

Use the GPIOARENABLE parameter for !CUSTOM to choose the method.

- AT commands:
  - !SARSTATE—Set (or report) the current SAR backoff state (override the default state). This change in state is non-persistent across power cycles.
- Dynamic power control:
  - The module's firmware monitors DPR (pin 25) with logic as detailed in [Table 3-9](#), and adjusts the RF Tx power appropriately with the Smart Transmit feature. For details, refer to [11] *EM919X-EM7690 Non-mmWave Smart Transmit (Doc# 2174291)*.

**Table 3-9: DPR Logic**

!SARINTGPIOMODE <sup>a</sup>	DPR Internal Pull	DPR Pin
0 (default)	Pull-up	High <sup>b</sup>
		Low (Active)
1	Pull-down	Low
		High (Active)

- a. The AT command !SARINTGPIOMODE can be used to invert the DPR logic, as shown.  
b. The host can implement an open collector drive for the DPR pin (if a 1.8V-compatible drive is not available).

## 3.9 mmWave Antenna Power Control

*Note: For EM9190 only. Host support for mmWave power control signals is optional.*

The EM9190 provides five output signals (listed in [Table 3-10](#)) that are used to power on/off the mmWave antenna modules attached to the mmWave IF connectors.

**Table 3-10: mmWave Antenna Power Control Signals**

Name	Pin	Description
QTM0_PON	40	Power control (on/off) signals for mmWave antennas attached to the module's mmWave connector
QTM1_PON	42	
QTM2_PON	44	
QTM3_PON	46	
QTM_IO_1.9V	48	1.904 V power supply, current limit is 500 mA

## 3.10 Antenna Control

*Note: Host support for the antenna control signal is optional.*

The EM91 module provides one output signal (ANT\_CTRL0) listed in [Table 3-11](#) that may be used for host designs that incorporate tunable low-band (< 1000 MHz) antennas. Customers can configure this signal as appropriate for the operating band(s) using the command AT!ANTSEL. (See [1] *Sierra Wireless EM919X AT Command Reference (Doc# 41113480)* for details.)

**Table 3-11: Antenna Control Signals**

Name	Pin	Description
ANT_CTRL0	59	Customer-defined external switch controls for tunable antennas.
ANT_CTRL1	61	Reserved for EM92xx compatibility
ANT_CTRL2	63	
ANT_CTRL3	65	

## >> 4: RF Specifications

### 4.1 RF Antenna Connectors

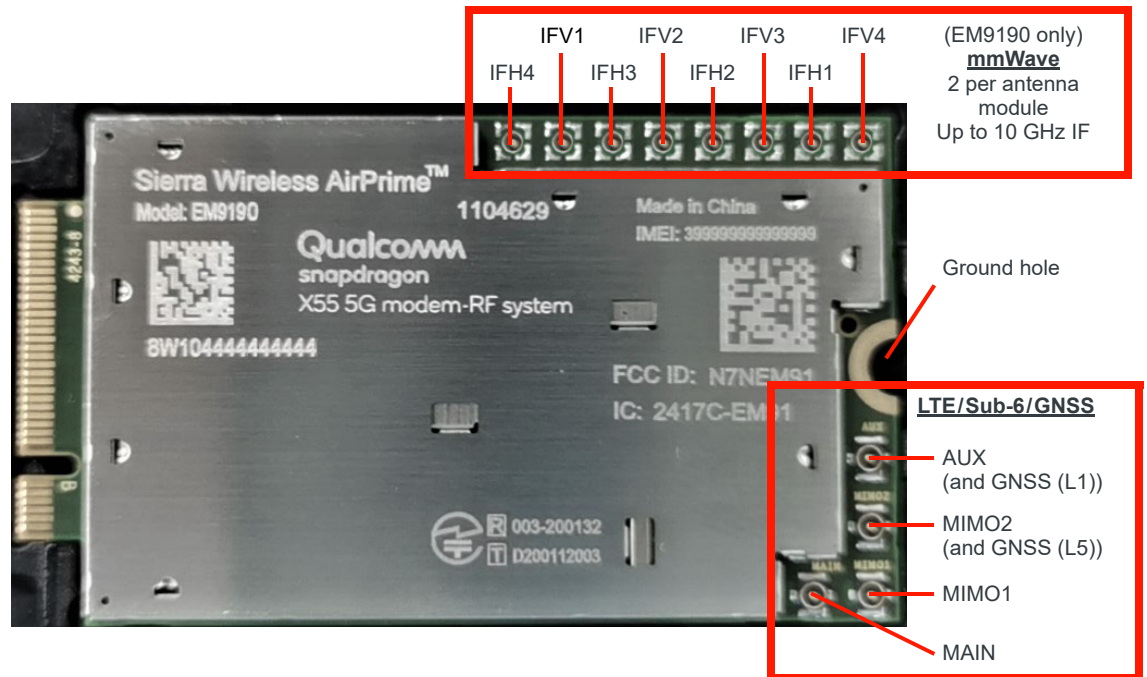


Figure 4-1: Module RF Connectors

EM91 modules include the following antenna connectors (Figure 4-1):

- LTE/Sub-6G/GNSS antenna connectors—Four MHF4 RF connectors for use with host-supplied antennas.

**Table 4-1: Antenna Connectors — RF Technology Support**

Freq Range	RAT	Bands	Tx	Rx				
				MAIN	MIMO1	MIMO2	AUX	
LB (Low Band)	< 1 GHz	LTE/ Sub-6G	5, 8, 12, 13, 14, 17, 18, 19, 20, 26, 28, 29, 71	MAIN	Y	—	—	Y
MLB (Middle L-Band)	1.4–1.6 GHz	LTE/ Sub-6G	32	MAIN	Y	Y	Y	Y
MB (Mid Band)	1.7–2.2 GHz	LTE/ Sub-6G	1, 2, 3, 4, 25, 34, 39, 66	MAIN	Y	Y	Y	Y
HB (High Band)	2.3–2.7 GHz	LTE/ Sub-6G	7, 30, 38, 40	MAIN	Y	Y	Y	Y
		LTE only	B41	MAIN	Y	Y	Y	Y
		Sub-6G	n41	MIMO1	Y	Y	Y	Y
UHB (Ultra High Band)	3–5 GHz	LTE/ Sub-6G	42, 43, 48	MAIN	Y	Y	Y	Y
		LTE only	B46 (Downlink only)	—	Y	—	—	Y

**Table 4-1: Antenna Connectors—RF Technology Support (Continued)**

Freq Range	RAT	Bands	Tx	Rx			
				MAIN	MIMO1	MIMO2	AUX
GNSS L1			—	—	—	—	Y
GNSS L5			—	—	—	Y	—

- (EM9190 only) mmW connectors—Eight MHF7S connectors for use with up to four mmWave antenna modules (2 connectors (H/V) per antenna module).

*Note: mmWave IF connectors are mounted only on EM9190.*

- Up to four mmWave antenna modules (QTM525 or QTM527) can connect to the EM9190. (Note—EM9190 modules do not have integrated antennas.)
- Refer to [Table 4-2](#) for specific QTM module band support.
- Refer to [Table 4-3](#) for each pair of coaxial connections.
- Note:
  - Low-power usage—If fewer than four QTM525 modules are used, integration sequence from QTM0 to QTM3 is recommended. Leave unused connectors NC, and contact Sierra Wireless—the RFC must be updated to reflect the number of QTMs.
  - High-power usage—Four QTM527 modules should be equipped—it is not recommended to leave any QTM527 NC as this will violate 3GPP EIRP compliance for PC1.

*Note: To ensure the best mmWave performance, refer to [6] EM9190 mmWave Design Guidelines (Doc# 2174276), [9] EM9190 Low Power mmWave RF Customization File Preparation (Doc# 2174286), and [10] EM9190 High Power mmWave RF Customization File Preparation (Doc# 2174282).*

**Table 4-2: 5G NR Band Support by QTM Module Type**

Module	n257	n258	n260	n261
QTM-525-2	Y	Y	—	Y
QTM-525-5	Y	Y	Y	Y
QTM-527-1	—	—	Y	Y
QTM-527-2	Y	Y	—	Y

**Table 4-3: mmWave Port Assignments**

QTM	P_ON	QTM525 IF port ↔ mmWave IF connector		QTM527 IF port ↔ mmWave IF connector	
		IF1	IF2	IF1	IF2
QTM0	QTM0_PON	QTM0_H ↔ IFH1	QTM0_V ↔ IFV4	QTM0_H ↔ IFH1	QTM0_V ↔ IFV4
QTM1	QTM1_PON	QTM1_H ↔ IFH4	QTM1_V ↔ IFV1	QTM1_H ↔ IFH2	QTM1_V ↔ IFV3

**Table 4-3: mmWave Port Assignments (Continued)**

QTM	P_ON	QTM525 IF port ↔ mmWave IF connector		QTM527 IF port ↔ mmWave IF connector	
		IF1	IF2	IF1	IF2
QTM2	QTM2_PON	QTM2_H ↔ IFH2	QTM2_V ↔ IFV3	QTM2_H ↔ IFH3	QTM2_V ↔ IFV2
QTM3	QTM3_PON	QTM3_H ↔ IFH3	QTM3_V ↔ IFV2	QTM3_H ↔ IFH4	QTM3_V ↔ IFV1

## 4.2 RF Connections

When attaching antennas to the module:

- LTE/Sub-6G/GNSS connectors:
  - Use RF plug connectors that are compatible with I-PEX (20449-001E (MHF4)) RF receptacle connectors.
  - Match coaxial connections between the module and the antenna to 50  $\Omega$ .
  - Minimize RF cable losses to the antenna; the recommended maximum cable loss for antenna cabling is 0.5 dB.
- mmWave connector (EM9190 only):
  - Use RF plug connectors that are compatible with I-PEX (20981-001E-02 (MHF7S)) RF receptacle connectors.
  - See [mmWave Antennas on page 84](#) for mmWave antenna module tips.
- To ensure best thermal performance, use the ground hole (if possible) to attach (ground) the device to a metal chassis.

---

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

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### 4.2.1 Sub-6G Antennas and Cabling

When selecting sub-6G antennas and cables, it is critical to RF performance to match antenna gain and cable loss.

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*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 [Appendix A: Antenna Specification](#) on page 81.*

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#### 4.2.1.1 Choosing the Correct Sub-6G Antenna and Cabling

When matching antennas and cabling:

- The antenna (and associated circuitry) should have a nominal impedance of 50  $\Omega$  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.

### 4.2.1.2 Designing Custom Sub-6G Antennas

Consider the following points when designing custom antennas:

- A skilled RF engineer should do the development to ensure that the RF performance is maintained.
- If multiple modules will be installed in the same platform, you may want to develop separate antennas for maximum performance.

### 4.2.1.3 Determining the Sub-6G 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  $\Omega$  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 47](#).

### 4.2.1.4 Disabling the Auxiliary (Diversity) Antenna

Certification testing of a device with an integrated EM91 module may require the module's MAIN and AUX (diversity) antennas to be tested separately.

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).

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**Important:** *LTE networks expect modules to have more than one antenna enabled for proper operation. Therefore, customers must not commercially deploy their systems with the AUX (diversity) antenna disabled.*

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For details, refer to [1] *Sierra Wireless EM919X AT Command Reference (Doc# 41113480)*.

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

---

## 4.3 Shielding

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

---

## 4.4 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 4-1 on page 43](#).
- 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.

## 4.5 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 48](#)) and radiated sensitivity measurement ([Radiated Sensitivity Measurement on page 48](#)).

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*Note: The EM91 module is based on ZIF (Zero Intermediate Frequency) technologies. When performing EMC (Electromagnetic Compatibility) tests, there are no IF (Intermediate Frequency) components from the module to consider.*

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### 4.5.1 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.

### 4.5.2 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

### 4.5.3 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.

### 4.5.4 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.

### 4.5.5 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  $\Omega$  emissions baseline. (Sierra Wireless embedded modules meet the 50  $\Omega$  conducted emissions requirement.)

### 4.5.6 Radiated Sensitivity Measurement

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

To determine the extent of any receiver performance desensitization due to self-generated noise in the host device, over-the-air (OTA) or radiated testing is required. This testing can be performed by Sierra Wireless or you can use your own OTA test chamber for in-house testing.

#### 4.5.6.1 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-6G bands (EM919x only)—Sensitivity is defined as the RF level at which throughput is 95% of maximum.

## 4.6 Supported RATs

The EM91 module supports:

- 5G:
  - Multiple-band 5G (EM919x only)—See [Table 4-4](#) (supported bands), [Table 4-6](#) (NR bandwidth support) and [Table 4-8](#) (Inter-band EN-DC NR UL combinations).
- LTE:
  - Multiple-band LTE—See [Table 4-4](#) (supported bands) and [Table 4-5 on page 51](#) (LTE bandwidth support).
  - LTE Advanced carrier aggregation:
    - Intra-band ULCA—3C, 7C, 41C, 42C
    - Inter-band ULCA—Low band and mid-high band combinations. See [Table 4-7](#).
- WCDMA:
  - Multiple-band WCDMA/HSPA/HSPA+/DC-HSPA+—See [Table 4-4](#).
  - Multiple-band WCDMA receive diversity
- [inter-RAT](#) and inter-frequency cell reselection and handover between supported frequency bands
- GNSS:
  - GPS, GLONASS, BeiDou, Galileo, QZSS—See [Table 4-13 on page 58](#).

### 4.6.1 Supported Bands

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

Band#	5G <sup>a</sup> (n<band#>)	LTE (B<band#>)	3G (Band<band#>)	Frequency (Tx)	Frequency (Rx)
1	Y	Y	Y	1920–1980 MHz	2110–2170 MHz
2	Y	Y	Y	1850–1910 MHz	1930–1990 MHz
3	Y	Y		1710–1785 MHz	1805–1880 MHz
4		Y	Y	1710–1755 MHz	2110–2155 MHz
5	Y	Y	Y	824–849 MHz	869–894 MHz
6			Y	830–840 MHz	875–885 MHz
7	Y <sup>b</sup>	Y		2500–2570 MHz	2620–2690 MHz
8	Y <sup>b</sup>	Y	Y	880–915 MHz	925–960 MHz
9			Y	1749.9–1784.9 MHz	1844.9–1879.9 MHz
12	Y <sup>b</sup>	Y		699–716 MHz	729–746 MHz
13		Y		777–787 MHz	746–756 MHz
14		Y		788–798 MHz	758–768 MHz

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

Band#	5G <sup>a</sup> (n<band#)	LTE (B<band#>)	3G (Band<band#)	Frequency (Tx)	Frequency (Rx)
17		Y		704–716 MHz	734–746 MHz
18		Y		815–830 MHz	860–875 MHz
19		Y	Y	830–845 MHz	875–890 MHz
20	Y <sup>b</sup>	Y		832–862 MHz	791–821 MHz
25	Y <sup>b</sup>	Y		1850–1915 MHz	1930–1995 MHz
26		Y		814–849 MHz	859–894 MHz
28	Y	Y		703–748 MHz	758–803 MHz
29		Y		n/a	717–728 MHz
30		Y		2305–2315 MHz <i>Note: B30 Tx is disabled.<sup>c</sup></i>	2350–2360 MHz
32		Y		n/a	1452–1496 MHz
34		Y		2010–2025 MHz (TDD)	
38	Y <sup>b</sup>	Y		2570–2620 MHz (TDD)	
39		Y		1880–1920 MHz (TDD)	
40	Y <sup>b</sup>	Y		2300–2400 MHz (TDD)	
41	Y	Y		2496–2690 MHz (TDD)	
42		Y		3400–3600 MHz (TDD)	
43		Y <sup>b</sup>		3600–3800 MHz (TDD)	
46 <sup>d</sup>		Y		n/a	5150–5925 MHz (TDD)
48	Y <sup>b</sup>	Y		3550–3700 MHz (TDD)	
66	Y	Y		1710–1780 MHz	2110–2200 MHz
71	Y	Y		663–698	617–652
77	Y			3300–4200 MHz (TDD)	
78	Y			3300–3800 MHz (TDD)	
79	Y			4400–5000 MHz (TDD)	
257 <sup>e</sup>	Y			26500–29500 MHz (TDD)	
258 <sup>e</sup>	Y			24250–27500 MHz (TDD)	
260 <sup>e</sup>	Y			37000–40000 MHz (TDD)	
261 <sup>e</sup>	Y			27500–28350 MHz (TDD)	

- a. EM919x only
- b. Band support is firmware and SKU dependent.
- c. To assist OEMs to meet FCC and PTCRB rules, LTE band 30 is set to downlink only by default.
- d. LTE-LAA B46 (downlink only)
- e. EM9190 only

**Table 4-5: LTE Bandwidth Support<sup>a</sup>**

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 <sup>b</sup>	Y <sup>b</sup>
B3	Y	Y	Y	Y	Y <sup>b</sup>	Y <sup>b</sup>
B4	Y	Y	Y	Y	Y	Y
B5	Y	Y	Y	Y <sup>b</sup>		
B7			Y	Y	Y <sup>c</sup>	Y <sup>b,c</sup>
B8	Y	Y	Y	Y <sup>b</sup>		
B12	Y	Y	Y <sup>b</sup>	Y <sup>b</sup>		
B13			Y <sup>b</sup>	Y <sup>b</sup>		
B14			Y <sup>b</sup>	Y <sup>b</sup>		
B17			Y <sup>b</sup>	Y <sup>b</sup>		
B18			Y	Y <sup>b</sup>	Y <sup>b</sup>	
B19			Y	Y <sup>b</sup>	Y <sup>b</sup>	
B20			Y	Y <sup>b</sup>	Y <sup>b</sup>	Y <sup>b</sup>
B25	Y	Y	Y	Y	Y <sup>b</sup>	Y <sup>b</sup>
B26	Y	Y	Y	Y <sup>b</sup>	Y <sup>b</sup>	
B28		Y	Y	Y <sup>b</sup>	Y <sup>b</sup>	Y <sup>b,c</sup>
B29		Y	Y	Y		
B30			Y	Y <sup>b</sup>		
B32			Y	Y	Y	Y
B34			Y	Y	Y	
B38			Y	Y	Y <sup>c</sup>	Y <sup>c</sup>
B39			Y	Y	Y <sup>c</sup>	Y <sup>c</sup>
B40			Y	Y	Y	Y
B41			Y	Y	Y	Y
B42			Y	Y	Y	Y
B43 <sup>d</sup>			Y	Y	Y	Y
B46				Y		Y
B48			Y	Y	Y	Y
B66	Y	Y	Y	Y	Y	Y
B71			Y	Y <sup>b</sup>	Y <sup>b</sup>	Y <sup>b</sup>

a. Table contents are derived from 3GPP TS 36.521-1 v15.5.0, table 5.4.2.1-1.

- b. 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.
- c. 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).
- d. Band support is firmware and SKU dependent.

**Table 4-6: EM919x<sup>a</sup> NR Bandwidth<sup>b</sup> and 5G Architecture Support<sup>c</sup>**

Band	Bandwidth (MHz) <i>(Default architecture support: NSA—Non-Standalone; SA—Standalone)</i>												
	5	10	15	20	25	30	40	50	60	70	80	90	100
n1	NSA,SA	NSA,SA	NSA,SA	NSA,SA		NSA,SA	NSA,SA						
n2	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n3	NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA							
n5	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n7 <sup>d</sup>	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n8 <sup>d</sup>	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n12 <sup>d</sup>	NSA,SA <sup>e</sup>	NSA,SA <sup>e</sup>	NSA,SA <sup>e</sup>										
n20 <sup>d</sup>	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n25 <sup>d</sup>	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n28	NSA,SA	NSA,SA	NSA,SA	NSA,SA		NSA,SA							
n38 <sup>d</sup>				NSA,SA									
n40 <sup>d</sup>				NSA,SA		NSA,SA	NSA,SA	NSA,SA	NSA,SA		NSA,SA		
n41				NSA,SA		NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA <sup>e</sup>	NSA,SA	NSA,SA	NSA,SA
n48 <sup>d</sup>		NSA,SA <sup>e</sup>		NSA,SA <sup>e</sup>			NSA,SA <sup>e</sup>	NSA,SA <sup>e,f</sup>	NSA,SA <sup>e,f</sup>		NSA,SA <sup>e,f</sup>	NSA,SA <sup>e,f</sup>	NSA,SA <sup>e,f</sup>
n66	NSA,SA	NSA,SA	NSA,SA	NSA,SA		NSA,SA	NSA,SA <sup>e</sup>						
n71	NSA,SA	NSA,SA	NSA,SA	NSA,SA									
n77				NSA,SA		NSA,SA	NSA,SA	NSA,SA <sup>e</sup>	NSA,SA	NSA,SA <sup>e</sup>	NSA,SA	NSA,SA <sup>e</sup>	NSA,SA
n78				NSA,SA		NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA	NSA,SA
n79							NSA,SA	NSA,SA	NSA,SA		NSA,SA	NSA,SA <sup>e</sup>	NSA,SA
n257								NSA					NSA <sup>e</sup>
n258								NSA					NSA <sup>e</sup>
n259								NSA					NSA
n260								NSA					NSA

- a. EM919x only. Table contents are derived from 3GPP TS 38.521-1 v15.3.0, table 5.3.5-1.
- b. SCS: 30 kHz (FR1 TDD bands); 15 kHz (FR1 FDD bands); 120 kHz (FR2 bands)
- c. Architecture support is SKU-dependent. All FR1 bands capable of supporting Standalone (SA) and Non-standalone (NSA) architecture; FR2 bands support NSA only.
- d. Band support is firmware and SKU-dependent.
- e. Indicated bandwidths may be disabled by default due to carrier deployment requirements.
- f. Downlink only

## 4.6.2 CA/EN-DC Support

The following tables describe LTE UL CA and NR UL EN-DC support. For comprehensive LTE CA and NR EN-DC support details (including UL and DL combinations), refer to [15] EM9 Carrier Aggregations and EN-DC (Doc# 2174317).

**Table 4-7: LTE Inter-band UL CA Summary<sup>a</sup>**

Mid-High Bands →	B1	B2	B3	B4	B7	B66
Low Bands ↓						
<b>B5</b>	Y	Y	Y	Y	Y	Y
<b>B8</b>	Y		Y		Y	
<b>B12</b>		Y		Y		Y
<b>B13</b>		Y		Y		Y
<b>B18</b>	Y		Y			
<b>B19</b>	Y		Y			
<b>B20</b>	Y		Y		Y	
<b>B26</b>	Y		Y			
<b>B28</b>	Y		Y		Y	

a. LTE UL CA summary only. For full LTE CA details, refer to [15] EM9 Carrier Aggregations and EN-DC (Doc# 2174317).

**Table 4-8: NR UL Combination of EN-DC<sup>a</sup>**

NR Bands		Inter-band EN-DC (4G LTE Anchor's Tx)		
		Low Band 4G	Mid Band 4G	High Band 4G
FR1	n1	B8, B20		
	n2	B5, B12		
	n3	B8, B20, B28		
	n5		B1, B2, B3, B66	B7, B30
	n7 <sup>b</sup>	B5, B12, B20, B28		
	n8 <sup>b</sup>		B1, B3, B7	
	n12 <sup>b</sup>		B2, B66	
	n20 <sup>b</sup>		B1, B3, B7	
	n25 <sup>b</sup>	B12		
	n28		B1, B3	B7
	n38 <sup>b</sup>	B5, B12, B20, B71		
	n40 <sup>b</sup>	B8, B28		
	n41		B2, B3, B4, B25	
	n48 <sup>b</sup>	B13	B66	
	n66	B5, B12, B13, B14, B71		
	n71		B2, B66	B7
	n77	B8, B18, B28	B1, B3	B41
n78	B5, B8, B12, B18, B19, B20, B28	B1, B2, B3, B66	B7, B38, B41	
n79	B19	B1, B3, B39	B41	

- a. EM919x only. NR UL EN-DC summary only. For full NR EN-DC details, refer to [15] EM9 Carrier Aggregations and EN-DC (Doc# 2174317).
- b. Band support is firmware and SKU dependent.

## 4.7 Conducted Rx Sensitivity / Tx Power

**Table 4-9: Typical Conducted Rx Sensitivity — NR Bands<sup>a</sup>**

Band	Duplex Mode	SCS (KHz)	BW (MHz)	Typical Conducted Rx Sensitivity (dBm) <sup>b</sup>				Worst Case <sup>c</sup>	
				PRx	DRx	PRx+DRx	4 Rx	Antenna Port	Requirement (dBm)
n1	FDD	15	20	-95.5	-94	-97	-100	4 Rx	-95.8
n2	FDD	15	20	-95	-94	-97	-100.5	4 Rx	-93.8
n3	FDD	15	20	-94.5	-94	-97	-100.5	4 Rx	-92.8
n5	FDD	15	20	-95.5	-97	-100	n/a	2 Rx	-90.1

**Table 4-9: Typical Conducted Rx Sensitivity—NR Bands<sup>a</sup> (Continued)**

Band	Duplex Mode	SCS (KHz)	BW (MHz)	Typical Conducted Rx Sensitivity (dBm) <sup>b</sup>				Worst Case <sup>c</sup>	
				PRx	DRx	PRx+DRx	4 Rx	Antenna Port	Requirement (dBm)
n7	FDD	15	20	-96.5	-95.0	-97.5	-100.5	4 Rx	-93.8
n8	FDD	15	20	-97.0	-98.5	-99.5	n/a	2 Rx	-89.3
n12	FDD	15	15	-100.0	-101.5	-102.5	n/a	2 Rx	-83.3
n20	FDD	15	20	-98.0	-98.5	-100.5	n/a	2 Rx	-89.1
n25	FDD	15	20	-96.0	-95.5	-98.0	-101.0	2 Rx	-89.6
n28	FDD	15	20	-95	-97	-99	n/a	2 Rx	-90.1
n38	TDD	30	20	-96.0	-95.5	-97.5	-99.5	4 Rx	-96
n40	TDD	30	20	-95.5	-95.0	-97.5	-99.5	4 Rx	-96
n41	TDD	30	20	-96	-95	-98.5	-100.5	4 Rx	-94
n48	TDD	30	20	-97.5	-98.0	-100.0	-102.0	4 Rx	-94.1
n66	FDD	15	20	-93.5	-93.5	-96	-99	4 Rx	-95.3
n71	FDD	15	20	-96.5	-97.5	-100	n/a	2 Rx	-85.3
n77	TDD	30	100	-86.5	-87.5	-89	-91.5	4 Rx	-86.8
n78	TDD	30	40	-91	-92	-94	-96.5	4 Rx	-90.9
n79	TDD	30	100	-85.5	-85.5	-88	-89.5	4 Rx	-86.8

a. EM919x only

b. Results at room temperature. Based on Lab test result and Call box only in a shielded test environment. There might be MSD for the cases which has harmonic and IMD exceptions, we guarantee better performance than the level that 3GPP defined.

c. Per 3GPP specification

**Table 4-10: Typical Conducted Rx (Receive) Sensitivity—LTE Bands at 10 MHz BW**

LTE bands	Typical Conducted Rx sensitivity (dBm) <sup>a b</sup>				Worst Case <sup>c</sup>
	PRx	DRx	PRx+DRx	4 Rx	PRx+DRx (dBm)
B1	-98.5	-98	-102	-104.5	-96.3
B2	-99.5	-98.5	-101.5	-103.5	-94.3
B3	-98.5	-98	-100.5	-103.5	-93.3
B4	-99	-99	-101	-104	-96.3
B5	-100	-100	-103	—	-94.3
B7	-97	-96	-100	-102.5	-94.3
B8	-100	-100	-103	—	-93.3
B12	-100.5	-101	-104	—	-93.3
B13	-101	-101	-103.5	—	-93.3

**Table 4-10: Typical Conducted Rx (Receive) Sensitivity—LTE Bands at 10 MHz BW**

LTE bands	Typical Conducted Rx sensitivity (dBm) <sup>a b</sup>				Worst Case <sup>c</sup>
	PRx	DRx	PRx+DRx	4 Rx	PRx+DRx (dBm)
B14	-101	-101	-103.5	—	-93.3
B17	-100.5	-101.5	-104	—	-93.3
B18	-100.5	-101	-103.5	—	-96.3
B19	-100.5	-100.5	-103	—	-96.3
B20	-100.5	-100.5	-103.5	—	-93.3
B25	-98	-97.5	-100.5	-103	-92.8
B26	-99	-100.5	-102.5	—	-93.8
B28	-100.5	-100.5	-103.5		-94.8
B29 <sup>d</sup>	-100.5	-101	-103.5	—	-93.3
B30	-99	-99	-101.5	-103	-95.3
B32 <sup>d</sup>	-100	-100	-102.5	-105	-96.5
B34	-98.5	-97.5	-101	-104	-96.3
B38	-97	-97	-100	-103	-96.3
B39	-98	-98	-101	-103.5	-96.3
B40	-97	-97	-100	-102.5	-96.3
B41	-97	-97	-100	-102.5	-94.3
B42	-98	-98.5	-101	-103.5	-95.0
B43	-99.0	-95.5	-102.0	-104.5	-93.8
B46 <sup>e</sup>	-94	-94.5	-96.5	—	-90
B48	-98.5	-98.5	-101.0	-103.5	-95.3
B66	-99	-99	-101.5	-104	-95.8
B71	-101	-101	-103.5	—	-93.5

- a. Sensitivity values scale with bandwidth:  $x\_MHz\_Sensitivity = 10\_MHz\_Sensitivity - 10 \cdot \log(10\text{ MHz}/x\_MHz)$  Note: Bandwidth support is dependent on firmware version.
- b. Results at room temperature. Based on Lab test result and Call box only in a shielded test environment, and the test is based on standalone mode only.
- c. Per 3GPP specification
- d. SDL (Rx only) band, and the typical result is based on certain 2DL CA cases such as B2+B29, B2+B46, B20+B32.
- e. B46 is based on 20 MHz BW as most combinations for B46 LAA are 20 MHz BW only.



**Table 4-11: Conducted Rx (Receive) Sensitivity — UMTS Bands**

UMTS bands		Conducted Rx sensitivity (dBm)		
		Primary (Typical) <sup>a</sup>	Secondary (Typical)	Primary/Secondary (Worst case) <sup>b</sup>
Band 1	0.1% BER 12.2 kbps	-110	-110	-106.0
Band 2		-110	-109	-104.0
Band 4		-110	-109.5	-106.0
Band 5		-111	-112.5	-104.0
Band 6		-111	-112.5	-106.0
Band 8		-111	-112.5	-103.0
Band 9		-109.5	-109.5	-105.0
Band 19		-111	-112.5	-106.0

a. The typical result is at room temperature and based on Lab test result and Call box only at a shielded test environment.

b. Per 3GPP specification

**Table 4-12: Conducted Maximum Tx (Transmit) Power<sup>a</sup> Tolerances**

Bands		Conducted Tx Power	Notes
<b>5G</b>			
FR1 Sub-6G Bands	n2, n5, n48, n66, n77	+23.7 dBm +0.8/-2.2 dB	EM919x only Power Class 3
	All other bands	+23 dBm ± 1.5 dB	
<b>LTE</b>			
LTE B3, B7, B41, B42		+23 dBm +1.8/-1.0 dB	Power Class 3
B41 HPUE		+25 dBm ± 1 dB	Power Class 2 for B41 standalone mode only
LTE all other bands		+23 dBm ± 1 dB	Power Class 3
<b>UMTS</b>			
All bands (12.2 kbps)		+23.5 dBm ± 1 dB	Connectorized (Power Class 3)

a. Tx Power is based on no maximum power reduction (MPR) configuration as 3GPP defined. For configurations that require MPR or additional MPR, refer to 3GPP for the power reduction.

## 4.8 GNSS Specifications

*Note: For detailed electrical performance criteria, see [Recommended GNSS Antenna Specifications on page 83](#).*

**Table 4-13: GNSS Specifications**

Parameter/feature	Description
Satellite channels	Support all in-view satellites (L1 + L5) for simultaneous tracking
TTFF <sup>a</sup>	Hot start: ≤1 s Warm start: ≤20 s Cold start: ≤28 s
Accuracy <sup>a</sup>	Horizontal: < 2 m (50%); < 4 m (95%) Altitude: < 2 m (50%); < 4 m (95%) Velocity: < 0.2 m/s
Sensitivity <sup>b</sup>	Tracking <sup>c</sup> : <ul style="list-style-type: none"> <li>• GPS: -160 dBm</li> <li>• GLONASS: -158 dBm</li> </ul> Reacquisition <sup>d</sup> : <ul style="list-style-type: none"> <li>• GPS: -157 dBm</li> <li>• GLONASS: -156 dBm</li> </ul> Cold start (autonomous) acquisition <sup>d</sup> : <ul style="list-style-type: none"> <li>• GPS: -148 dBm</li> <li>• GLONASS: -140 dBm</li> </ul> Hot start acquisition <sup>d</sup> : <ul style="list-style-type: none"> <li>• GPS: -155 dBm</li> <li>• GLONASS: -147 dBm</li> </ul>
Operational Limits	Altitude <6000 m or velocity <100 m/s (Either limit may be exceeded, but not both.)

- a. TTFF (without AGNSS) and accuracy are measured under open sky conditions with signal strength of -135 dBm.
- b. Performance is tested in conducted mode with GNSS signal simulator under room temperature and without external GNSS LNAs as the module includes internal LNAs for both L1 and L5.
- c. Tracking sensitivity is the lowest GNSS signal level in which the device can still detect in-view satellites and get fixed at least 50% of the time when in sequential tracking mode.
- d. Acquisition sensitivity is the lowest GNSS signal strength for which the device can still detect in-view satellites and get fixed at least 50% of the time.

# >> 5: Power

## 5.1 Power Consumption

*Note: The power consumption data are measured with typical use cases of EM9190 for reference, refer to [8] EM9190 Current Consumption Application Note (Doc# 2174287) for details.*

The module does not have its own power source and depends on the host device for power. For a description of input voltage requirements, see [Power Supply on page 30](#).

**Table 5-1: Averaged Standby DC Power Consumption**

Signal	Description	Bands <sup>a</sup>	Current <sup>b</sup>			Notes / configuration
			Typ	Max	Unit	
VCC	<b>Standby current consumption (Host interface suspended<sup>c</sup>)</b>					
	5G	NR bands	2.7	—	mA	DRX cycle = 1.28 s
	LTE	LTE bands	2.7	—	mA	DRX cycle = 1.28 s
	HSPA / WCDMA	UMTS bands	2.6	—	mA	DRX cycle = 2.56 s
	<b>Standby current consumption (Host interface active)</b>					
	5G	NR bands	31.6	—	mA	DRX cycle = 1.28 s
	LTE	LTE bands	31.9	—	mA	DRX cycle = 1.28 s
	HSPA / WCDMA	UMTS bands	30.7	—	mA	DRX cycle = 2.56 s
	<b>Low Power Mode (LPM)/Offline Mode (Host interface suspended<sup>c</sup>)</b>					
	RF disabled, but module is operational		5.0	—	mA	
	<b>Low Power Mode (LPM)/Offline Mode (Host interface active)</b>					
	RF disabled, but module is operational		28.4	—	mA	
	<b>Leakage Current</b>					
	Module powered off—Full_Card_Power_Off# is Low, and VCC is supplied		70	120	μA	

- For supported bands, see [Table 4-4, Supported Frequency Bands, by RAT \(5G/LTE/3G\)](#), on page 49.
- Measured at 25°C/nominal 3.3 V voltage.
- Indicated measurements assume the host interface is fully suspended (e.g., USB in USB SS, or PCIe in L1SS (see [12] EM919x/EM7690 PCIe Integration Guide (Doc# 41114276) for details))

**Table 5-2: Averaged Call Mode DC Power Consumption**

Mode	Description	Tx power (dBm)	Current <sup>a,b</sup> (mA)	Configuration <sup>c</sup>	Bands
3G	3G Data Call, max RF power	23	800	HSDPA DL 7.2 Mbps	B1
LTE	LTE FDD DL 5CA 4x4 / UL 2CA	0	905	DL 2000 Mbps/UL 200 Mbps;	1A+3C+7C
		20	1120	FDD, 20 MHz/CC, DL: 5CC, 4x4 MIMO, 256QAM, RB=100, MCS=27; UL: 2CC, 256QAM	
	LTE FDD DL 5CA 4x4 / UL 2CA, max RF power	23	1435	DL 2000 Mbps/UL 1 Mbps; FDD, 20 MHz/CC, DL: 5CC, 4x4 MIMO, 256QAM, RB=100, MCS=27; UL: 2CC, QPSK	
Sub-6 NSA	PDCCH 1CC, no data	—	410	DL/UL 0 Gbps; Sub-6 100 MHz /CC, 4Rx, RB=0; LTE no data	1A+n78
	Sub-6 DL / UL 1CC	0	660	DL 1600 Mbps/UL 95 Mbps; Sub-6 100 MHz/CC, DL: duty cycle ~ 80%, 1CC, 4x4 MIMO, -50 dBm, 256QAM, RB=273, MCS=27; UL: SISO, 256QAM, RB=273, MCS=27; LTE no data	
Sub-6 EN-DC	LTE 5CC + Sub-6 DL / UL 1CC	0	1360	DL 3600 Mbps/200 Mbps;	1A+3C+7C+n78
		20	1780	Sub-6 100 MHz/CC, DL/UL duty cycle ~80/20, Rx: 1CC, 4x4 MIMO, -50 dBm, 256QAM, RB=273, MCS=27; Tx: SISO, 256QAM; LTE: DL 5CC, 4x4 MIMO, 20 MHz/CC, 256QAM, RB=100, MCS=27; Tx: 256QAM	
	LTE 5CC + Sub-6 DL / UL 1CC, max RF power	23	2030	DL 3600 Mbps/UL 1 Mbps; Sub-6 100 MHz/CC, DL/UL duty cycle ~80/20, Rx: 1CC, 4x4 MIMO, -50 dBm, 256QAM, RB=273, MCS=27; Tx: SISO, QPSK; LTE: DL 5CC, 4x4 MIMO, 20 MHz/CC, 256QAM, RB=100, MCS=27; Tx: SISO QPSK	

**Table 5-2: Averaged Call Mode DC Power Consumption (Continued)**

Mode	Description	Tx power (dBm)	Current <sup>a,b</sup> (mA)	Configuration <sup>c</sup>	Bands
mmWave EN-DC	DL 4CC + UL 1CC LTE UL 23 dBm, max RF power	23	1480 <sup>d</sup>	DL 3.1 Gbps/UL TBD; 5G DL/UL duty cycle: ~80/20 mmW DL: 64QAM, 2x2 MIMO, Rx=-50 dBm; mmW UL: 64QAM, Tx=21 dBm (TRP), SISO	2A+66A+n261I
	DL 8CC <sup>e</sup> + UL 1CC LTE UL 23 dBm, max RF power	23	2000 <sup>d</sup>	DL 5.1 Gbps/UL TBD; 5G DL/UL duty cycle: ~80/20 mmW DL: 64QAM, 2x2 MIMO, Rx=-50 dBm; mmW UL: 64QAM, Tx=21 dBm (TRP), SISO	2A+66A+n261M

- a. Measured at 25°C/nominal 3.3 V voltage
- b. Test data does not include current consumption of data transfer between module and host—the additional current increase is less than 100 mA in the worst case.
- c. The measurement is using the EM919X/EM7690 development kit with a heatsink, refer to [3] EM9190 Thermal Application Note (Doc# 2174257) for details.
- d. mmWave EN-DC current measurement is for the EM9190 only. QTM (mmW antenna) current is not included.
- e. 8CC is supported only on LE1.2/LE1.4.

**Table 5-3: Miscellaneous DC Power Consumption**

Signal	Description	Current / Voltage				Description
		Min	Typ	Max	Unit	
VCC	USB active current	—	30	—	mA	<ul style="list-style-type: none"> <li>High-speed USB connection, but no data transmission, CL = 50 pF on D+ and D- signals.</li> <li>RF is disabled.</li> </ul>
	PCIe active current	—	53	—	mA	<ul style="list-style-type: none"> <li>PCIe connection, but no data transmission.</li> <li>RF is disabled.</li> </ul>
	Inrush current	—	—	3.0	A	<ul style="list-style-type: none"> <li>Assume power supply turn-on time &gt; 100 μs</li> <li>Dependent on host power supply rise time.</li> </ul>
	Peak current	EM9190 with mmWave	—	—	5.0	A
EM9190 without mmWave	—	—	3.0	A		
EM9191	—	—	2.7	A		
	EM7690	—	—	2.3	A	

## 5.2 Module Power States

The module has five power states, as described in [Table 5-4](#).

**Table 5-4: Module Power States**

State	Details	Host is powered	Host interface active	RF enabled
Normal (Default state)	<ul style="list-style-type: none"> <li>Module is active</li> <li>Default state. Occurs when VCC is first applied, Full_Card_Power_Off# is deasserted (pulled high), and W_DISABLE# is deasserted</li> <li>Module is capable of placing/receiving calls, or establishing data connections on the wireless network</li> <li>Current consumption is affected by several factors, including:                             <ul style="list-style-type: none"> <li>Radio band being used</li> <li>Transmit power</li> <li>Receive gain settings</li> <li>Data rate</li> </ul> </li> </ul>	✓	✓	✓
Low power (Airplane mode)	<ul style="list-style-type: none"> <li>Module is active</li> <li>Module enters this state:                             <ul style="list-style-type: none"> <li>Under host interface control:                                     <ul style="list-style-type: none"> <li>Host issues AT+CFUN=0 ([16] AT Command Set for User Equipment (UE) (Release 6) (Doc# 3GPP TS 27.007)), or</li> <li>Host asserts W_DISABLE#, after AT!PCOFFEN=0 has been issued.</li> </ul> </li> <li>Automatically, when critical temperature or voltage trigger limits have been reached))</li> </ul> </li> </ul>	✓	✓	✗
Sleep	<ul style="list-style-type: none"> <li>Normal state of module between calls or data connections</li> <li>Module cycles between wake (polling the network) and sleep, at network provider-determined interval.</li> </ul>	✓	✗	✗
Off	<ul style="list-style-type: none"> <li>Host keeps module powered off by asserting Full_Card_Power_Off# (signal pulled low or left floating)</li> <li>Module draws minimal current</li> <li>See <a href="#">Full_Card_Power_Off# and RESET# on page 39</a> for more information.</li> </ul>	✓	✗	✗
Disconnected	<ul style="list-style-type: none"> <li>Host power source is disconnected from the module and all voltages associated with the module are at 0 V.</li> </ul>	✗	✗	✗

### 5.2.1 Power State Transitions

The module uses state machines to monitor supply voltage and operating temperature, and notifies the host when critical threshold limits are exceeded. (See [Table 5-5](#) for trigger details and [Figure 5-1](#) for state machine behavior.)

Power state transitions may occur:

- Automatically, when critical supply voltage or module temperature trigger levels are encountered.
- Under host control, using available AT commands in response to user choices (for example, opting to switch to airplane mode) or operating conditions.

**Table 5-5: Power State Transition Default Trigger Levels**

Transition	Voltage		Temperature <sup>a</sup>		Notes
	Trigger	V	Trigger	°C	
Normal to Low Power	VOLT_HI_CRIT	4.6	TEMP_LO_CRIT	-45	RF activity suspended
	VOLT_LO_CRIT	2.9	TEMP_HI_CRIT	118	
Low Power to Normal	VOLT_HI_NORM	4.4	TEMP_NORM_LO	-30	RF activity resumed
Low Power to Normal or Remain in Normal (Remove warnings)	VOLT_LO_NORM	3.135	TEMP_HI_NORM	100	
Normal (Issue warning)	VOLT_LO_WARN	3.135	TEMP_HI_WARN	100	In the TEMP_HI_WARN state, the module may have reduced performance (Class B temperature range).
Power off/on (Host-initiated)	-	-	-	-	Power off recommended when supply voltage or module operating temperature is critically low or high.

a. Highest junction temperature among onboard chipsets (PAs, PMIC, XO, SDX55)

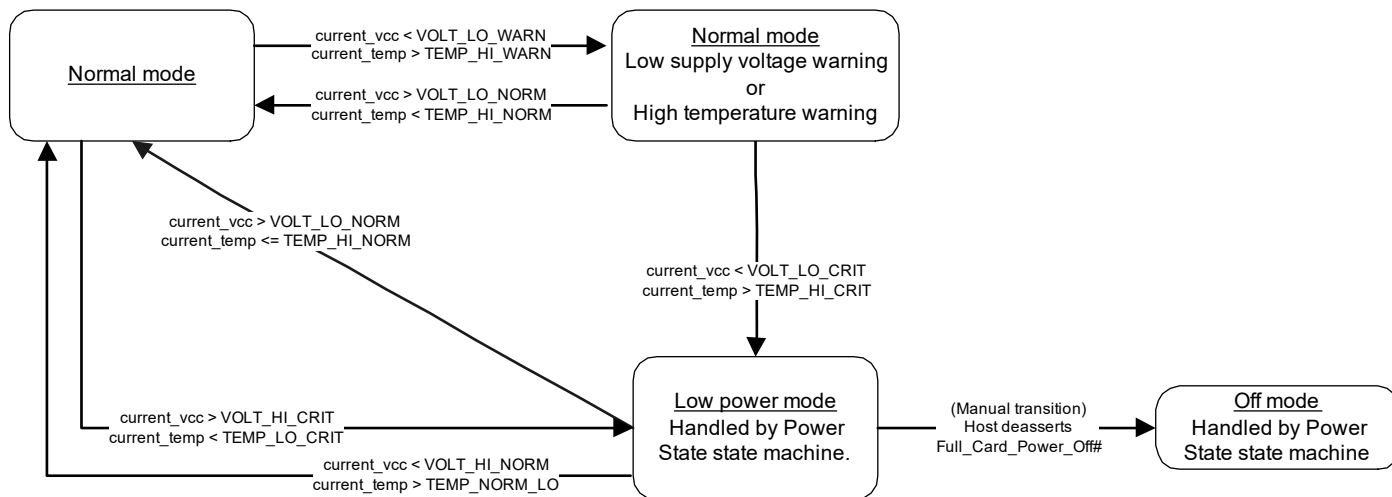


Figure 5-1: Voltage/Temperature Monitoring State Machines

## 5.3 Power Interface

### 5.3.1 Power Ramp-up

On initial power up, inrush current depends on the power supply rise time—turn on time  $>100 \mu\text{s}$  is required for  $< 3 \text{ A}$  inrush current.

The supply voltage must remain within specified tolerances while this is occurring.

### 5.3.2 Timing

#### 5.3.2.1 Power On/Off Timing for PCIe Port

Figure 5-2 describes the timing of PCIe port detection in the power-on/off sequence.

*Note: Before reaching the “Active” state, signals on the host port are undefined and signal transitions may occur. This undefined state also applies when the module is in reset mode, during a firmware update, or during the Power-off sequence. The host must consider these undefined signal activities when designing the module interface.*

*Note: The host must not drive any signals to the module until  $>100 \text{ ms}$  from the start of the power-on sequence.*

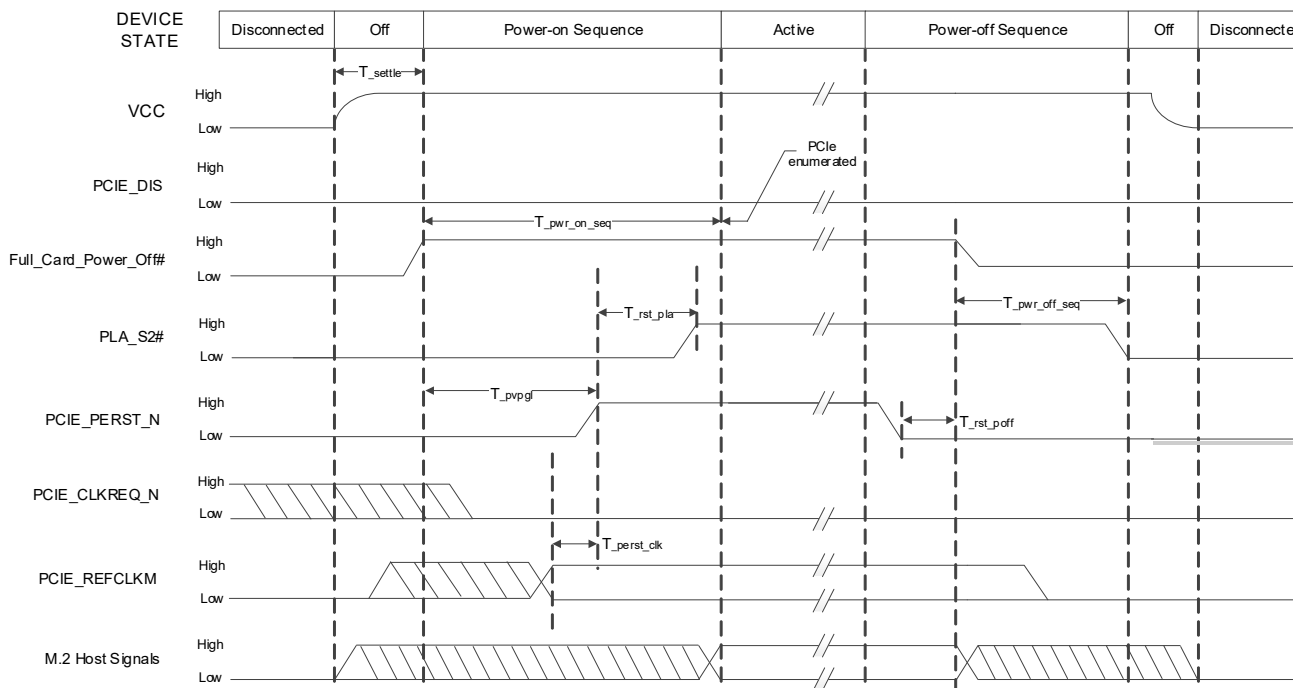


Figure 5-2: Power On/Off Timing—PCIe Port



**Table 5-6: PCIe Timing**

Symbol	Parameter	Min	Typ	Max	Unit
T_settle	Power on to Power Valid	—	—	—	ms
T_pvpgl <sup>a</sup>	Power Valid to PCIE_PERST_N input high	50	—	—	ms
T_rst_pla	PCIE_PERST_N high to PLA_S2# high	—	157	—	ms
T_rst_poff	PCIE_PERST_N low to Full_Card_Power_Off# low	0	See <sup>b</sup>	—	s
T_pwr_on_seq	Power on sequence time	—	4.5	10	s
T_pwr_off_seq	Power off sequence time	—	4.5	8	s
T_perst_clk	PCIE_REFCLKM stable before PCIE_PERST_N high	100	—	—	μs

- a. T\_pvpgl is dependent on the host PCIe controller implementation.  
b. PCIE\_PERST\_N can be asserted (signal low) any time up to the moment Full\_Card\_Power\_Off# is asserted.

*Note: Power Valid when all the voltage supply rails have reached their respective V<sub>min</sub>. T<sub>settle</sub> is depending on the host power design, (i.e. a typical Adapter with a load capacitance of 330 μF and a 200 mA Soft-Start current limited ramp on the 3.3 V power rail, should settle within 5 ms.)*

### 5.3.2.2 Power On/Off Timing for USB Port

Figure 5-3 describes the timing of USB port detection in the power on/off sequence.

*Note: Before reaching the “Active” state, signals on the host port are undefined and signal transitions may occur. This undefined state also applies when the module is in reset mode, during a firmware update, or during the Power-off sequence. The host must consider these undefined signal activities when designing the module interface.*

*Note: The host must not drive any signals to the module until > 100 ms from the start of the power-on sequence.*

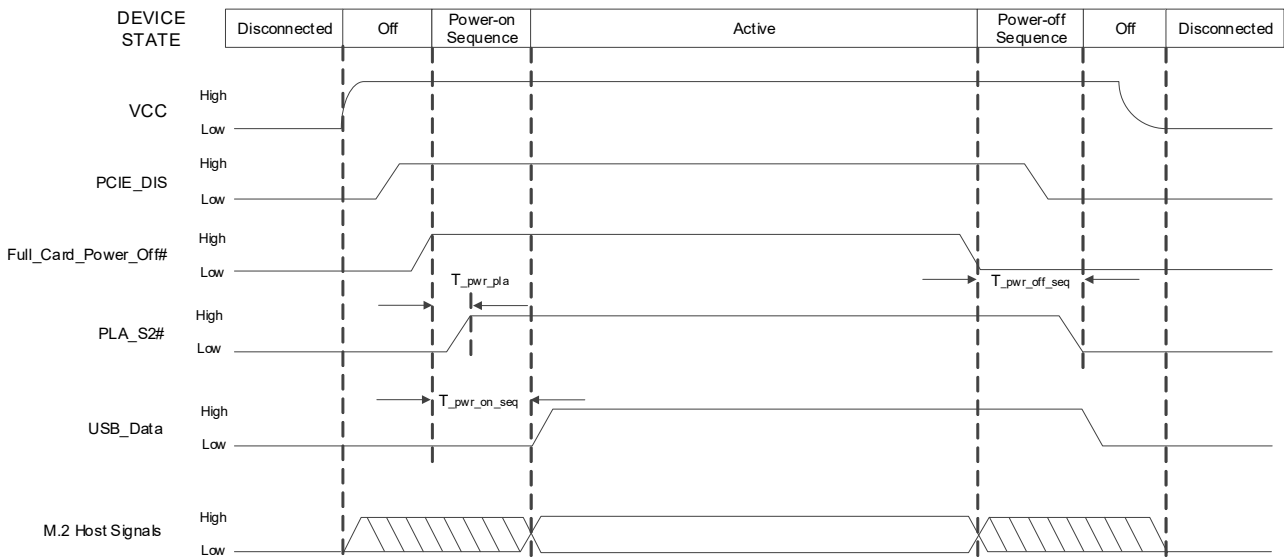


Figure 5-3: Signal Timing (Full\_Card\_Power\_Off#, and USB Enumeration)

**Table 5-7: USB Power-On /Off Timing Parameters**

Symbol	Parameter	Min	Typ	Max	Unit
T_pwr_on_seq	Power on sequence time	—	14.7	35	s
T_pwr_pla	Power on to PLA_S2# high	—	250	300	ms
T_pwr_off_seq	Power off sequence time	—	4.5	8	s

### 5.3.2.3 Reset Timing

To reset the module, see [Table 3-8 on page 39](#) for RESET# signal usage instructions.

### 5.3.2.4 Required Shutdown Sequence

**Important:** To avoid causing issues with the file system, follow this shutdown sequence. Note that this sequence works only on a module that has completely booted up.

To safely power off the module:

1. Drive Full\_Card\_Power\_Off# low to trigger the firmware to safely power off.

*Note: The power off process finishes within ~8 seconds.*

2. Wait until PLA\_S2# is asserted to low.
3. Remove power.

### 5.3.3 Power Supply Noise

Noise in the power supply can lead to noise in the RF signal.

The power supply ripple limit for the module is no more than 100 mVp-p, 1–100 kHz. This limit includes voltage ripple due to transmitter burst activity.

Additional decoupling capacitors can be added to the main VCC line to filter noise into the device.

### 5.3.4 SED (Smart Error Detection)

The module uses a form of SED to track premature modem resets.

- Module tracks consecutive resets occurring soon after power-on.
- After a sixth consecutive reset, the module waits in boot-and-hold mode for a firmware download to resolve the power-cycle problem.

## >> 6: Software

Mobile Broadband Packages are available for EM91 modules on the specific device pages at [source.sierrawireless.com](http://source.sierrawireless.com).

EM91 modules support USB and PCIe as physical host interfaces.

These packages are software suites that include:

- Device drivers
- SDK
- Tools and documentation (Firmware Logging and troubleshooting utilities, Developer's guide)

For PCIe development resources (available subject to license agreement), please contact your Sierra Wireless representative.

## >> 7: Mechanical and Environmental Specifications

EM91 modules comply with the mechanical and environmental specifications in [Table 7-1](#). Final product conformance to these specifications depends on the [OEM](#) device implementation.

**Table 7-1: Mechanical and Environmental Specifications**

	Mode	Details
Ambient temperature	Operational Class A	-30°C to +70°C—3GPP compliant, with appropriate heatsinking
	Operational Class B	-40°C to +85°C, with appropriate heatsinking—non-3GPP compliant (reduced operating parameters required)
Humidity Test	15 minutes Idle/ 15 minutes Off	Test temperature: 85°C Relative humidity: 85% Stress duration: 10 days
Thermal Shock Test	Non-operational	Test temperature: -40°C to +85°C Temperature transition time: < 30 seconds Dwell time: 10 minutes Stress duration: 300 cycles
High Temperature Operating Life Test	45 minutes Max TX / 15 minutes Idle	Temperature: 85°C Stress duration: 20 days (480 cycles)
Low Temperature Cold Start Test	30 minutes Off / 5 minutes Idle	Test temperature: -40°C Stress duration: 5 days
Mechanical Shock	Non-operational	Waveform: Half sine Peak acceleration: 30 g Shock duration: 6 ms Number of shocks: 3 Shock direction: ±X, ±Y, ±Z Stress duration: 1 day
Drop	Non-operational	Number of drops: 1 drop per direction (±X, ±Y, ±Z), 6 directions—total 6 drops per module (1 round) Surface type: Unprotected drops onto a surface that meets the test standard requirement Drop height: 1 m Stress duration: 1 day
Electrostatic Discharge (See <a href="#">Electrostatic Discharge (ESD) on page 74.</a> )	Operational	The LTE/Sub-6 antenna ports comply with the IEC 61000-4-2 standard: <ul style="list-style-type: none"> <li>• Electrostatic discharge immunity: Test Level 3</li> <li>• Air discharge: ±8 kV</li> <li>• Contact discharge: ±6 kV</li> </ul>
	Non-operational	The host connector interface (M.2) and mmWave IF ports (EM9190 only) comply with the following standard only: <ul style="list-style-type: none"> <li>• Minimum ±500 V Human Body Model (JS-001-2017)</li> </ul>

**Table 7-1: Mechanical and Environmental Specifications (Continued)**

	Mode	Details
Form factor		M.2 Form Factor (Conforms to width specification)
Dimensions		Length: 52±0.15 mm (max, exclude de-panel burr) Width: 30±0.15 mm (max, exclude de-panel burr) Thickness: 2.38 mm (max): <ul style="list-style-type: none"> <li>• Above PCB—1.50 mm (max)</li> <li>• PCB—0.88 mm (max)</li> </ul> Weight: 9 g (max)
MTBF		87.01 years Temperature: 25°C

## 7.1 Device Views

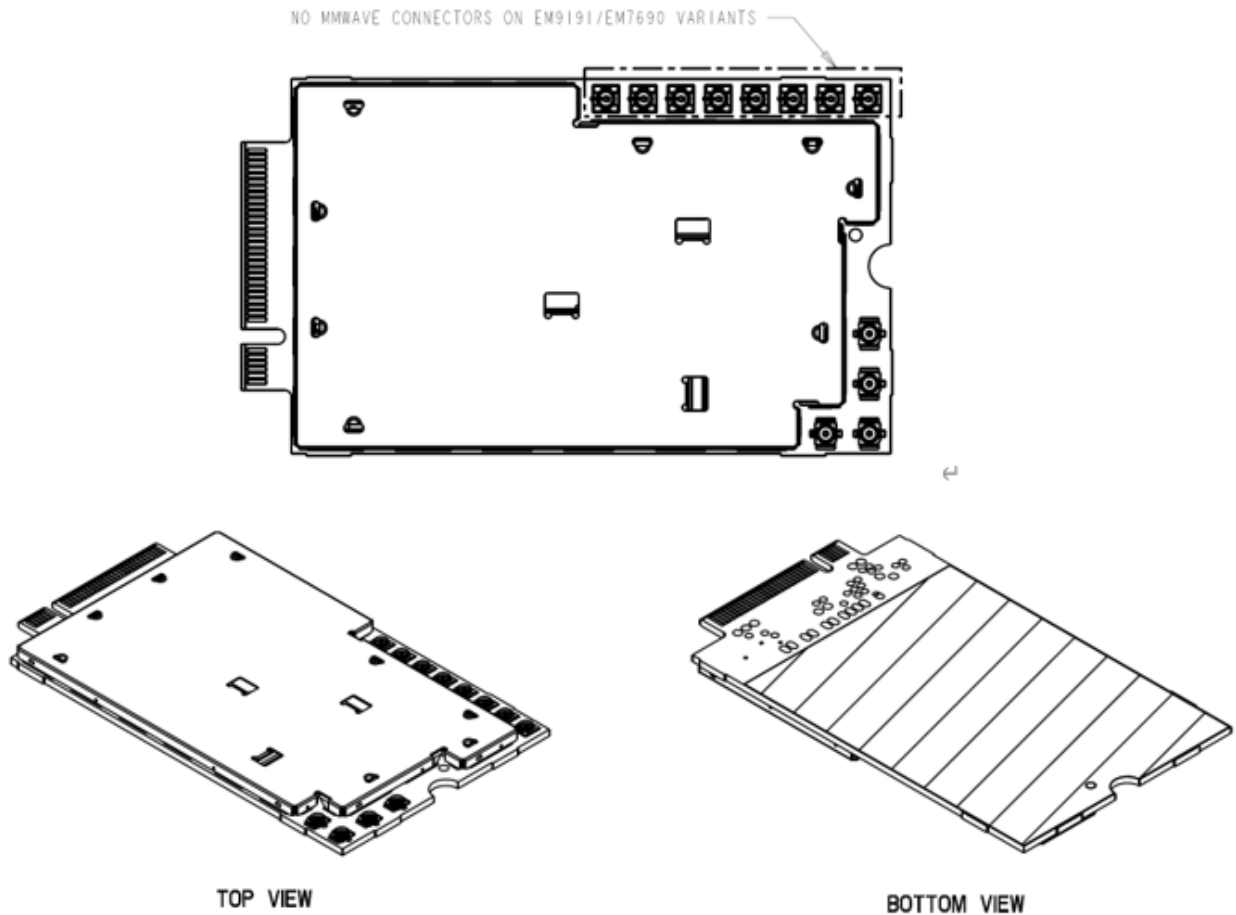


Figure 7-1: Top View and Bottom View

**MECHANICAL OUTLINE DRAWING**

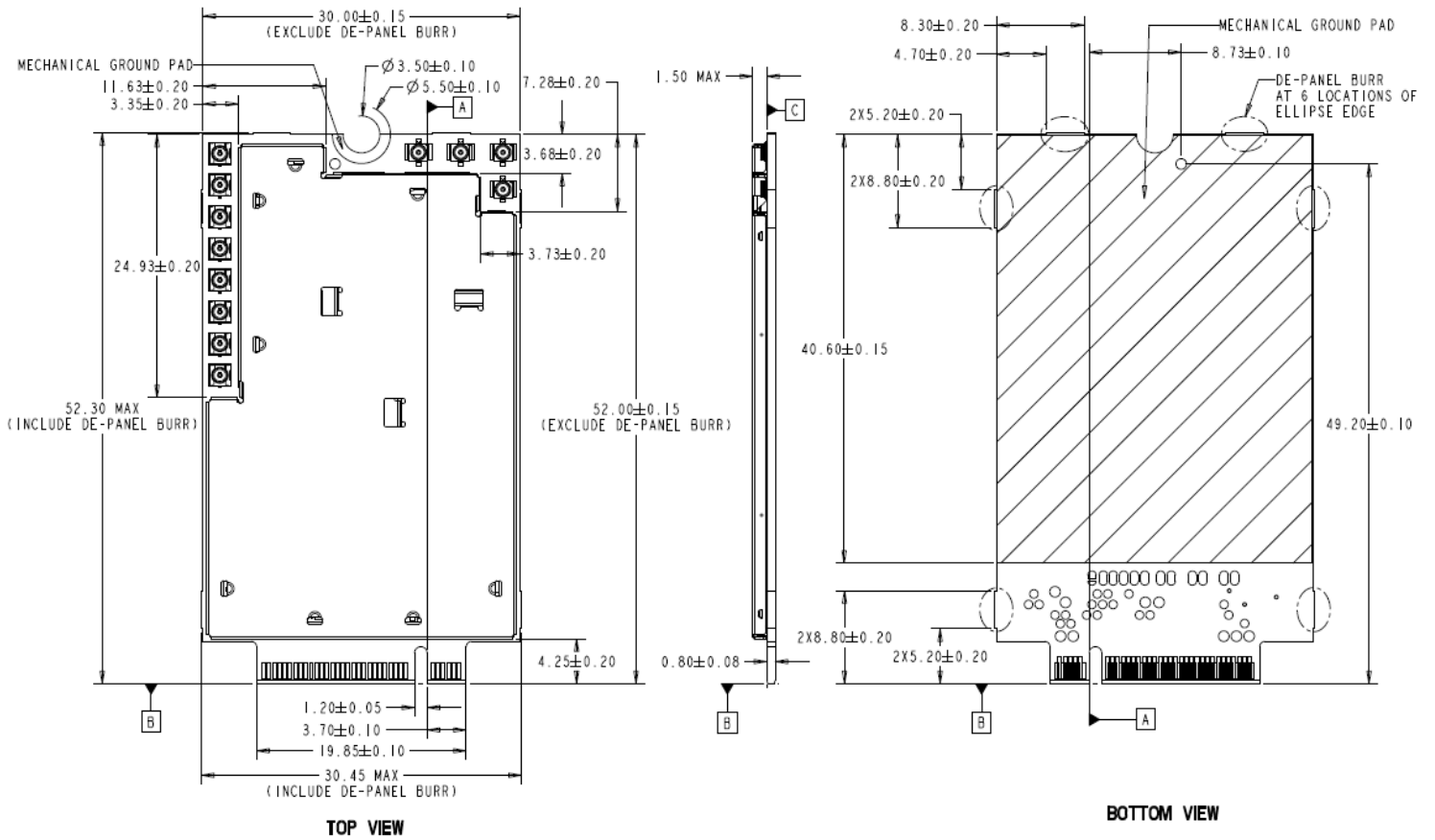
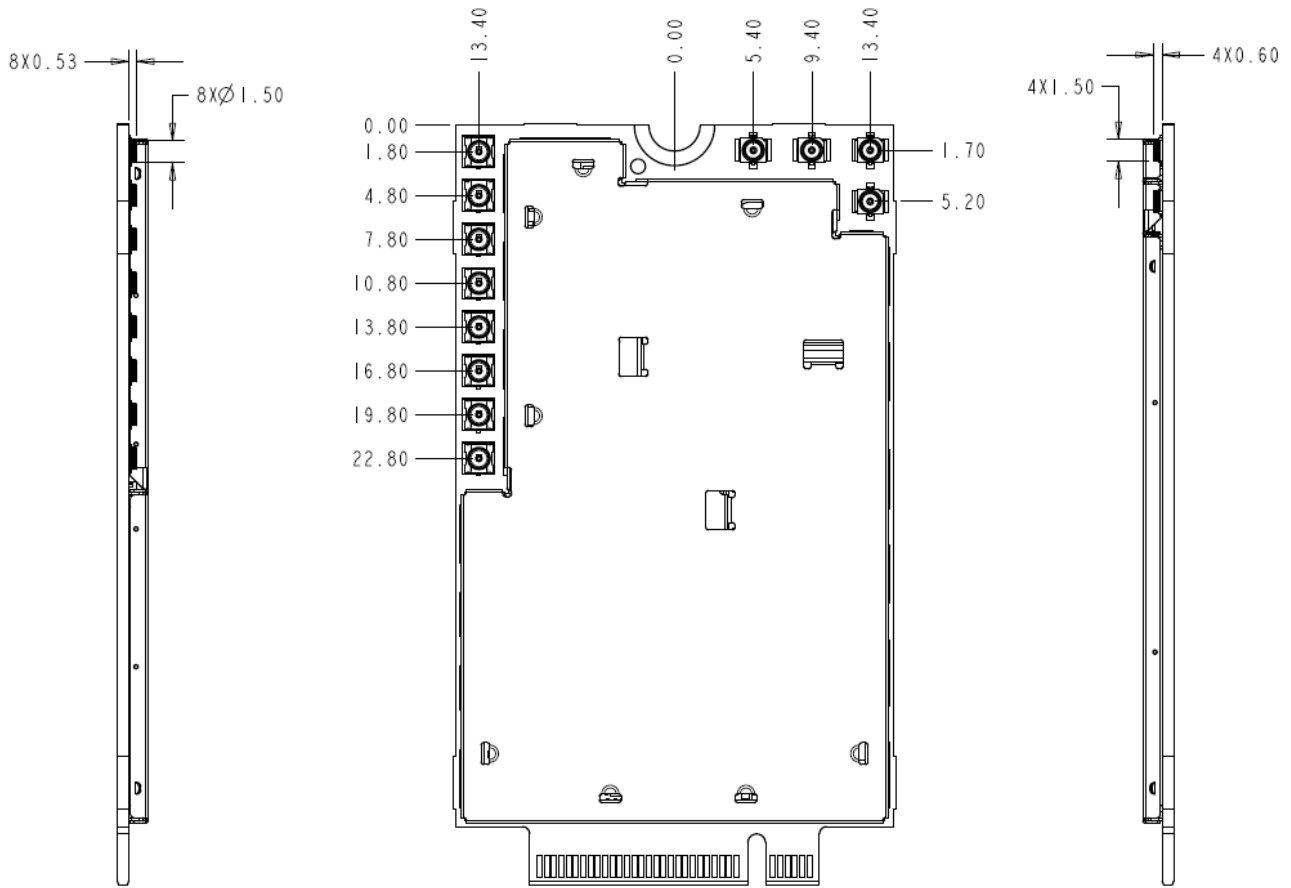


Figure 7-2: Dimensioned View of Mechanical Outline

### CONNECTOR LOCATIONS DRAWING



GENERAL TOLERANCE IS  $\pm 0.15$

TOP VIEW

Figure 7-3: Dimensioned View of Connector Locations



### PIN-OUT DRAWING

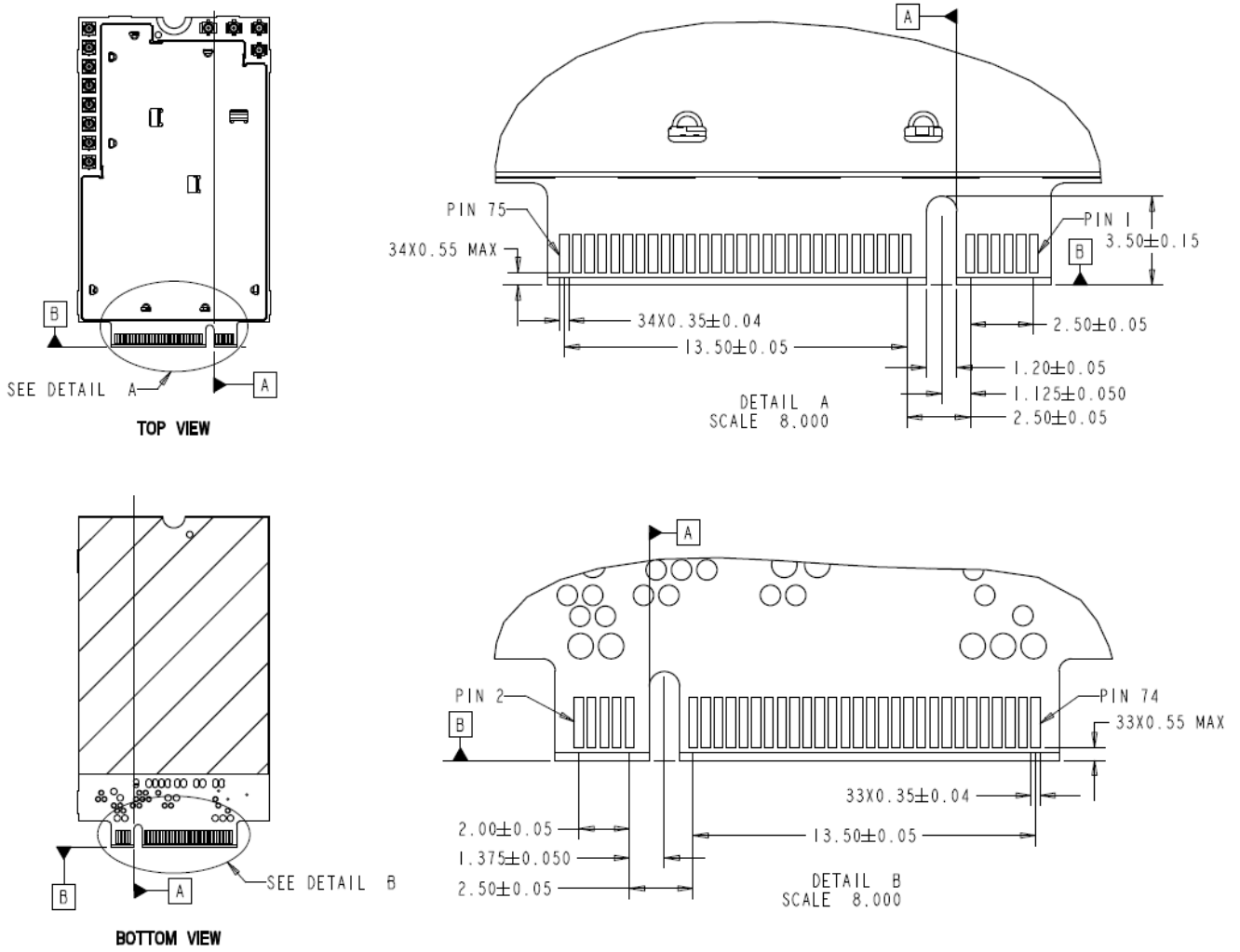


Figure 7-4: Dimensioned View of Pin-out

## 7.2 Product Marking (Labeling)



Figure 7-5: Unit Product Marking Example—Laser-etched, Typical Representation (Contents vary by SKU.)

The EM91 module's product marking is laser-etched and may contain:

- Sierra Wireless logo and product name
- [IMEI](#) number in Data Matrix barcode format
- [SKU](#) number (when required)
- Factory Serial Number ([FSN](#)) in alphanumeric format
- Manufacturing date code (incorporated into FSN)
- Licensed vendor logo
- Certification marks/details
- CPN
- Barcodes
- Manufacture location

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*Note:* EM91 modules support [OEM](#) partner-specific label requirements.

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## 7.3 Electrostatic Discharge (ESD)

The OEM is responsible for ensuring that the EM91 module's host interface pins are not exposed to ESD during handling or normal operation. (See [Table 7-1 on page 69](#) for specifications.)

ESD protection is highly recommended for the SIM connector at the point where the contacts are exposed, and for any other signals from the host interface that would be subjected to ESD by the user of the product. (The device includes ESD protection on the Sub-6G antenna ports.)

## 7.4 Thermal Considerations

Embedded modules can generate significant amounts of heat that must be dissipated in the host device for safety and performance reasons. [Figure 7-6](#) and [Figure 7-7](#) display the location of heat sources

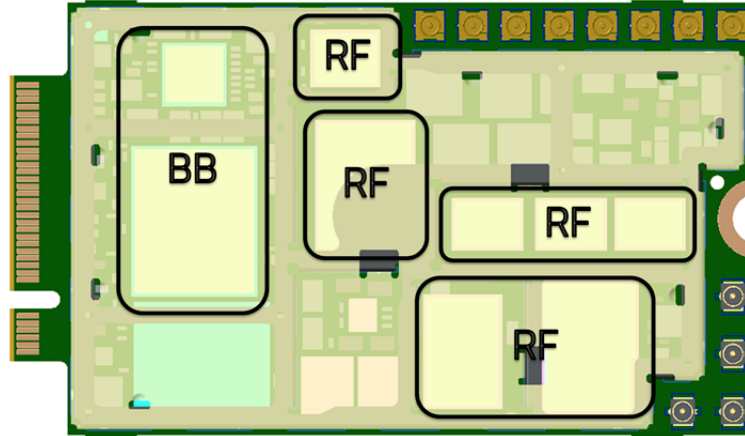
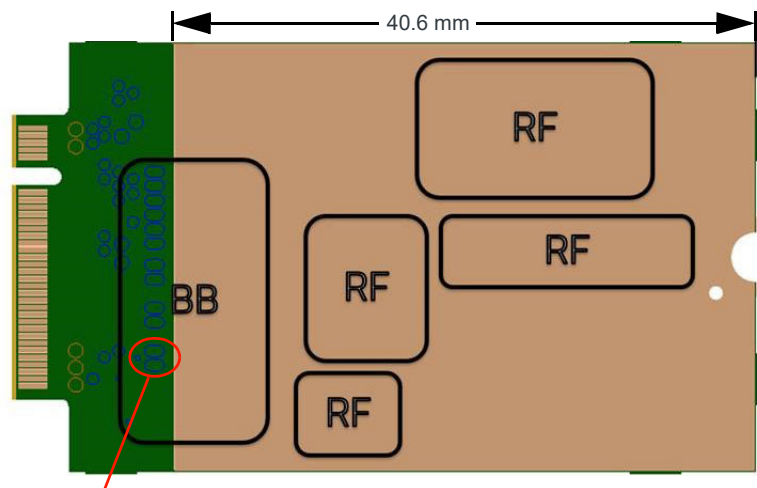


Figure 7-6: Shield Locations (Top View)



Debugging test points

Figure 7-7: Copper Pad Location on Bottom Side of Module

Specific areas requiring heat dissipation are shown in [Figure 7-7](#):

- RF—Bottom face of module near RF connectors. Likely to be the hottest area.
- Baseband—Bottom face of module, below the baseband area.

To enhance heat dissipation:

- Sierra Wireless recommends adding a heat sink that mounts the module to the main PCB or metal chassis.

**Important**—A non-conductive thermal compound or pad must be used between the module and the heat sink.

Note—Sierra Wireless recommends that test points TP328 and TP329 (see [Figure 7-7](#)) remain accessible for Sierra Wireless to assist in system debugging. Make sure the test points are not shorted to anything.

- Maximize airflow over/around the module.
- Locate the module away from other hot components.
- Module ground holes must be used to attach (ground) the device to the main PCB ground or a metal chassis.
- You may also need active cooling to pull heat away from the module.

---

*Note: Adequate dissipation of heat is necessary to ensure that the module functions properly. Refer to [3] EM9190 Thermal Application Note (Doc# 2174257) for more details.*

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## 7.5 Module Integration Testing

When testing your integration design:

- Test to your worst case operating environment conditions (temperature and voltage)
- Test using worst case operation
- Monitor temperature at all shield locations. Attach thermocouples to the areas indicated in [Figure 7-6 on page 75](#) (RF, Baseband).

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*Note: Make sure that your system design provides sufficient cooling for the module.*

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## 7.6 Secure Boot/Secure Debug

EM91 modules incorporate the following permanently enabled features to enhance device security:

- Secure Boot—Ensures only firmware images signed by Sierra Wireless can be loaded and run on EM91 modules; unauthorized code cannot be loaded to the module.  
Specifically, Secure Boot applies to the following firmware components: system boot loader, carrier configuration, and telecom FW.  
For details, refer to [9] EM9 Series Secure Boot (Doc# 2174333 (Forthcoming)).
- Secure Debug—Disables debug features such as RAM dump collection and JTAG access to the module. For details, refer to [10] EM9 Series Secure Debug (Doc# 2174334 (Forthcoming)).

## >> 8: Regulatory Compliance and Industry Certifications

This module is designed to meet, and upon commercial release, will meet the requirements of the following regulatory bodies and regulations, where applicable:

- Federal Communications Commission (FCC) of the United States
- The National Communications Commission (NCC) of Taiwan, Republic of China
- The Certification and Engineering Bureau of Industry Canada (IC)
- Radio Equipment Directive (RED) and RoHS Directive of the European Union
- Russia Agency of Communications (FAC)
- China CCC, NAL and SRRC
- South Korea KCC

Upon commercial release, the following industry certifications will have been obtained, where applicable:

- GCF
- PTCRB

Additional certifications and details on specific country approvals may be obtained upon customer request—contact your Sierra Wireless account representative for details.

Additional testing and certification may be required for the end product with an embedded EM919X/EM7690 module and are the responsibility of the [OEM](#). Sierra Wireless offers professional services-based assistance to OEMs with the testing and certification process, if required.

### 8.1 Important Notice

Because of the nature of wireless communications, transmission and reception of data can never be guaranteed. Data may be delayed, corrupted (i.e., have errors) or be totally lost. Although significant delays or losses of data are rare when wireless devices such as the Sierra Wireless module are used in a normal manner with a well-constructed network, the Sierra Wireless module should not be used in situations where failure to transmit or receive data could result in damage of any kind to the user or any other party, including but not limited to personal injury, death, or loss of property. Sierra Wireless and its affiliates accept no responsibility for damages of any kind resulting from delays or errors in data transmitted or received using the Sierra Wireless module, or for failure of the Sierra Wireless module to transmit or receive such data.

### 8.2 Safety and Hazards

Do not operate your EM919X/EM7690 module:

- In areas where blasting is in progress
- Where explosive atmospheres may be present including refueling points, fuel depots, and chemical plants
- Near medical equipment, life support equipment, or any equipment which may be susceptible to any form of radio interference. In such areas, the EM919X/EM7690 module **MUST BE POWERED OFF**. Otherwise, the EM919X/EM7690 module can transmit signals that could interfere with this equipment.

In an aircraft, the EM919X/EM7690 module **MUST BE POWERED OFF**. Otherwise, the EM919X/EM7690 module can transmit signals that could interfere with various onboard systems and may be dangerous to the operation of the aircraft or disrupt the cellular network. Use of a cellular phone in an aircraft is illegal in some jurisdictions. Failure to observe this instruction may lead to suspension or denial of cellular telephone services to the offender, or legal action or both.

Some airlines may permit the use of cellular phones while the aircraft is on the ground and the door is open. The EM919X/EM7690 module may be used normally at this time.

## 8.3 Important Compliance Information for the United States and Canada

The EM919X/EM7690 module, upon commercial release, will have been granted modular approval for mobile applications. Integrators may use the EM919X/EM7690 module in their final products without additional FCC/IC (Industry Canada) certification if they meet the following conditions. Otherwise, additional FCC/IC 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/IC 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 8-1 on page 79](#).
3. The EM919X/EM7690 module may transmit simultaneously with other collocated radio transmitters within a host device, provided the following conditions are met:
  - Each collocated radio transmitter has been certified by FCC/IC 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 8-1 on page 79](#).

**Table 8-1: Antenna Gain and Collocated Radio Transmitter Specifications**

	Operating mode	Tx Freq Range (MHz)		Max Time-Avg Cond Power (dBm)	Antenna Gain Limit (dBi)	
					Standalone	Collocated
EM919x EM7690	WCDMA Band 2	1850	1910	24.5	8.5	8
	WCDMA Band 4	1710	1755	24.5	5.5	5.5
	WCDMA Band 5	824	849	24.5	6	5.5
	LTE B2	1850	1910	24	8.5	8
	LTE B4	1710	1755	24	5.5	5.5
	LTE B5	824	849	24	6	6
	LTE B7	2500	2570	24.8 <sup>a</sup>	8	8
	LTE B12	699	716	24	6	5.5
	LTE B13	777	787	24	6	5.5
	LTE B14	788	798	24	6	6
	LTE B17	704	716	24	6	5.5
	LTE B25	1850	1915	24	8.5	8
	LTE B26	814	849	24	6	6
	LTE B30	2305	2315	24	0	0
	LTE B41	2496	2690	24.8 <sup>a</sup>	7	7
	LTE B41-HPUE	2496	2690	26	7	7
	LTE B42 <sup>b</sup>	3450	3550	24.8	5	5
	LTE B42/B43 <sup>c</sup>	3450	3650	24.8 <sup>a</sup>	-1.8	-1.8
	LTE B48	3550	3700	24.8 <sup>a</sup>	-1.8	-1.8
	LTE B66	1710	1780	24	6	6
LTE B71	663	698	24	6	5.5	
EM919x	5G NR n2	1850	1910	24.5	8.5	8
	5G NR n5	824	849	24.5	6	5.5
	5G NR n7	2500	2570	24.5	8	8
	5G NR n12	699	716	24.5	6	5
	5G NR n25	1850	1915	24.5	8.5	8
	5G NR n41	2496	2690	24.5	7	7
	5G NR n48 <sup>b</sup>	3550	3700	24.5	-1.8	-1.8
	5G NR n66	1710	1780	24.5	5.5	5.5
	5G NR n71	663	698	24.5	5.5	5
	5G NR n77 <sup>b</sup> /n78 <sup>b</sup>	3450	3550	24.5	5.5	5.5
		3700	3980			
5G NR n77 <sup>c</sup> /n78 <sup>c</sup>	3450	3650	24.5	-1.5	-1.5	

**Table 8-1: Antenna Gain and Collocated Radio Transmitter Specifications (Continued)**

	Operating mode	Tx Freq Range (MHz)		Max Time-Avg Cond Power (dBm)	Antenna Gain Limit (dBi)	
					Standalone	Collocated
Collocated transmitters	WLAN 2.4 GHz	2400	2500	20	—	5
	WLAN 5 GHz	5150	5850	20	—	8
	Bluetooth	2400	2500	17	—	5

- a. Includes 0.8 dB offset from single-cell tolerance ([Table 4-12 on page 57](#)) for UL CA
- b. USA only
- c. Canada only

**\*Important:** The FCC and IC have a strict EIRP limit in Band 30 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 0 dBi in Band 30. Additionally, both the FCC and IC prohibit the use of external vehicle-mounted antennas for mobile and portable stations in this band.

Fixed stations may use antennas with higher gain in Band 30 due to relaxed EIRP limits. EM919X/EM7690 modules used as fixed subscriber stations in Canada or fixed customer premises equipment (CPE) stations in the United States may have an antenna gain up to 9 dBi in Band 30, however, the use of outdoor antennas or outdoor station installations are prohibited except if professionally installed in locations that are at least 20 meters from roadways or in locations where it can be shown that the ground power level of -44 dBm per 5 MHz in the bands 2305–2315 MHz and 2350–2360 MHz or -55 dBm per 5 MHz in the bands 2315–2320 MHz and 2345–2350 MHz will not be exceeded at the nearest roadway. For the purposes of this notice, a roadway includes a highway, street, avenue, parkway, driveway, square, place, bridge, viaduct or trestle, any part of which is intended for use by the general public for the passage of vehicles.

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

**\*Important:** Airborne operations in LTE Band 48 are prohibited.

4. A label must be affixed to the outside of the end product into which the EM919X/EM7690 module is incorporated, with a statement similar to the following:
  - **This device contains FCC ID: N7NEM91, IC: 2417-EM91.**
5. A user manual with the end product must clearly indicate the operating requirements and conditions that must be observed to ensure compliance with current FCC/IC RF exposure guidelines.

The end product with an embedded EM919X/EM7690 module may also need to pass the FCC Part 15 unintentional emission testing requirements and be properly authorized per FCC Part 15.

**Note:** If this module is intended for use in a portable device, you are responsible for separate approval to satisfy the SAR requirements of FCC Part 2.1093 and IC RSS-102.



# >> A: Antenna Specification

This appendix describes recommended electrical performance criteria for Sub-6G, GNSS, and mmWave 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.

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

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## A.1 Recommended Sub-6 Antenna Specifications

**Table A-1: Sub-6 Antenna Requirements<sup>a</sup>**

Parameter	Requirements	Comments
Antenna system	<ul style="list-style-type: none"> <li>NR/LTE: External multi-band 4×4 DL MIMO antenna system—MAIN, AUX, MIMO1, MIMO2</li> <li>3G: External multi-band antenna system with diversity—MAIN, AUX</li> </ul>	If AUX or MIMO2 includes GNSS, it must also satisfy requirements in <a href="#">Table A-2 on page 83</a> .
Operating bands	<ul style="list-style-type: none"> <li>MAIN—All supported Tx and Rx frequency bands.</li> <li>AUX, MIMO1, MIMO2—All supported Rx frequency bands, plus GNSS frequency bands if AUX is used in shared Diversity/MIMO/GNSS mode.</li> </ul>	
VSWR	<ul style="list-style-type: none"> <li>MAIN, AUX:           <ul style="list-style-type: none"> <li>&lt; 2:1 (recommended)</li> <li>&lt; 3:1 (worst case)</li> </ul> </li> </ul>	On all bands including band edges
Total radiated efficiency	> 50% on all bands	<ul style="list-style-type: none"> <li>Measured at the RF connector.</li> <li>Includes mismatch losses, losses in the matching circuit, and antenna losses, excluding cable loss.</li> <li>Sierra Wireless recommends using antenna efficiency as the primary parameter for evaluating the antenna system.</li> <li>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.</li> </ul>

**Table A-1: Sub-6 Antenna Requirements<sup>a</sup> (Continued)**

Parameter	Requirements	Comments
Radiation patterns	Nominally omni-directional radiation pattern in azimuth plane.	
Envelope correlation coefficient	Between MAIN and AUX: <ul style="list-style-type: none"> <li>&lt; 0.5 on Rx bands below 960 MHz</li> <li>&lt; 0.2 on Rx bands above 1.4 GHz</li> </ul>	
Mean Effective Gain (MEG)	MAIN (MEG1), AUX (MEG2), MIMO1 (MEG3), MIMO2 (MEG4): <ul style="list-style-type: none"> <li>≥ -3 dBi</li> </ul>	
Mean Effective Gain Imbalance $\frac{ MEG_x }{ MEG_y }$	Between any two antennas: <ul style="list-style-type: none"> <li>&lt; 2 dB for MIMO operation</li> <li>&lt; 6 dB for diversity operation</li> </ul>	
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 <a href="#">Important Compliance Information for the United States and Canada on page 78</a> .
Isolation	<ul style="list-style-type: none"> <li>B41: &gt;20 dB for MAIN and MIMO2</li> <li>All antennas for all other bands: &gt;10 dB</li> </ul>	<ul style="list-style-type: none"> <li>If antennas can be moved, test isolation for all positions.</li> <li>Make sure all other wireless devices (Bluetooth or WLAN antennas, etc.) are turned OFF to avoid interference.</li> </ul>
Maximum input power at antenna port	<ul style="list-style-type: none"> <li>MAIN—10 dBm</li> <li>AUX—10 dBm (*0 dBm)</li> <li>MIMO1—10 dBm</li> <li>MIMO2—10 dBm (*0 dBm)</li> </ul>	<b>*Important:</b> GPS inband signals on AUX and MIMO2 must be < 0 dBm to avoid damaging LNAs.
Power handling	<ul style="list-style-type: none"> <li>&gt; 1 W</li> </ul>	<ul style="list-style-type: none"> <li>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.</li> <li>Visually inspect device to ensure there is no damage to the antenna structure and matching components.</li> <li>VSWR/TIS/TRP measurements taken before and after this test must show similar results.</li> </ul>

a. 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.

## A.2 Recommended GNSS Antenna Specifications

Table A-2: GNSS Antenna Requirements

Parameter	Requirements	Comments
Frequency range	<ul style="list-style-type: none"> <li>Wide-band GNSS: 1559–1606 MHz recommended</li> <li>Narrow-band GPS: 1575.42 MHz <math>\pm</math>2 MHz minimum</li> <li>Narrow-band Galileo: 1575.42 MHz <math>\pm</math>2 MHz minimum</li> <li>Narrow-band BeiDou: 1561.098 MHz <math>\pm</math>2 MHz minimum</li> <li>Narrow-band GLONASS: 1601.72 MHz <math>\pm</math>4.2 MHz minimum</li> <li>Narrow-band QZSS: 1575.42 MHz <math>\pm</math>2 MHz minimum</li> </ul>	
Field of view (FOV)	<ul style="list-style-type: none"> <li>Omni-directional in azimuth</li> <li>-45° to +90° in elevation</li> </ul>	
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 $\pm$ 180° in azimuth.
Gain	<ul style="list-style-type: none"> <li>Maximum gain and uniform coverage in the high elevation angle and zenith.</li> <li>Gain in azimuth plane is not desired.</li> </ul>	
Average 3D gain	> -5 dBi	
Isolation between GNSS and WWAN Tx (MAIN and AUX)	> 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.	

*Note: GNSS active antenna is forbidden to use.*

## A.3 Sub-6 Antenna Tests

The following guidelines apply to the requirements described in [Table A-1 on page 81](#) and [Table A-2 on page 83](#):

- Perform electrical measurements at room temperature (+20°C to +26°C) unless otherwise specified

- For the MAIN and AUX (diversity) antennas, make sure the antennas (including contact device, coaxial cable, connectors, and matching circuit with no more than six components, if required) have nominal impedances of 50  $\Omega$  across supported frequency bands.
- All tests (except isolation/correlation coefficient)—Test the MAIN or AUX antenna with the other antenna terminated.
- Any metallic part of the antenna system that is exposed to the outside environment needs to meet the electrostatic discharge tests per IEC61000-4-2 (conducted discharge +8 kV).
- The functional requirements of the antenna system are tested and verified while the embedded module’s antenna is integrated in the host device.

*Note: Additional testing, including active performance tests, mechanical, and accelerated life tests can be discussed with Sierra Wireless’ engineering services. Contact your Sierra Wireless representative for assistance.*

## A.4 mmWave Antennas

*Note: For EM9190 only.*

The mmWave-capable EM9190 module is available in low-power (connectorized) antenna module SKU configurations or high-power (soldered down) antenna module SKU configurations. The EM9190 module can support up to four antenna modules.

[Table A-3](#) describes the primary mechanical and functional differences between low and high power mmWave antenna modules. For more information, refer to [6] EM9190 mmWave Design Guidelines (Doc# 2174276).

**Table A-3: Low Power / High Power mmWave Antenna Comparison**

Parameter	Low Power Modules	High Power Modules
Module type	QTM525	QTM527
Typical applications	Laptops Tablets Home gateways	CPE (outdoor) products
Simultaneously active	No. Only one active at a time.	Yes. All four antennas work together for active power.
EIRP	23 dBm	45 dBm
Connection method to EM9190 module	10-pin connectorized	Solder down
Module footprint area	~100 mm <sup>2</sup>	~400 mm <sup>2</sup>

### A.4.1 Low Power mmWave Antenna Modules

When integrating an EM9190 with QTM525 low power mmWave antenna modules on a host platform:

- The OEM/ODM provides 1–4 antenna modules on the platform.
- The customer uses two MHF7S IF cables to connect each antenna module to the appropriate mmWave connectors on the EM9190.
- The customer provides external 3.8 V supply to power the antenna modules.
- Non-RF logic signals (QTMx\_PON, QTM\_IO\_1.9V) are supplied via the EM9190 M.2 interface and routed to the antenna modules via one of the following methods:
  - Recommended—Direct board-to-board connection (i.e. direct connections on PCB from M.2 connector to antenna modules)
  - Alternate—FPC (i.e. FPC connections from host platform PCB to antenna modules mounted on separate adapter boards)

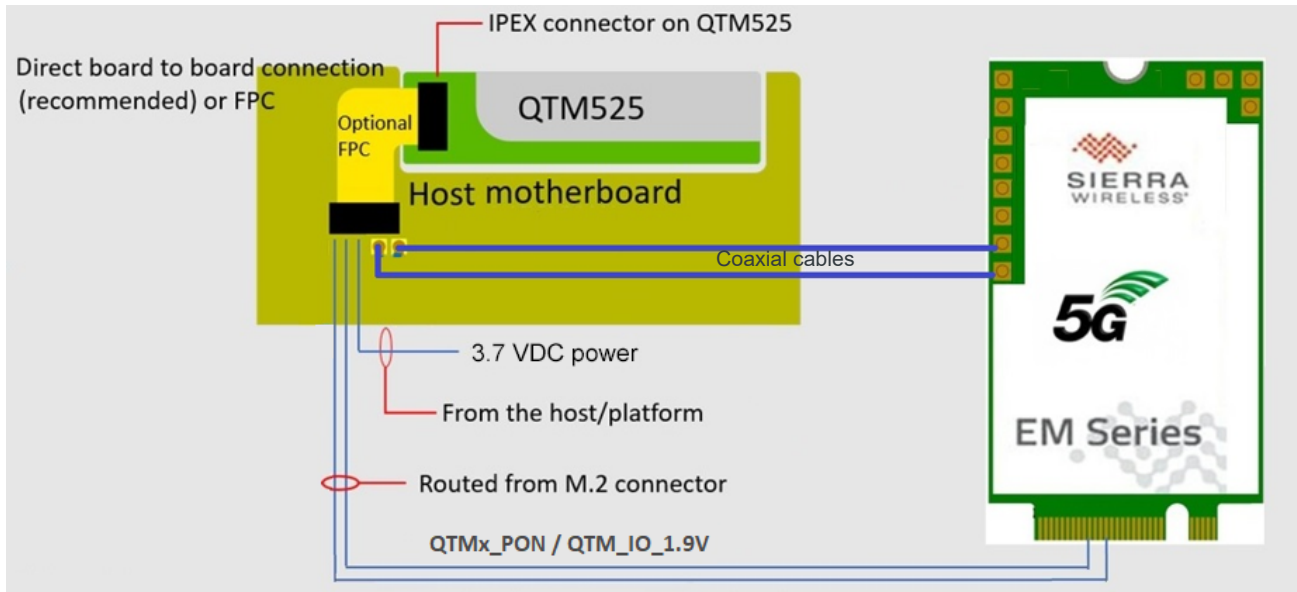


Figure A-1: Example—Connecting Low Power mmWave Antenna Module to Host Platform

## A.4.2 High Power mmWave Antenna Modules

When integrating an EM9190 with QTM527 high power mmWave antenna modules on a host platform:

- The OEM/ODM provides 4 antenna modules in a 2x2 array on the platform.
- The antenna module type (e.g. QTM527-1 or QTM527-2) chosen by the customer depends on the bands to be provided by the host platform.
- The customer uses two MHF7S IF cables to connect each antenna module to the appropriate mmWave connectors on the EM9190.
- The customer provides external 3.8 V supply to power the antenna modules. Each antenna module is independently powered, and multiple antenna modules can be used simultaneously for increased power.

For details, refer to [6] EM9190 mmWave Design Guidelines (Doc# 2174276).

## >> B: Thermal Testing

### B.1 Worst Case Testing

Sierra Wireless recommends that customers identify realistic worst-case conditions for their platforms and perform appropriate thermal testing.

For example:

- If the device has very good throughput, it is likely near a tower so will not have to transmit at maximum Tx output power.
- If the device is transmitting at maximum Tx power, it is likely not near a tower and will not reach maximum throughput rates.
- Networks usually are sharing capacity among many users, so no single user is likely to reach maximum throughput rates for any significant length of time.
- If the device is transmitting at maximum throughput, it will likely do so for a limited time to limit the amount of data usage consumed from their data plan.

### B.2 Thermal Testing Process

To perform thermal testing of the module:

1. Mount the module in its designed location on the platform.
2. Provide the same amount of airflow as will be experienced in your platform.
3. Set the platform's ambient to the higher limit of the specification and observe the junction temperature ramp. (Use **AT!PCTEMP?**)
4. Set up a call with the use case for the platform (throughput rate, output power, duty cycle) on the worst-case band.
5. Observe the ramp in junction temperature due to the call, and confirm whether the overall system performance still meets customer requirements.
6. Use **AT!TMSTATUS?** to check the module's thermal mitigation status (refer to [1] Sierra Wireless EM919X AT Command Reference (Doc# 41113480) for details).
7. Increase the platform's ambient temperature to determine the margin that exists over the desired temperature specifications as subsequent mitigation methods activate (e.g. UL data rate throttled, DL throughput throttled (third and second CA dropped), UL power reduced, Emergency Service).

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*Note: Refer to [3] EM9190 Thermal Application Note (Doc# 2174257) for more details.*

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## >> C: Production Testing

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*Note: All Sierra Wireless embedded modules are factory-tested to ensure they conform to published product specifications.*

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Developers of OEM devices integrating Sierra Wireless embedded modules should include a series of test phases in their manufacturing process to make sure their devices work properly with the embedded modules. For more information, refer to [5] EM919X Customer Production Test Mode (Doc# 41113679).

Sierra Wireless offers optional professional services-based assistance to OEMs with regulatory approvals.

## >> D: Packaging

Sierra Wireless Embedded Modules are shipped in sealed boxes. The standard packaging (see [Figure D-1](#)), contains a single tray with a capacity of 100 modules. (Note that some SKUs may have custom packaging—contact Sierra Wireless for SKU-specific details.)

In the standard packaging, Embedded Modules are inserted, system connector first, into the bottom portion (T1) of a two-part tray. All facing the same direction. This allows the top edge of each Embedded Module to contact the top of the triangular features in the top portion (T2) of the tray (Detail A).

The top and bottom portions of the tray snap together at the four connection points.

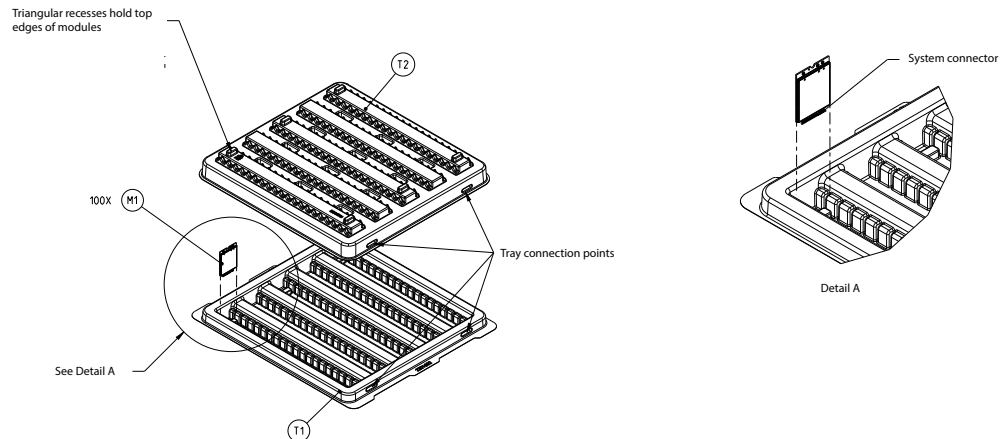


Figure D-1: Device Placement in Module Tray

The tray cover is secured to the tray base with ESD-safe tape (EP1) at the locations indicated. The tray is placed in a manufacturing box (B1), sealed with a security tape (P1), a manufacturing label (L3) is placed on the bottom-right corner, above the security tape, and if required a label (L4) is applied beside the manufacturing label. (See [Figure D-2](#).)

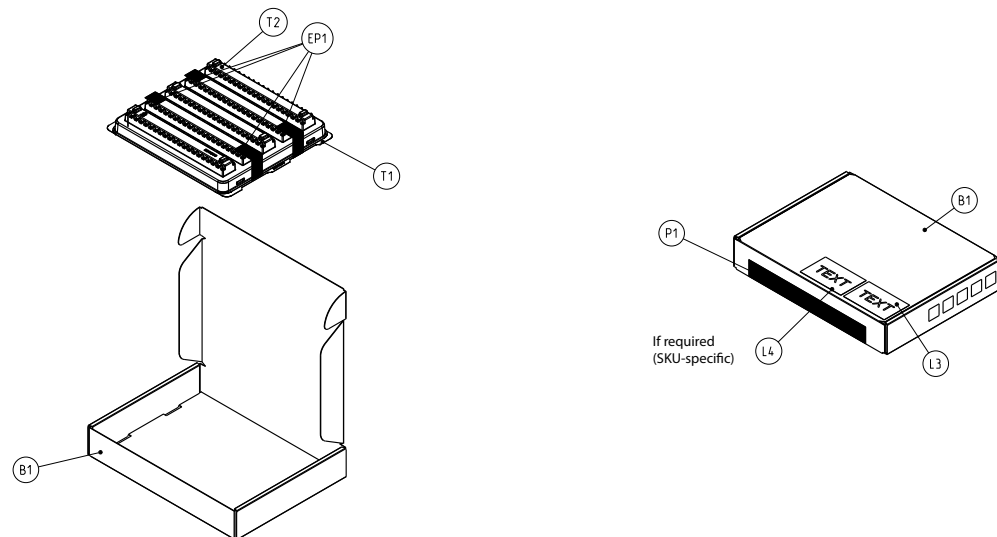


Figure D-2: Shipping Package



# >> E: Design Checklist

This chapter provides a summary of the design considerations mentioned throughout this guide. This includes items relating to the power interface, RF integration, thermal considerations, cabling issues, and so on.

*Note: This is NOT an exhaustive list of design considerations. It is expected that you will employ good design practices and engineering principles in your integration.*

**Table E-1: Hardware Integration Design Considerations**

Suggestion	Section where discussed
<b>Component Placement</b>	
If an ESD suppressor is not used on the host device, allow space on the SIM connector for series resistors in layout. (Up to 100 $\Omega$ may be used depending on ESD testing requirements).	<a href="#">SIM Implementation on page 35</a>
Minimize RF cable losses as these affect performance values listed in product specification documents.	<a href="#">RF Connections on page 45</a>
<b>Antennas</b>	
Match the module/antenna coax connections to 50 $\Omega$ —mismatched antenna impedance and cable loss negatively affect RF performance.	<a href="#">RF Connections on page 45</a>
If installing UMTS and CDMA modules in the same device, consider using separate antennas for maximum performance.	<a href="#">Sub-6G Antennas and Cabling on page 45</a>
<b>Power</b>	
Make sure the power supply can handle the maximum current specified for the module type.	<a href="#">Power Consumption on page 59</a>
Limit the total impedance of VCC and GND connections to the SIM at the connector to less than 1 $\Omega$ (including any trace impedance and lumped element components—inductors, filters, etc.). All other lines must have a trace impedance less than 2 $\Omega$ .	<a href="#">SIM Implementation on page 35</a>
Decouple the VCC line close to the SIM socket. The longer the trace length (impedance) from socket to module, the greater the capacitance requirement to meet compliance tests.	
<b>PCB Signal Routing</b>	
USB—Route the USB interface signals over 90 $\Omega$ differential lines on the PCB.	
PCIe 3.0—Route the data and clock differential pairs over 90 $\Omega$ differential lines on the PCB.	
I2C port—If supported, route these signals away from noise-sensitive signals on the PCB.	
PCM port—If supported, route these signals away from noise-sensitive signals on the PCB.	
<b>EMI/ESD</b>	
Investigate sources of localized interference early in the design cycle.	<a href="#">Methods to Mitigate Decreased Rx Performance on page 48</a>

**Table E-1: Hardware Integration Design Considerations (Continued)**

Suggestion	Section where discussed
Provide ESD protection for the SIM connector at the exposed contact point (in particular, the CLK, VCC, IO, and RESET# lines).	<a href="#">SIM Implementation on page 35</a>
Keep very low capacitance traces on the UIM_DATA and UIM_CLK signals.	
To minimize noise leakage, establish a very good ground connection between the module and host.	<a href="#">Ground Connection on page 47</a>
Route cables away from noise sources (for example, power supplies, LCD assemblies, etc.).	<a href="#">Methods to Mitigate Decreased Rx Performance on page 48</a>
Shield high RF-emitting components of the host device (for example, main processor, parallel bus, etc.).	
Use discrete filtering on low frequency lines to filter out unwanted high-order harmonic energy.	
Use multi-layer PCBs to form shielding layers around high-speed clock traces.	
<b>Thermal</b>	
Test to worst case operating conditions—temperature, voltage, and operation mode (transmitter on 100% duty cycle, maximum power).	<a href="#">Thermal Considerations on page 75</a>
Use appropriate techniques to reduce module temperatures (for example, airflow, heat sinks, heat-relief tape, module placement, etc.).	

## >> F: References

### F.1 Sierra Wireless Documents

Sierra Wireless documents are available from [source.sierrawireless.com](https://source.sierrawireless.com), or on request (subject to license agreements or NDAs) from your Sierra Wireless representative.

#### Sierra Wireless Documents on the Source

The following documents are available from [source.sierrawireless.com](https://source.sierrawireless.com):

- [1] Sierra Wireless EM919X AT Command Reference (Doc# 41113480)
- [2] Sierra Wireless EM919x/EM7690 Development Kit User Guide (Doc# 41113875)
- [3] EM9190 Thermal Application Note (Doc# 2174257)
- [4] EM919x/EM7690 Thermal Mitigation Application Note (Doc# 2174267)
- [5] EM919X Customer Production Test Mode (Doc# 41113679)
- [6] EM9190 mmWave Design Guidelines (Doc# 2174276)
- [7] EM919X 5G NR Peak Throughput (Doc# 2174277)
- [8] EM9190 Current Consumption Application Note (Doc# 2174287)
- [9] EM9190 Low Power mmWave RF Customization File Preparation (Doc# 2174286)
- [10] EM9190 High Power mmWave RF Customization File Preparation (Doc# 2174282)
- [11] EM919X-EM7690 Non-mmWave Smart Transmit (Doc# 2174291)
- [12] EM919x/EM7690 PCIe Integration Guide (Doc# 41114276)
- [13] Software Integration and Development Guide for Linux USB Platforms (Doc# 41114212)

#### Sierra Wireless Documents Requiring License Agreement

The following documents are available under license agreement—contact your Sierra Wireless representative:

- [14] Software Integration and Development Guide for Linux Platforms (Doc# 41113764)

#### Sierra Wireless Documents Requiring NDA

The following documents are available under NDA—contact your Sierra Wireless representative:

- [15] EM9 Carrier Aggregations and EN-DC (Doc# 2174317)

For additional documents that may be used (under NDA) to assist with regulatory and certification submissions, contact your Sierra Wireless representative.

### F.2 Industry/Other Documents

The following referenced document are not provided by Sierra Wireless:

- [16] AT Command Set for User Equipment (UE) (Release 6) (Doc# 3GPP TS 27.007)
- [17] FCC Regulations - Part 15 - Radio Frequency Devices
- [18] IEC-61000-4-2 level 3 (Electrostatic Discharge Immunity Test)

- [19]** Mobile Station (MS) Conformance Specification; Part 4: Subscriber Interface Module (Doc# 3GPP TS 11.10-4)
- [20]** PCI Express M.2™ Specification Revision 3.0, Version 1.2
- [21]** Universal Serial Bus Specification, Rev 2.0
- [22]** Universal Serial Bus Specification, Rev 3.1
- [23]** JESD22-A114-B
- [24]** JESD22-C101
- [25]** MIPI Alliance Specification for RF Front-End Control Interface

# >> G: Abbreviations

**Table G-1: Abbreviations and Definitions**

Abbreviation or Term	Definition
3GPP	3rd Generation Partnership Project
8PSK	Octagonal Phase Shift Keying
AGC	Automatic Gain Control
A-GPS	Assisted GPS
API	Application Programming Interface
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
CQI	Channel Quality Indication
COM	Communication port
CPE	Customer-Premises Equipment
CS	Circuit-switched
CSG	Closed Subscriber Group
CW	Continuous waveform
dB	Decibel = $10 \times \log_{10} (P1/P2)$ <i>P1 is calculated power; P2 is reference power</i> Decibel = $20 \times \log_{10} (V1/V2)$ <i>V1 is calculated voltage, V2 is reference voltage</i>
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+
DCS	Digital Cellular System A cellular communication infrastructure that uses the 1.8 GHz radio spectrum.
DL	Downlink (network to mobile)
DRx	Diversity Receiver
DRX	Discontinuous Reception
DSM	Distributed Shared Memory
DUT	Device Under Test

**Table G-1: Abbreviations and Definitions (Continued)**

<b>Abbreviation or Term</b>	<b>Definition</b>
EGNOS	European Geostationary Navigation Overlay Service (SBAS for GPS, GLONASS, Galileo)
eICIC	Enhanced Inter-Cell Interference Coordination
EIRP	Effective (or Equivalent) Isotropic Radiated Power
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ENDC	E-UTRAN New Radio—Dual Connectivity
EP	End Point
ERP	Effective Radiated Power
ESD	Electrostatic Discharge
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 <a href="http://www.fcc.gov">www.fcc.gov</a> .
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
feICIC	Further Enhanced Inter-Cell Interference Coordination
FER	Frame Error Rate—A measure of receive sensitivity.
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.
FOTA	Firmware Over The Air—Technology used to download firmware upgrades directly from the service provider, over the air.
FOV	Field Of View
FPC	Flexible Printed Cable
FSN	Factory Serial Number—A unique serial number assigned to the module during manufacturing.
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.
GMSK	Gaussian Minimum Shift Keying modulation
GNSS	Global Navigation Satellite Systems (GPS, GLONASS, BeiDou, and Galileo)

**Table G-1: Abbreviations and Definitions (Continued)**

<b>Abbreviation or Term</b>	<b>Definition</b>
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
IMEI	International Mobile Equipment Identity
IMS	IP Multimedia Subsystem—Architectural framework for delivering IP multimedia services.
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.
ISIM	IMS Subscriber Identity Module (Also referred to as a SIM card)
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
LPM	Low Power Mode
LPT	Line Print Terminal
LTE	Long Term Evolution—a high-performance air interface for cellular mobile communication systems.
MB	Mid Band
MCS	Modulation and Coding Scheme
MEO	Medium Earth Orbit

**Table G-1: Abbreviations and Definitions (Continued)**

<b>Abbreviation or Term</b>	<b>Definition</b>
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.
MPR	Maximum Power Reduction
MSAS	Multi-functional Satellite Augmentation System (SBAS for GPS)
NAS/AS	Network Access Server
NC	No Connect
NIC	Network Interface Card
NLIC	Non-Linear Interference Cancellation
NMEA	National Marine Electronics Association
NSA	5G Non-standalone architecture
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer—a company that manufactures a product and sells it to a reseller.
OFDMA	Orthogonal Frequency Division Multiple Access
OMA DM	Open Mobile Alliance Device Management—A device management protocol.
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.
PCB	Printed Circuit Board
PCC	Primary Component Carrier
PCS	Personal Communication System A cellular communication infrastructure that uses the 1.9 GHz radio spectrum.
PDN	Packet Data Network
PMI	Pre-coding Matrix Index
PRx	Primary Receiver
PSS	Primary synchronization signal
PST	Product Support Tools
PTCRB	PCS Type Certification Review Board
QAM	Quadrature Amplitude Modulation. This form of modulation uses amplitude, frequency, and phase to transfer data on the carrier wave.



**Table G-1: Abbreviations and Definitions (Continued)**

<b>Abbreviation or Term</b>	<b>Definition</b>
QCI	QoS Class Identifier
QMI	Qualcomm MSM/Modem Interface
QOS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
QPST	Qualcomm Product Support Tools
QZSS	Quasi-Zenith Satellite System—Japanese system for satellite-based augmentation of GPS.
RAT	Radio Access Technology
RC	Root Complex
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
SA	5G Standalone architecture
SAR	Specific Absorption Rate
SBAS	Satellite-based Augmentation System
SCC	Secondary Component Carrier
SCS	Subcarrier Spacing
SDK	Software Development Kit
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.

**Table G-1: Abbreviations and Definitions (Continued)**

<b>Abbreviation or Term</b>	<b>Definition</b>
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).
S/N	Signal-to-noise (ratio)
SNR	Signal-to-Noise Ratio
SOF	Start of Frame—A USB function.
SSS	Secondary synchronization signal.
SUPL	Secure User Plane Location
TDD	Time Division Duplexing
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
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 <a href="http://www.tiaonline.org">www.tiaonline.org</a> .
TIS	Total Isotropic Sensitivity
TRP	Total Radiated Power
TRx	Transceiver Transmits and receives signals
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
WAN	Wide Area Network

**Table G-1: Abbreviations and Definitions (Continued)**

<b>Abbreviation or Term</b>	<b>Definition</b>
WCDMA	Wideband Code Division Multiple Access (also referred to as UMTS)
WLAN	Wireless Local Area Network
WAAS	Wide Area Augmentation System (SBAS for GPS)
ZIF	Zero Intermediate Frequency
ZUC	ZUC stream cypher