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XBee/XBee-PRO S2C 802.15.4

Radio Frequency (RF) Module

User Guide

Revision history—90001500

Revision	Date	Description
D	April 2017	Added Japan certification data for the S2C TH and S2C SMT devices.
E	June 2017	Modified regulatory and certification information as required by RED (Radio Equipment Directive).
F	February 2018	Added Brazil certification information.
G	May 2018	Added note on range estimation. Changed IC to ISED.
H	June 2018	Changes to the Active Scan command.

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XBee/XBee-PRO S2C 802.15.4 RF Module User Guide

XBee/XBee-PRO S2C 802.15.4 RF Modules are embedded solutions providing wireless end-point connectivity to devices. These devices use the IEEE 802.15.4 networking protocol for fast point-to-multipoint or peer-to-peer networking. They are designed for high-throughput applications requiring low latency and predictable communication timing.

There are two footprints for the XBee/XBee-PRO S2C 802.15.4 RF Module hardware: through-hole (TH) and surface-mount (SMT). TH devices include a 20-pin header and require the placement of two 1x10 sockets on the carrier board for mounting the device. SMT devices include 37 pads. They are placed directly on the carrier board, which means they do not require holes or sockets for mounting.

The TH version may be useful for prototyping and production, but we recommend SMT for high-volume applications, as the component can be placed automatically by a pick-and-place machine and you save the cost of a socket on each board.

The XBee/XBee-PRO S2C 802.15.4 RF Module supports the needs of low-cost, low-power wireless sensor networks. The devices require minimal power and provide reliable delivery of data between devices. The devices operate within the ISM 2.4 GHz frequency band.

The XBee/XBee-PRO S2C 802.15.4 RF Module uses S2C hardware and the Silicon Labs EM357 chipset. As the name suggests, the 802.15.4 module is over-the-air compatible with our Legacy 802.15.4 module (S1 hardware), and the TH versions of the new product are also form factor compatible with designs that use the Legacy module.

Note OTA capability is only available when **MM** (Mac Mode) = 0 or 3

Applicable firmware and hardware

This manual supports the following firmware:

- 802.15.4 version 20xx

It supports the following hardware:

- XB24C TH
- XB24C SMT
- XBP24C TH
- XBP24C SMT

Technical specifications

Performance specifications

The following table describes the performance specifications for the devices.

Note Range figure estimates are based on free-air terrain with limited sources of interference. Actual range will vary based on transmitting power, orientation of transmitter and receiver, height of transmitting antenna, height of receiving antenna, weather conditions, interference sources in the area, and terrain between receiver and transmitter, including indoor and outdoor structures such as walls, trees, buildings, hills, and mountains.

Specification	XBee value	XBee-PRO value
Indoor / urban range	Up to 200 ft (60 m)	Up to 300 ft. (90 m)
Outdoor RF line-of-sight range	Up to 4000 ft (1200 m)	Up to 2 miles (3200 m)
Transmit power output (software selectable)	6.3 mW (8 dBm), Boost mode[1] 3.1 mW (5 dBm), Normal mode Channel 26 max power is 0.3 mW (-5 dBm)	63 mW (18 dBm)[2]
RF data rate	250,000 b/s	250,000 b/s
Maximum data throughput	Up to 96,000 b/s	Up to 96,000 b/s
UART interface data rate	1200 b/s to 250,000 b/s	1200 b/s to 250,000 b/s
SPI data rate	Up to 5 Mb/s (burst)	Up to 5 Mb/s (burst)
Receiver sensitivity	-102 dBm, Boost mode -100 dBm, Normal mode	-101 dBm

Power requirements

The following table describes the power requirements for the XBee/XBee-PRO S2C 802.15.4 RF Module.

Specification	XBee	XBee-PRO
Supply voltage	2.1 - 3.6 V	2.7 - 3.6 V
Transmit current (typical, VCC = 3.3 V)	45 mA (8 dBm, Boost mode) 33 mA (5 dBm, Normal mode)	120 mA (18 dBm)
Idle / receive current (typical, VCC = 3.3 V)	31 mA (Boost mode) 28 mA (Normal mode)	31 mA
Power-down current	<1 uA @ 25C	<1 uA @ 25C

[1]Boost mode enabled by default; see PM (Power Mode).

[2]See Regulatory information for region-specific certification requirements.

General specifications

The following table describes the general specifications for the devices.

Specification	XBee	XBee-PRO
Operating frequency	ISM 2.4 GHz	
Supported channels	11 - 26	12 - 23
Form factor	TH: 2.438 x 2.761 cm (0.960 x 1.087 in) SMT: 2.199 x 3.4 x 0.305 cm (0.866 x 1.33 x 0.120 in)	TH: 2.438 x 3.294 cm (0.960 x 1.297 in) SMT: 2.199 x 3.4 x 0.305 cm (0.866 x 1.33 x 0.120 in)
Operating temperature	-40 to 85 ºC (industrial)	
Antenna options	TH: PCB antenna, U.FL connector, RPSMA connector, or integrated wire SMT: RF pad, PCB antenna, or U.FL connector	

Regulatory conformity summary

This table describes the agency approvals for the devices.

Country	XBee (surface-mount)	XBee-PRO (surface-mount)	XBee (through-hole)	XBee-PRO (through-hole)
United States (FCC Part 15.247)	FCC ID: MCQ-XBS2C	FCC ID: MCQ-PS2CSM	FCC ID: MCQ-S2CTH	FCC ID: MCQ-PS2CTH
Innovation, Science and Economic Development Canada (ISED)	IC: 1846A-XBS2C	IC: 1846A-PS2CSM	IC: 1846A-S2CTH	IC: 1846A-PS2CTH
FCC/IC test transmit power output range	-26 to +8 dBm	-0.7 to +19.4 dBm	-26 to +8 dBm	+1 to +19 dBm
Europe (CE)	Yes	-	Yes	-
Australia	RCM	RCM	RCM	RCM
Japan	R201WW10215369		R210- 105563	
South Korea	MSIP-CRM-DIG-XBee-S2C		MSIP-CRM-DIG-XBee-S2C-TH	
RoHS	Compliant			

Serial communication specifications

The XBee/XBee-PRO S2C 802.15.4 RF Module supports both Universal Asynchronous Receiver / Transmitter (UART) and Serial Peripheral Interface (SPI) serial connections.

UART pin assignments

The SC1 (Serial Communication Port 1) of the Ember 357 is connected to the UART port. The following table provides the UART pin assignments.

Specifications UART pins	Module pin number XBee (surface-mount)	 XBee (through-hole)
DOUT	3	2
DIN / $\overline{\text{CONFIG}}$	4	3
$\overline{\text{CTS}}$ / DIO7	25	12
$\overline{\text{RTS}}$ / DIO6	29	16

SPI pin assignments

The SC2 (Serial Communication Port 2) of the Ember 357 is connected to the SPI port.

Specifications SPI pins	Module pin number XBee (surface-mount)	 XBee (through-hole)
SPI_SCLK	14	18
SPI_$\overline{\text{SSEL}}$	15	17
SPI_MOSI	16	11
SPI_MISO	17	4
SPI_$\overline{\text{ATTN}}$	12	19

GPIO specifications

XBee/XBee-PRO S2C 802.15.4 RF Modules have 15 General Purpose Input / Output (GPIO) ports available. The exact list depends on the device configuration, as some GPIO pads are used for purposes such as serial communication.

GPIO Electrical Specification	Value
Low Schmitt switching threshold	0.42 - 0.5 x VCC
High Schmitt switching threshold	0.62 - 0.8 x VCC
Input current for logic 0	-0.5 µA

GPIO Electrical Specification	Value
Input current for logic 1	0.5 µA
Input pull-up resistor value	29 kΩ
Input pull-down resistor value	29 kΩ
Output voltage for logic 0	0.18 x VCC (maximum)
Output voltage for logic 1	0.82 x VCC (minimum)
Output source/sink current for pad numbers 3, 4, 5, 10, 12, 14, 15, 16, 17, 25, 26, 28, 29, 30, and 32 on the SMT modules	4 mA
Output source/sink current for pin numbers 2, 3, 4, 9, 12, 13, 15, 16, 17, and 19 on the TH modules	4 mA
Output source/sink current for pad numbers 7, 8, 24, 31, and 33 on the SMT modules	8 mA
Output source/sink current for pin numbers 6, 7, 11, 18, and 20 on the TH modules	8 mA
Total output current (for GPIO pads)	40 mA

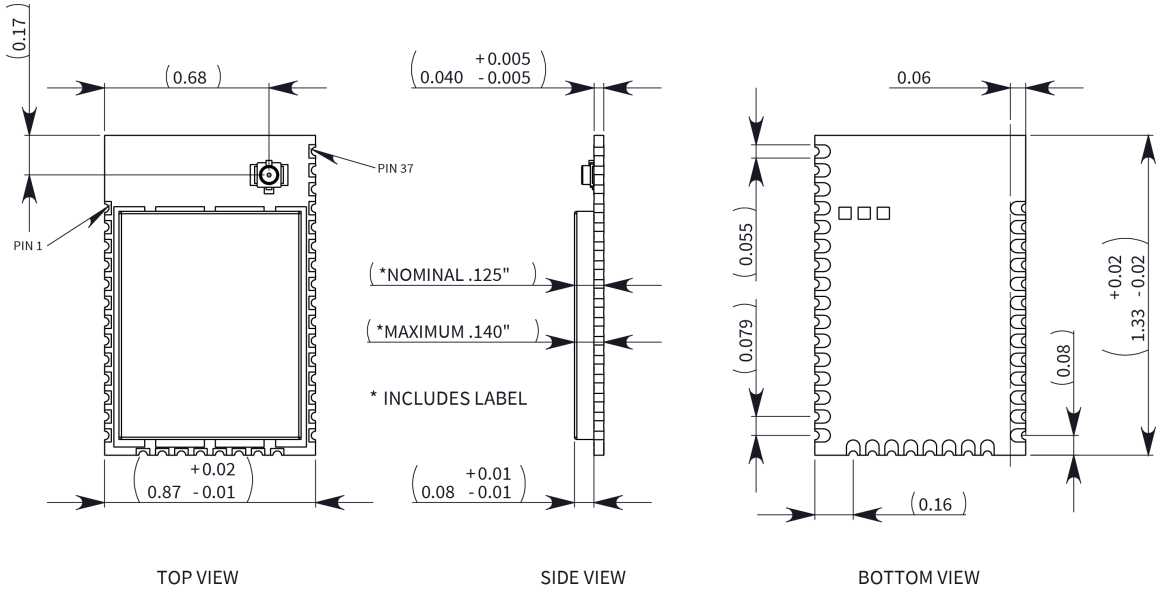
Hardware

Antenna options

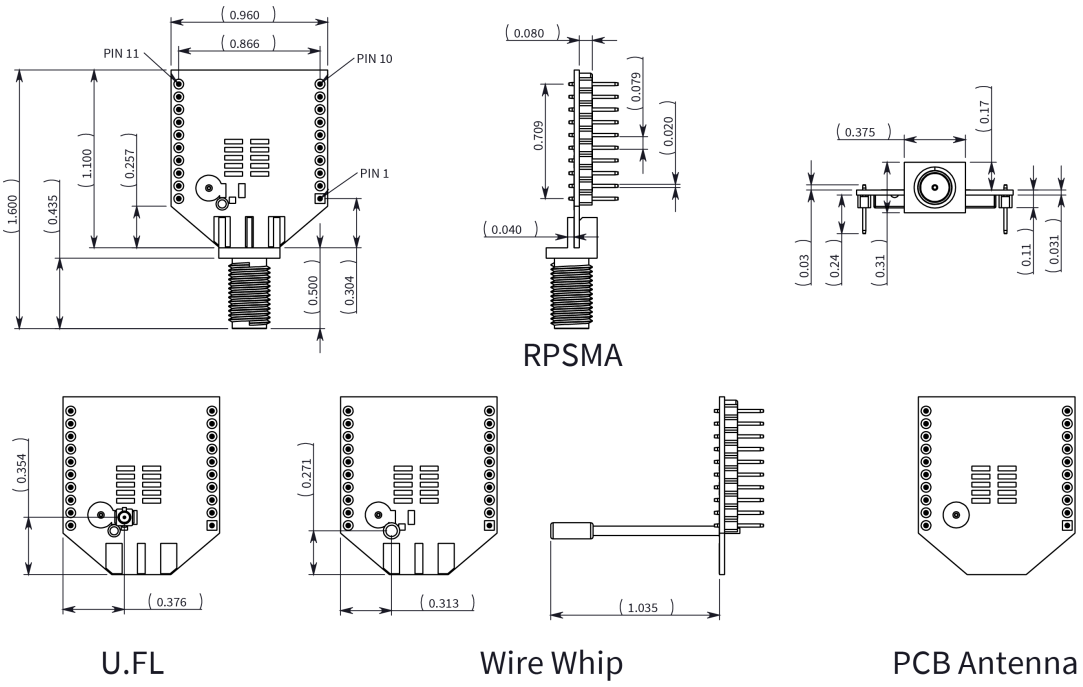
The ranges specified are typical for the integrated whip (1.5 dBi) and dipole (2.1 dBi) antennas. The printed circuit board (PCB) antenna option provides advantages in its form factor; however, it typically yields shorter range than the whip and dipole antenna options when transmitting outdoors. For more information, see XBee and XBee-PRO OEM RF Module Antenna Considerations Application Note.

Mechanical drawings

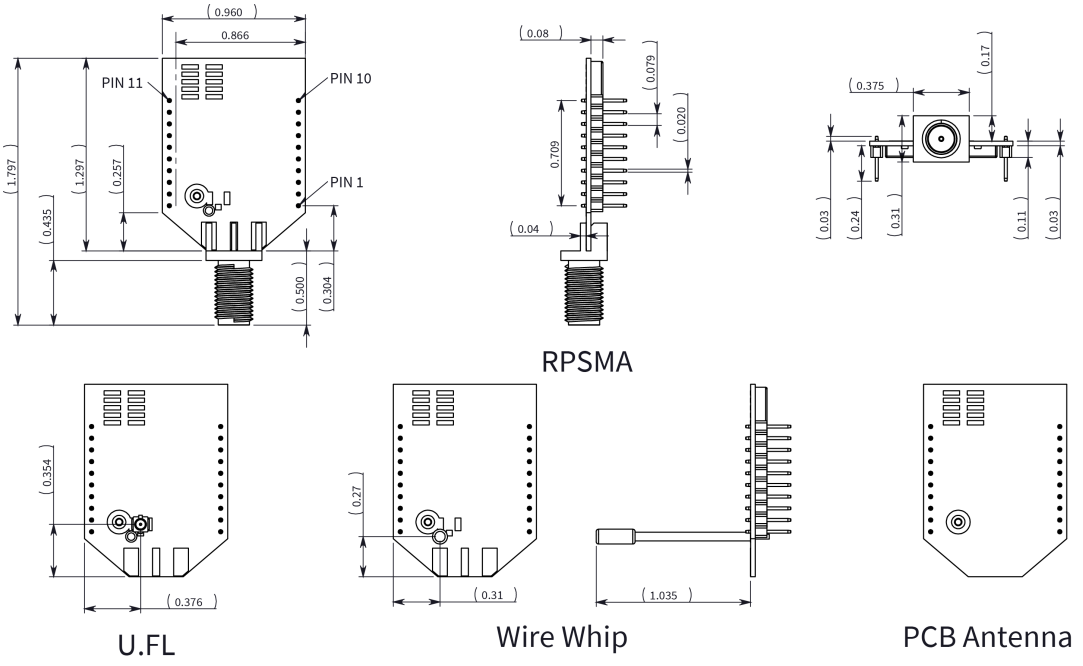
The following mechanical drawings of the XBee/XBee-PRO S2C 802.15.4 RF Module show all dimensions in inches. The first drawing shows the surface-mount device (antenna options not shown).



The following drawings show the standard (non-PRO) through-hole device.



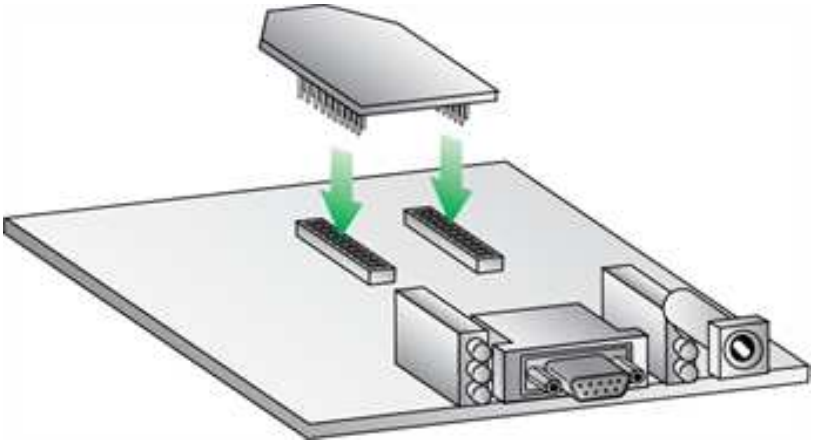
The following drawings show the XBee-PRO through-hole device.



Mounting considerations

We design the through-hole module to mount into a receptacle so that you do not have to solder the module when you mount it to a board. The development kits may contain RS-232 and USB interface boards that use two 20-pin receptacles to receive modules.

The following illustration shows the module mounting into the receptacle on the RS-232 interface board.



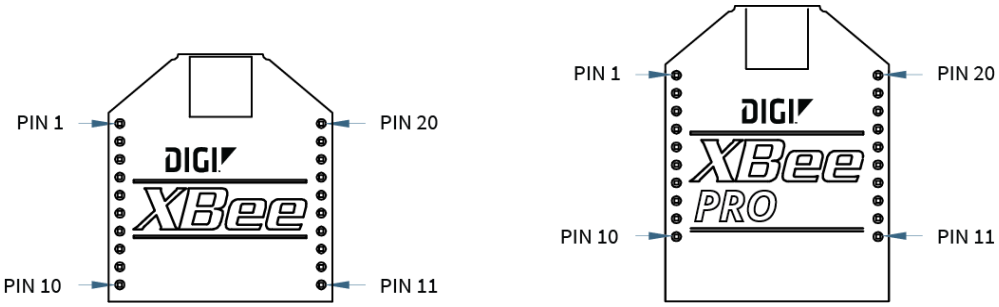
Century Interconnect and Samtec manufacture the 2 x 10 pin 2 mm spacing receptacles on Digi development boards. Several other manufacturers provide comparable mounting solutions; we currently use the following receptacles:

- Through-hole single-row receptacles: Samtec part number: MMS-110-01-L-SV (or equivalent)
- Surface-mount double-row receptacles: Century Interconnect part number: CPRMSL20-D-0-1 (or equivalent)
- Surface-mount single-row receptacles: Samtec part number: SMM-110-02-SM-S

Note We recommend that you print an outline of the module on the board to indicate the correct orientation for mounting the module.

Pin signals

The following image shows the pin numbers; it shows the device's top sides, the shields are on the bottom.



The following table shows the pin assignments for the through-hole device. In the table, low-asserted signals have a horizontal line above signal name.

Pin	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART data out
3	DIN/$\overline{\text{CONFIG}}$	Input	UART data In
4	SPI_MISO	Output	Serial Peripheral Interface (SPI) Data Out
5	$\overline{\text{RESET}}$	Input	Module reset (reset pulse must be at least 200 ns). This must be driven as an open drain/collector. The device drives this line low when a reset occurs. Never drive this line high.
6	PWM0/RSSI PWM	Output	PWM output 0 / RX signal strength indicator
7	PWM1	Output	PWM output 1
8	[Reserved]	-	Do not connect
9	DI8/$\overline{\text{SLEEP}}$_RQ/DTR	Input	Pin sleep control line or digital input 8
10	GND	-	Ground
11	DIO4/SPI_MOSI	Both	Digital I/O 4 / SPI Data In
12	DIO7/$\overline{\text{CTS}}$	Both	Digital I/O 7 / Clear-to-send flow control
13	ON/$\overline{\text{SLEEP}}$	Output	Device sleep status indicator
14	V_{REF}	-	Feature not supported on this device. Used on other XBee devices for analog voltage reference.
15	DIO5/ASSOC	Both	Digital I/O 5 / Associated indicator
16	DIO6/$\overline{\text{RTS}}$	Both	Digital I/O 6 / Request-to-send flow control
17	$\underline{\text{DIO3}}$/AD3/SPI_SSEL	Both	Digital I/O 3 / Analog input 3 / SPI select
18	DIO2/AD2/SPI_CLK	Both	Digital I/O 2 / Analog input 2 / SPI clock
19	$\underline{\text{DIO1}}$/AD1/SPI_ATTN	Both	Digital I/O 1 / Analog input 1 / SPI Attention
20	DIO0/AD0	Both	Digital I/O 0 / Analog input 0

The following table shows the pin assignments for the surface-mount device.

Pin	Name	Direction	Function
1	GND	-	Ground
2	VCC	-	Power supply

Pin	Name	Direction	Function
3	DOUT	Output	UART data out
4	DIN/$\overline{\text{CONFIG}}$	Input	UART data in
5	[Reserved]	Output	Do not connect
6	$\overline{\text{RESET}}$	Input	Module reset (reset pulse must be at least 200 ns). This must be driven as an open drain/collector. The device drives this line low when a reset occurs. Never drive this line high.
7	PWM0/RSSI PWM	Output	PWM output 0 / RX signal strength indicator
8	PWM1	Output	PWM output 1
9	[Reserved]	-	Do not connect
10	DI8/SLEEP_RQ/$\overline{\text{DTR}}$	Input	Pin sleep control line or digital input 8
11	GND	-	Ground
12	$\overline{\text{SPI\_ ATTN}}$/$\overline{\text{BOOTMODE}}$	Output	SPI Attention. Do not tie low on reset.
13	GND	-	Ground
14	SPI_CLK	Input	SPI clock
15	SPI_$\overline{\text{SSEL}}$	Input	SPI select
16	SPI_MOSI	Input	SPI Data In
17	SPI_MISO	Output	SPI Data Out
18	[Reserved]	-	Do not connect
19	[Reserved]	-	Do not connect
20	[Reserved]	-	Do not connect
21	[Reserved]	-	Do not connect
22	GND	-	Ground
23	[Reserved]	-	Do not connect
24	DIO4	Both	Digital I/O 4
25	DIO7/$\overline{\text{CTS}}$	Both	Digital I/O 7 / Clear-to-send flow control
26	ON/$\overline{\text{SLEEP}}$	Output	Device sleep status indicator
27	V_{REF}	-	Feature not supported on this device. Used on other XBee devices for analog voltage reference.
28	DIO5/ASSOC	Both	Digital I/O 5 / Associated indicator

Pin	Name	Direction	Function
29	DIO6/$\overline{\text{RTS}}$	Both	Digital I/O 6 / Request-to-send flow control
30	DIO3/AD3	Both	Digital I/O 3 / Analog input 3
31	DIO2/AD2	Both	Digital I/O 2 / Analog input 2
32	DIO1/AD1	Both	Digital I/O 1 / Analog input 1
33	DIO0/AD0	Both	Digital I/O 0 / Analog input 0
34	[Reserved]	-	Do not connect
35	GND	-	Ground
36	RF	Both	RF connection
37	[Reserved]	-	Do not connect

Notes

Minimum connections: VCC, GND, DOUT and DIN.

Minimum connections for updating firmware: VCC, GND, DIN, DOUT, RTS and DTR.

The table specifies signal direction with respect to the device.

The device includes a 50 kΩ pull-up resistor attached to RESET.

Use the **PR** (Pull-up/Down Resistor Enable) command to configure several of the input pull-ups.

You can connect other pins to external circuitry for convenience of operation including the Associate LED pin (pin 15). The Associate LED flashes differently depending on the state of the device.

Leave any unused pins disconnected.

Design notes

The following guidelines help to ensure a robust design.

Power supply design

A poor power supply can lead to poor device performance, especially if you do not keep the supply voltage within tolerance or if it is excessively noisy. To help reduce noise, place a 1.0 µF and 8.2 pF capacitor as near as possible to pin 1 on the PCB. If you are using a switching regulator for the power supply, switch the frequencies above 500 kHz. Limit the power supply ripple to a maximum 100 mV peak to peak.

Board layout

We design XBee devices to be self sufficient and have minimal sensitivity to nearby processors, crystals or other printed circuit board (PCB) components. Keep power and ground traces thicker than signal traces and make sure that they are able to comfortably support the maximum current specifications. There are no other special PCB design considerations to integrate XBee devices, with the exception of antennas.

Antenna performance

Antenna location is important for optimal performance. The following suggestions help you achieve optimal antenna performance. Point the antenna up vertically (upright). Antennas radiate and receive the best signal perpendicular to the direction they point, so a vertical antenna's omnidirectional radiation pattern is strongest across the horizon.

Position the antennas away from metal objects whenever possible. Metal objects between the transmitter and receiver can block the radiation path or reduce the transmission distance. Objects that are often overlooked include:

- metal poles
- metal studs
- structure beams
- concrete, which is usually reinforced with metal rods

If you place the device inside a metal enclosure, use an external antenna. Common objects that have metal enclosures include:

- vehicles
- elevators
- ventilation ducts
- refrigerators
- microwave ovens
- batteries
- tall electrolytic capacitors

Do not place XBee devices with the chip or integrated PCB antenna inside a metal enclosure.

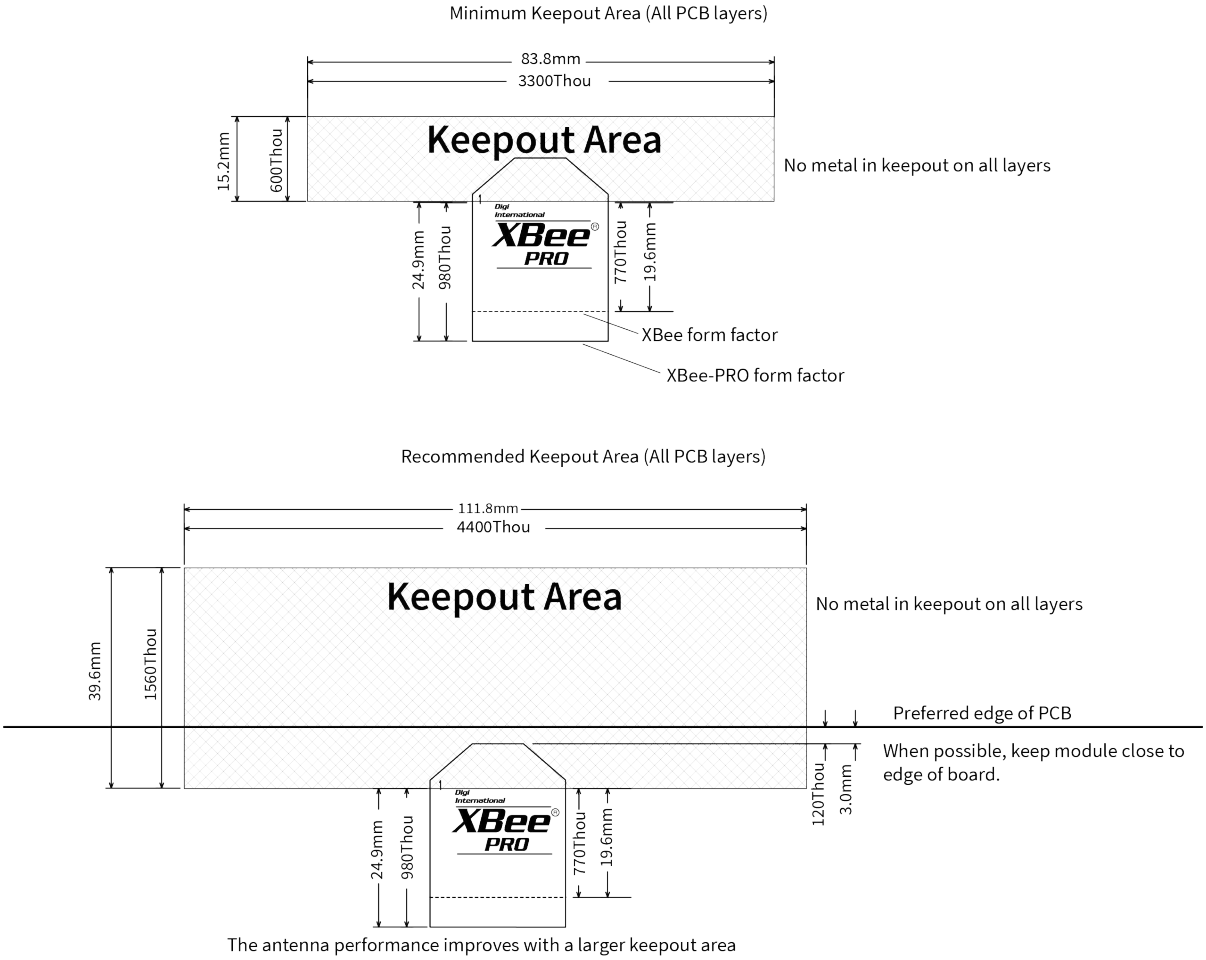
Do not place any ground planes or metal objects above or below the antenna.

For the best results, mount the device at the edge of the host PCB. Ensure that the ground, power, and signal planes are vacant immediately below the antenna section.

Keepout area

We recommend that you allow a “keepout” area, which the following drawings show.

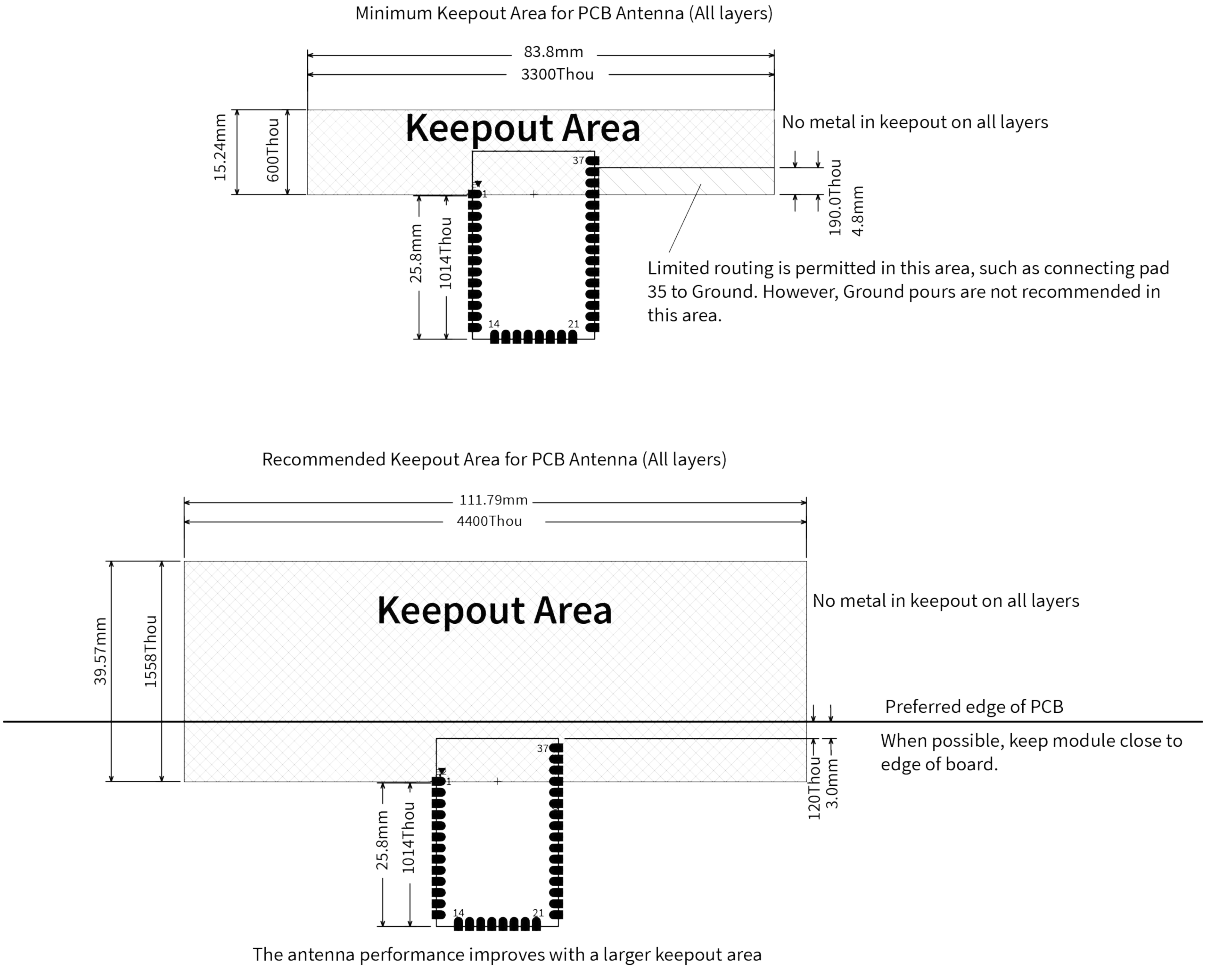
Through-hole keepout



Notes

1. We recommend non-metal enclosures. For metal enclosures, use an external antenna.
2. Keep metal chassis or mounting structures in the keepout area at least 2.54 cm (1 in) from the antenna.
3. Maximize the distance between the antenna and metal objects that might be mounted in the keepout area.
4. These keepout area guidelines do not apply for wire whip antennas or external RF connectors. Wire whip antennas radiate best over the center of a ground plane.

Surface-mount keepout



RF pad version

The RF pad is a soldered antenna connection on the surface-mount device. The RF signal travels from pin 36 on the module to the antenna through a single ended RF transmission line on the PCB. This line should have a controlled impedance of 50 Ω.

For the transmission line, we recommend either a microstrip or coplanar waveguide trace on the PCB. We provide a microstrip example below, because it is simpler to design and generally requires less area on the host PCB than coplanar waveguide.

We do not recommend using a stripline RF trace because that requires routing the RF trace to an inner PCB layer, and via transitions can introduce matching and performance problems.

The following figure shows a layout example of a microstrip connecting an RF pad module to a through-hole RPSMA RF connector.

- The top two layers of the PCB have a controlled thickness dielectric material in between. The second layer has a ground plane which runs underneath the entire RF pad area. This ground plane is a distance *d*, the thickness of the dielectric, below the top layer.