XBee3® 802.15.4

Radio Frequency (RF) Module

User Guide

Revision history—90002273

Revision	Date	Description
A	February 2018	Initial release.

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XBee3® 802.15.4 RF Module User Guide

XBee3 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.

The XBee3 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 XBee3 802.15.4 RF Module uses XBee3 hardware and the Silicon Labs EFR32 chipset. As the name suggests, the 802.15.4 module is over-the-air compatible with our Legacy 802.15.4 modules (S1 and S2C hardware).

For information about XBee3 hardware, see the XBee3 RF Module Hardware Reference Manual.

Applicable firmware and hardware

This manual supports the following firmware:

- 802.15.4 version 20xx

It supports the following hardware:

- XBee3

Change the firmware protocol

You can switch the firmware loaded onto the XBee3 hardware to run either of the following protocols:

- Zigbee
- 802.15.4

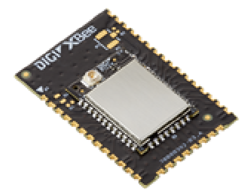
To change protocols, use the **Update firmware** feature in XCTU and select the firmware. See the XCTU User Guide.

Getting started

This section covers the following tasks and features:

Verify kit contents

The XBee3 802.15.4 RF Module development kit contains the following components:

Part	
XBee3 Zigbee SMT module (3)	
XBee Grove development board (3)	
Micro USB cable (3)	
Antenna - 2.4 GHz, half-wave dipole, 2.1 dBi, U.FL female, articulating (3)	
XBee stickers	

Assemble the hardware

This guide walks you through the steps required to assemble and disassemble the hardware components of your kit.

- Plug in the XBee3 802.15.4 RF Module
- How to unplug an XBee module

The kit includes several XBee Grove Development Boards. For more information about this hardware, see the XBee Grove Development Board documentation.

Plug in the XBee3 802.15.4 RF Module

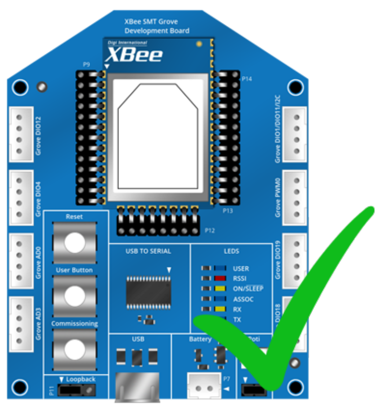
This kit includes two XBee Grove Development Boards. For more information about this hardware, visit the XBee Grove Development Board documentation.

Follow these steps to connect the XBee devices to the boards included in the kit:

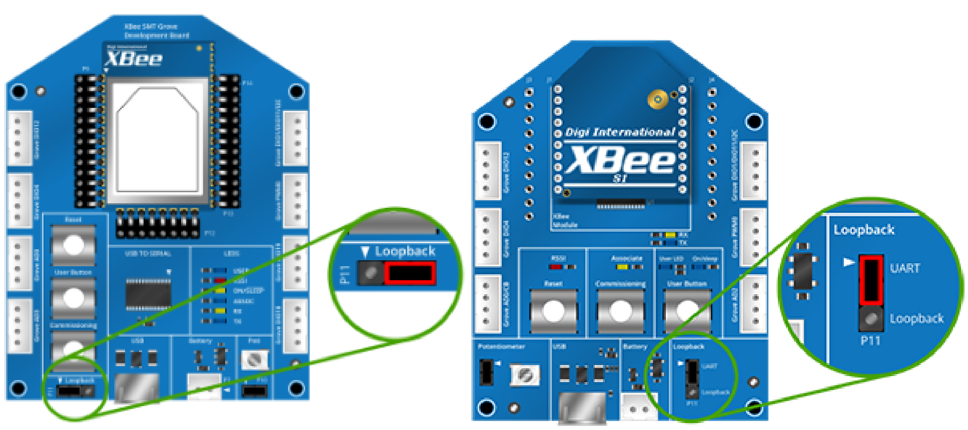
1. Plug one XBee3 802.15.4 RF Module module into the XBee Grove Development Board.

   Make sure the board is NOT powered (either by the micro USB or a battery) when you plug in the XBee module.

   For XBee SMT modules, align all XBee pins with the spring header and carefully push the module until it is hooked to the board.



2. Once the XBee module is plugged into the board (and not before), connect the board to your computer using the micro USB cables provided.
3. Ensure the loopback jumper is in the UART position.



How to unplug an XBee module

To disconnect your XBee module from the XBee Grove Development Board:

1. Disconnect the micro USB cable (or the battery) from the board so it is not powered.
2. Remove the XBee module from the board socket, taking care not to bend any of the pins.

Make sure the board is **not** powered when you remove the XBee module.

Configure the device using XCTU

XBee Configuration and Test Utility (XCTU) is a multi-platform program that enables users to interact with Digi radio frequency (RF) devices through a graphical interface. The application includes built-in tools that make it easy to set up, configure, and test Digi RF devices.

For instructions on downloading and using XCTU, see the XCTU User Guide.

Configure remote devices

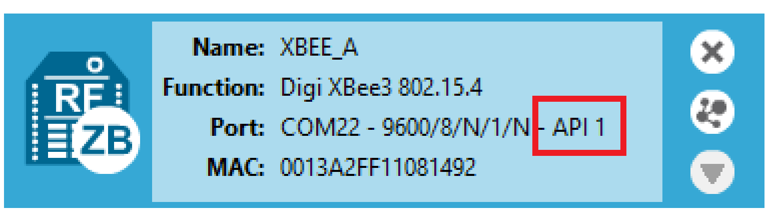
You can communicate with remote devices over the air through a corresponding local device.

Note Configure the local device in API mode because remote commands only work in API mode. Configure remote devices in either API or Transparent mode.

These instructions show you how to configure the LT command parameter on a remote device.

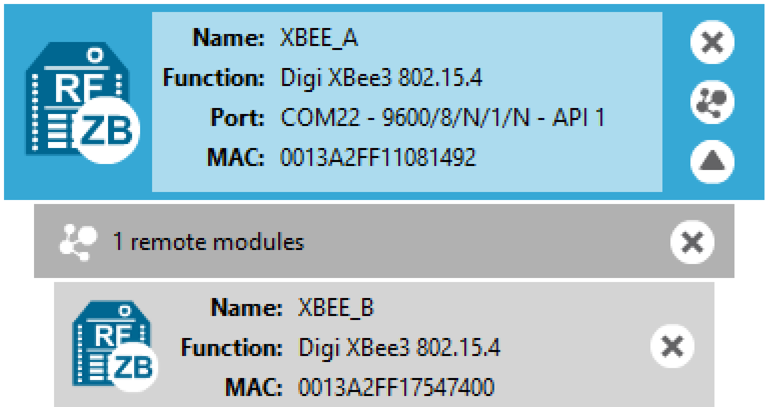
1. Add two XBee devices to XCTU.
2. Configure the first device in API mode and name it **XBEE_A**.
3. Configure the second device in either API or Transparent mode, and name it **XBEE_B**.
4. Disconnect XBEE_B from your computer and remove it from XCTU.
5. Connect XBEE_B to a power supply (or laptop or portable battery).

   The **Radio Modules** area should look something like this.



6. Select **XBEE_A** and click the **Discover radio nodes in the same network** button .

7. Click **Add selected devices** in the **Discovering remote devices** dialog. The discovered remote device appears below XBEE_A.



8. Select the remote device **XBEE_B**, and configure the following parameter:

   LT: FF (hexadecimal representation for 2550 ms)

9. Click the **Write radio settings** button .

   The remote XBee device now has a different LED blink time.

10. To return to the default LED blink times, change the **LT** parameter back to 0 for XBEE_B.

Configure the devices for a range test

When you connect the development board to a PC for the first time, the PC automatically installs drivers, which may take a few minutes to complete.

1. Add the two devices to XCTU.
2. Select the first module and click the **Load default firmware settings** button.
3. Configure the following parameters:

   ID: 2018

   NI: LOCAL_DEVICE

   AP: API Mode Enabled [1]

4. Click the **Write radio settings** button.
5. Select the other module and click the **Default firmware settings** button.
6. Configure the following parameters:

   ID: 2015

   NI: REMOTE_DEVICE

   AP: Transparent mode [0] (The remote node must be in transparent mode to loop back packets)

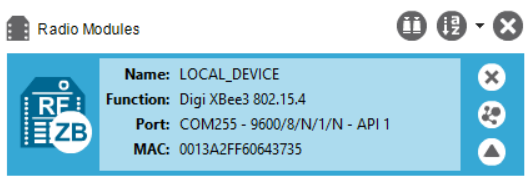
7. Click the **Write radio settings** button.

   After you write the radio settings for each device, their names appear in the **Radio Modules** area. The Port indicates that the LOCAL_DEVICE is in API mode.

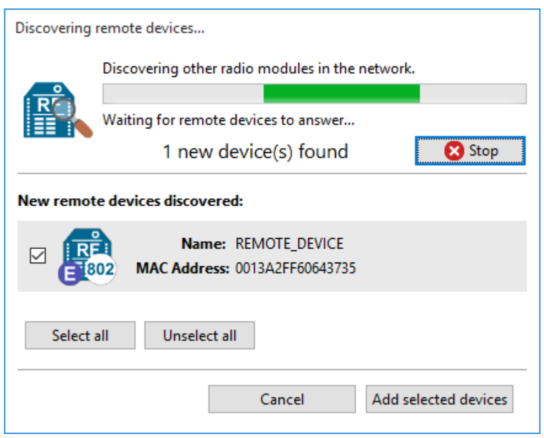
8. Disconnect REMOTE_DEVICE from the computer, remove it from XCTU, and connect it to its own power supply.
9. Leave LOCAL_DEVICE connected to the computer.

Perform a range test

1. Go to the XCTU display for radio 1.

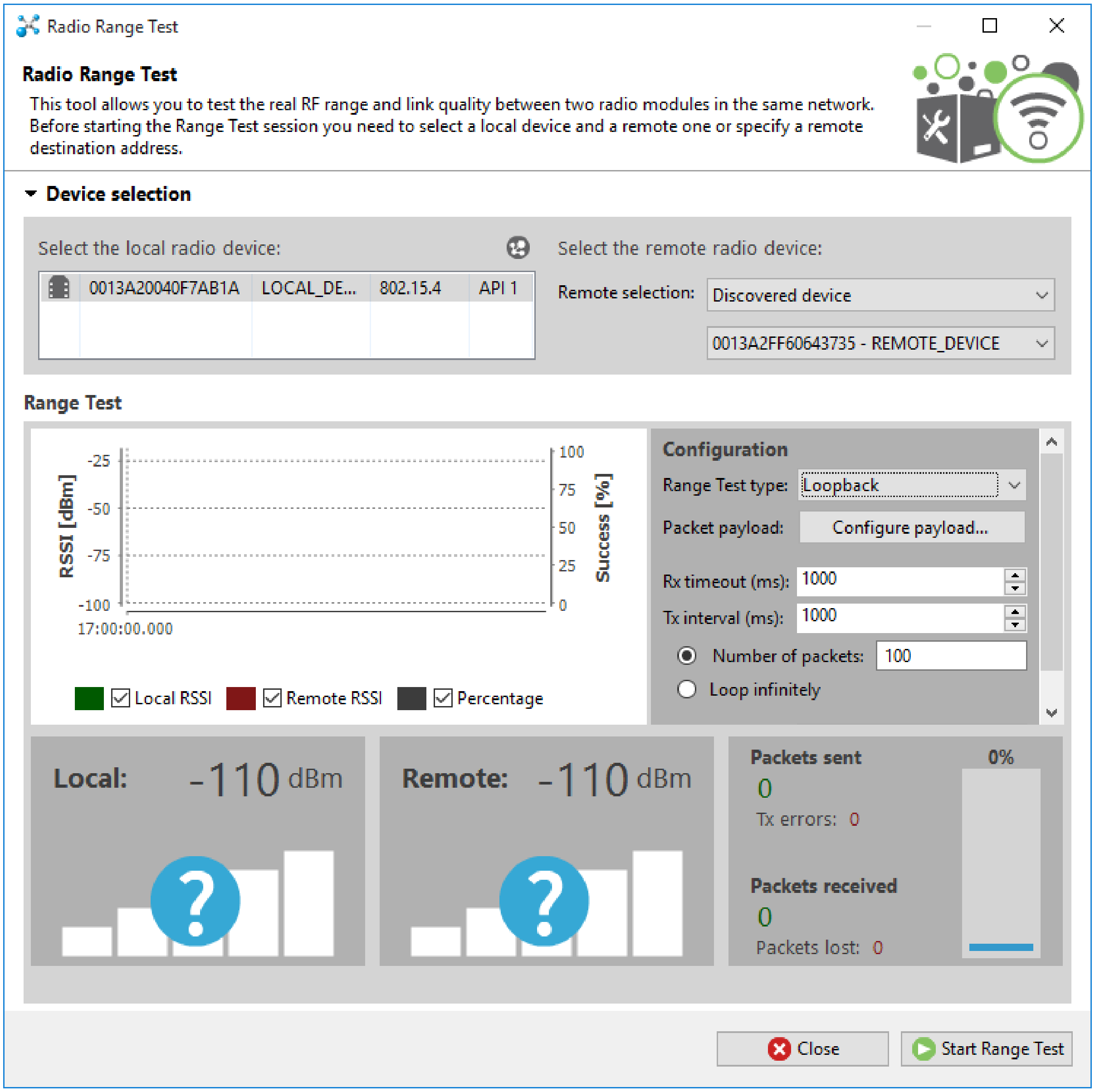


2. Click  to discover remote devices within the same network. The **Discover remote devices** dialog appears.



3. Click **Add selected devices**.

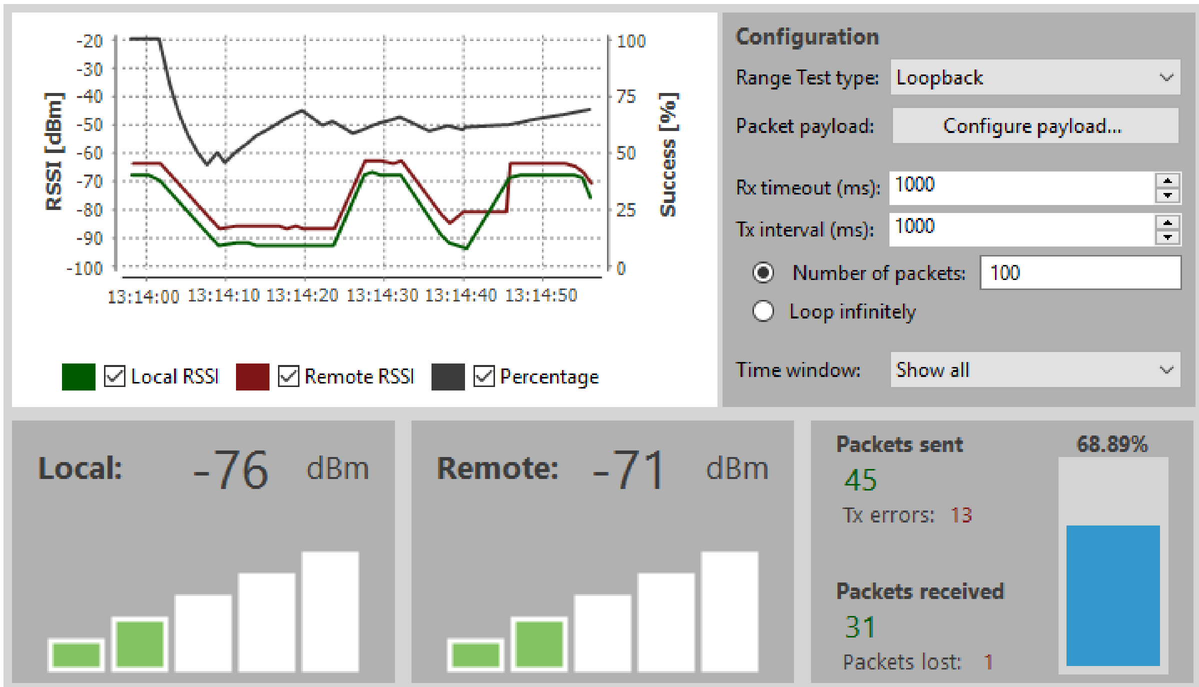
4. Click and select **Range test**. The **Radio Range Test** dialog appears.



5. In the **Select the local radio device** area, select radio 1. XCTU automatically selects the **Discovered device** option, and the **Start Range Test** button is active.

6. Click Start Range Test to begin the range test.

   If the test is running properly, the packets sent should match the packets received. You will also see the received signal strength indicator (RSSI) update for each radio after each reception.



7. Move Radio 1 around to see the resulting signal strength at different distances. You can also test different data rates by reconfiguring the **BR** (data rate) parameter on both radios. When the test is complete, click **Stop Range Test**.

Modes

Serial modes

The firmware operates in several different modes. Two top-level modes establish how the device communicates with other devices through its serial interface: Transparent operating mode and API operating mode. Use the **AP** command to choose Serial mode. XBee3 802.15.4 RF Modules use Transparent operation as the default serial mode.

The following subsections describe how the serial port sends and receives data.

Transparent operating mode

Devices operate in this mode by default. The device acts as a serial line replacement when it is in Transparent operating mode. The device queues all UART data it receives through the DIN pin for RF transmission. When a device receives RF data, it sends the data out through the DOUT pin. You can set the configuration parameters using Command mode.

Serial-to-RF packetization

Data is buffered in the incoming serial buffer until one of the following causes the data to be packetized and transmitted:

1. No serial characters are received for the amount of time determined by the **RO** (Packetization Timeout) parameter. If **RO** = 0, packetization begins when a character is received.
2. The maximum number of characters that will fit in an RF packet is received. There are a number of factors that determine payload size. You can query the NP (Maximum Packet Payload Bytes) to determine the maximum payload size based on current configuration. For more information, see Maximum payload.
3. The Command mode Sequence, **GT** + **CC** + **GT**, (including spaces) is received; this is any data in the serial receive buffer received before the sequence is transmitted. For more information, see Enter Command mode.

If the device cannot immediately transmit (for instance, if it is already receiving RF data), the serial data is stored in the serial receive buffer. The data is packetized and sent at any **RO** timeout or when **NP** bytes are received.

If the serial receive buffer becomes full, hardware flow control must be implemented in order to prevent overflow (loss of data between the host and device).

API operating mode

Application programming interface (API) operating mode is an alternative to Transparent mode. It is helpful in managing larger networks and is more appropriate for performing tasks such as collecting data from multiple locations or controlling multiple devices remotely. API mode is a frame-based protocol that allows you to direct data on a packet basis. It can be particularly useful in large networks where you need control over the operation of the radio network or when you need to know which node a data packet is from. The device communicates UART or SPI data in packets, also known as API frames. This mode allows for structured communications with serial devices.

For more information, see API mode overview.

Command mode

Command mode is a state in which the firmware interprets incoming characters as commands. It allows you to modify the device's firmware using parameters you can set using AT commands. When you want to read or set any parameter of the device when operating in Transparent mode, you have to send an AT command. Every AT command starts with the letters **AT** followed by the two characters that identify the command the device issues and then by some optional configuration values.

Command mode is available on the UART interface in both Transparent and API modes.

The availability of AT commands in API mode does not imply that Command mode is available in API mode. Also, Command mode may be entered whether or not API mode is configured, providing the UART is the serial interface.

Enter Command mode

To get a device to switch into this mode, you must issue the following sequence: **GT** + **CC**(**+++**) + **GT**. When **GT** is set to the default value, if the device sees a full second of silence in the data stream (the guard time) followed by the string **+++** (without Enter or Return) and another full second of silence, it knows to stop sending data through and start accepting commands locally.

Note Do not press Return or Enter after typing **+++** because it will interrupt the guard time silence and prevent you from entering Command mode.

When you send the Command mode sequence, the device sends **OK** out the UART pin. The device may delay sending the **OK** if it has not transmitted all of the serial data it received.

When the device is in Command mode, it listens for user input and is able to receive AT commands on the UART. If **CT** time (default is 10 seconds) passes without any user input, the device drops out of Command mode and returns to Receive mode.

You can customize the command character, the guard times and the timeout in the device's configuration settings. For more information, see CC (Command Character), CT (Command Mode Timeout) and GT (Guard Times).

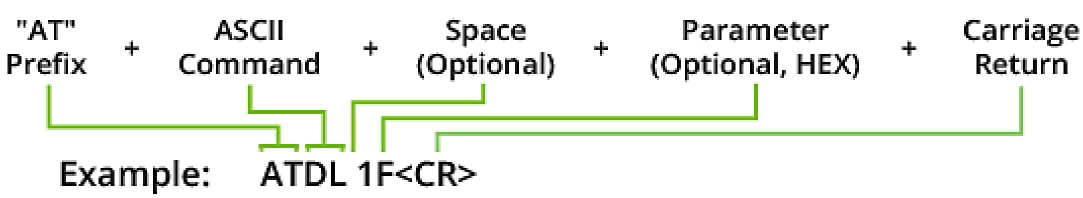
Troubleshooting

Failure to enter Command mode is often due to baud rate mismatch. Ensure that the baud rate of the connection matches the baud rate of the device. By default, the **BD** parameter = 3 (9600 baud).

Send AT commands

Once the device enters Command mode, use the syntax in the following figure to send AT commands. Every AT command starts with the letters **AT**, which stands for "attention." The **AT** is followed by two characters that indicate which command is being issued, then by some optional configuration values.

To read a parameter value stored in the device's register, omit the parameter field.



The preceding example changes the device's destination address (Low) to 0x1F.

To store the new value to non-volatile (long term) memory, send the **WR** (Write) command. This allows parameter values that you modify to persist in the device's registry after a reset. Otherwise, the device restores parameters to the previous values after a reset.

Multiple AT commands

You can send multiple AT commands at a time when they are separated by a comma in Command mode; for example, **ATSH**,**SL**.

Parameter format

Refer to the list of AT commands for the format of individual AT command parameters. Numeric parameters will always be represented in hexadecimal format. Some AT commands have ASCII string parameter, which will be represented as ASCII characters in Command mode and bytes in API mode. Valid formats for hexadecimal values include with or without a leading **0x** for example **FFFF** or **0xFFFF**.

Response to AT commands

When you send a command to the device, the device parses and runs the command. If the command runs successfully, the device returns an **OK** message.

Apply command changes

Any changes you make to the configuration command registers using AT commands do not take effect until you apply the changes. For example, if you send the **BD** command to change the baud rate, the actual baud rate does not change until you apply the changes. To apply changes:

1. Send the **AC** (Apply Changes) command.

   or:

2. Exit Command mode.

Exit Command mode

1. Send the **CN** (Exit Command mode) command followed by a carriage return.

   or:

2. If the device does not receive any valid AT commands within the time specified by **CT** (Command mode Timeout), it returns to Transparent or API mode. The default Command mode Timeout is 10 seconds.

For an example of programming the device using AT commands and descriptions of each configurable parameter, see AT commands.

Operation

Software libraries

One way to communicate with the XBee3 802.15.4 RF Module is by using a software library. The libraries available for use with the XBee3 802.15.4 RF Module include:

- XBee Java library
- XBee Python library

The XBee Java Library is a Java API. The package includes the XBee library, its source code and a collection of samples that help you develop Java applications to communicate with your XBee devices.

The XBee Python Library is a Python API that dramatically reduces the time to market of XBee projects developed in Python and facilitates the development of these types of applications, making it an easy process.

Addressing

Every RF data packet sent over-the-air contains a Source Address and Destination Address field in its header. The XBee3 802.15.4 RF Module conforms to the 802.15.4 specification and supports both short 16-bit addresses and long 64-bit addresses. A unique 64-bit IEEE source address is assigned at the factory and can be read with the **SL** (Serial Number Low) and **SH** (Serial Number High) commands. You must manually configure short addressing. A device uses its unique 64-bit address as its Source Address if its **MY** (16-bit Source Address) value is 0xFFFF.

Send packets to a specific device

To send a packet to a specific device using 64-bit addressing:

- Set the Destination Address (**DL** + **DH**) of the sender to match the Source Address (**SL** + **SH**) of the intended destination device.

To send a packet to a specific device using 16-bit addressing:

1. Set the **DL** parameter to equal the **MY** parameter of the intended destination device.
2. Set the **DH** parameter to 0.

Addressing modes

802.15.4 frames have a source address, a destination address, and a destination PAN ID in the over-the-air (OTA) frame. The source and destination addresses may be either long or short and the destination address may be either a unicast or a broadcast. The destination PAN ID is short and it may also be the broadcast PAN ID (**ID** is set to 0xFFFF).

In Transparent mode, the destination address is set by the **DH** and **DL** parameters, but, in API mode, it is set by the TX Request: 64-bit address (0x00) or TX Request: 16-bit Address (0x01) frames. In either Transparent mode or API mode, the destination PAN ID is set with the **ID** parameter, and the source address is set with the **MY** parameter.

Broadcasts and unicasts

Broadcasts are identified by the 16-bit short address of 0xFFFF. Any other destination address is considered a unicast and is a candidate for acknowledgments, if enabled.

Broadcast PAN ID

The Broadcast PAN ID is also 0xFFFF. Its effect is to traverse all PANs in the vicinity of a local device.

Short and long addresses

A short address is 16 bits and a long address is 64 bits. The short address is set with the **MY** parameter. If the short address is 0xFFFF, then the address of the device is long and it is the serial number of the device as read by the **SH** and **SL** parameters.

Maximum payload

The absolute maximum payload size for an 802.15.4 packet is 116 bytes. Depending on module configuration, the actual maximum payload size will be reduced.

If you attempt to send an API packet with a larger payload than specified, the device responds with a Transmit Status frame (0x89) with the Status field set to 74 (Data payload too large). When operating in transparent mode, if you attempt to send data larger than the maximum payload size, the data will be packetized and sent as multiple over-the-air transmissions. For more information, see Serial-to-RF packetization.

Maximum payload rules

1. If you enable transmit compatibility (**C8**) with the Legacy 802.15.4 module (S1 hardware):
   - There is a fixed maximum payload of 100 bytes
   - The rest of the rules do not apply. They apply only when you disable transmit compatibility with the Legacy 802.15.4 module.
2. The maximum achievable payload is 116 bytes. This is achieved when:
   - Not using encryption.
   - Not using the application header (**MM** is set to 1 or 2).
   - Using the short source address.
   - Using the short destination address.
3. If you are using the application header, the maximum achievable payload is reduced by 2 bytes if not using encryption.
4. If you are using the long source address, the maximum achievable payload is reduced by 6 bytes (size of long address (8) - size of short address (2) = 6).
5. If you are using the long destination address, the maximum achievable payload is reduced by 6 bytes (the difference between the 8 bytes required for a long address and the 2 bytes required for a short address).

Note You can query the NP command to determine the maximum achievable payload size based on current parameters.

Working with Legacy devices

The Legacy 802.15.4 module (S1 hardware) transmits packets one by one. It does not transmit a packet until it receives all expected acknowledgments of the previous packet or the timeout expires.

The XBee/XBee-PRO S2C 802.15.4 and XBee3 802.15.4 RF Modules enhance transmission by implementing a transmission queue that allows the device to transmit to several devices at the same time. Broadcast transmissions are performed in parallel with the unicast transmissions.

This enhancement in the XBee/XBee-PRO S2C 802.15.4 and XBee3 802.15.4 RF Modules can produce problematic behavior under certain conditions if the receiver is a Legacy 802.15.4 module (S1 hardware).

The conditions are:

- The sender is a XBee3 802.15.4 RF Module, and the receiver is a Legacy 802.15.4 module.
- The sender has the Digi header enabled (**MM** = 0 or 3) and **RR** (XBee Retries) > 0.
- The sender sends broadcast and unicast messages at the same time to the Legacy 802.15.4 module without waiting for the transmission status of the previous packet.

The effect is:

- The receiver may display duplicate packets.

The solution is:

- Set bit 0 of the **C8** (802.15.4 compatibility) parameter to 1 to enable TX compatibility mode in the XBee3 802.15.4 RF Module. This eliminates the transmission queue to avoid sending to multiple addresses simultaneously. It also limits the packet size to the levels of the Legacy 802.15.4 module.

For information on the specific differences between an XBee3 and Legacy 802.15.4 devices, refer to the Digi XBee3 802.15.4 Migration Guide.

Networking

MAC Mode configuration

Medium Access Control (MAC) Mode configures two functions:

1. Enables or disables the use of a Digi header in the 802.15.4 RF packet.

   When the Digi header is enabled (**MM** = 0 or 3), duplicate packet detection is enabled as well as certain AT commands.

   MAC Modes 1 and 2 do not include a Digi header, which disables many features of the device. All data is strictly pass-through. These modes are intended to provide some compatibility with third-party 802.15.4 devices.

2. Enables or disables MAC acknowledgment request for unicast packets.

   When MAC ACK is enabled (**MM** = 0 or 2), transmitting devices send packets with an ACK request so receiving devices send an ACK back (acknowledgment of RF packet reception) to the transmitter. If the transmitting device does not receive the ACK, it re-sends the packet up to three times or until the ACK is received.

   MAC Modes 1 and 3 disable MAC acknowledgment. Transmitting devices send packets without an ACK request so receiving devices do not send an ACK back to the transmitter.

   Broadcast messages are always sent with the MAC ACK request disabled.

The following table summarizes the functionality.

Mode	Digi header	MAC ACK
0 (default)	X	X
1		
2		X
3	X	

The default value for the **MM** configuration parameter is 0 which enables both the Digi header and MAC acknowledgment.

XBee retries configuration

If you are operating in a MAC Mode that enables MAC ACK (**MM**=0 or **MM**=2), each RF packet will be sent with up to three 802.15.4 MAC-Layer retries. This is enabled by default and provides a minimal amount of reliability to unicast transmissions.

If you are operating in a MAC Mode that enables the Digi header (**MM**=0 or **MM**=3), then you can optionally include Application-Layer retries using the RR (XBee Retries) command. Each Application-Layer retry attempt to send the packet using three MAC-Layer retries. This can greatly increase the reliability of unicast transmissions with a risk of reduced throughput.

Transmit status based on MAC mode and XBee retries configurations

When working in API mode, a transmit request frame sent by the user is always answered with a transmit status frame sent by the device, if the frame ID is non-zero. A Frame ID of 0 specifies that the packet should be sent without an acknowledgment.

The following tables report the expected transmit status for unicast transmissions and the maximum number of MAC and application retries the device attempts.

The tables also report the transmit status reported when the device detects energy above the CCA threshold (when a CCA failure happens).

The following table applies in either of these cases:

- Digi header is disabled.
- Digi header is enabled and XBee Retries (**RR** parameter) is equal to 0 (default configuration).

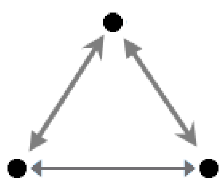
Mac ACK Config	Destination reachable			Destination unreachable			CCA failure happened		
	TX status	Retries		TX status	Retries		TX status	Retries	
		MAC	App		MAC	App		MAC	App
Enabled	00 (Success)	up to 3	0	01 (No acknowledgment received)	3	0	02 (CCA failure)	3	0
Disabled	00 (Success)	0	0	00 (Success)	0	0	02 (CCA failure)	3	0

The following table applies when:

- Digi header is enabled and XBee Retries (**RR** parameter) > 0.

Mac ACK Config	Destination reachable			Destination unreachable			CCA failure happened		
	TX status	Retries		TX status	Retries		TX status	Retries	
		MAC	App		MAC	App		MAC	App
Enabled	00 (Success)	up to 3 per app retry	up to **RR** value	21 (Network ACK Failure)	3	**RR** value	02 (CCA failure)	3	**RR** value
Disabled	00 (Success)	0	up to **RR** value	21 (Network ACK Failure)	0	**RR** value	02 (CCA failure)	3	**RR** value

Peer-to-peer networks



By default, XBee3 802.15.4 RF Modules are configured to operate within a peer-to-peer network topology and therefore are not dependent upon master/slave relationships. This means that devices remain synchronized without the use of master/server configurations and each device in the network shares both roles of master and slave. Our peer-to-peer architecture features fast synchronization times and fast cold start times. This default configuration accommodates a wide range of RF data applications.

Clear Channel Assessment (CCA)

Prior to transmitting a packet, the device performs a CCA (Clear Channel Assessment) on the channel to determine if the channel is available for transmission. The detected energy on the channel is compared with the **CA** (Clear Channel Assessment) parameter value. If the detected energy exceeds the **CA** parameter value, the device does not transmit the packet.

Also, the device inserts a delay before a transmission takes place. You can set this delay using the **RN** (Backoff Exponent) parameter. If you set **RN** to 0, there is no delay before the first CCA is performed. The **RN** parameter value is the equivalent of the “minBE” parameter in the 802.15.4 specification. The transmit sequence follows the 802.15.4 specification.

By default, the **MM** (MAC Mode) parameter = 0. On a CCA failure, the device attempts to re-send the packet up to two additional times.

When in Unicast packets with **RR** (Retries) = 0, the device executes two CCA retries. Broadcast packets always get two CCA retries.

Note Customers in Europe who have the XBee 802.15.4 module must manage their CCA settings. See CA (CCA Threshold) for **CA** values.

CCA operations

CCA is a method of collision avoidance that is implemented by detecting the energy level on the transmission channel before starting the transmission. The CCA threshold (defined by the **CA** parameter) defines the energy level that it takes to block a transmission attempt. For example, if CCA is set to the default value of 0x41 (which is interpreted as -65 dBm) then energy detected above the -65 dBm level (for example -60 dBm) temporarily blocks a transmission attempt. But if the energy level is less than that (for example -70 dBm), the transmission is not blocked. The intent of this feature is to prevent simultaneous transmissions on the same channel.

You can disable CCA by setting **CA** to 0. Disabling CCA can improve latency in noisy environments, but it can also interfere with other devices that are operating on the same channel.

In the event that the energy level exceeds the threshold, the transmission is blocked for a random number of backoff periods. The number of backoff periods is defined by the following formula: random (2^n - 1), where *n* is defined by the **RN** parameter and increments after each CCA failure. When **RN** is set to its default value of 0, then 2^n -1 is 0, preventing any delay before the first energy detection on a new frame. However, n increments after each CCA failure, giving a greater range for the number of backoff periods between each energy detection cycle.

In the event that five energy detection cycles occur and each one detects too much energy, the application tries again 1 to 48 ms later. After the application retries are exhausted, then the transmission fails with a CCA error.

Whenever the MAC code reports a CCA failure, meaning that it performed five energy detection cycles with exponential random back-offs, and each one failed, the **EC** parameter is incremented. The **EC** parameter can be read at any time to find out how noisy the operating channel is. It continues to increment until it reaches its maximum value of 0xFFFF. To get new statistics, you can set **EC** back to 0.

Serial interface

The XBee3 802.15.4 RF Module interfaces to a host device through a serial port. The device can communicate through its serial port with:

- Through logic and voltage compatible universal asynchronous receiver/transmitter (UART).
- Through a level translator to any serial device, for example, through an RS-232 or USB interface board.

Serial receive buffer

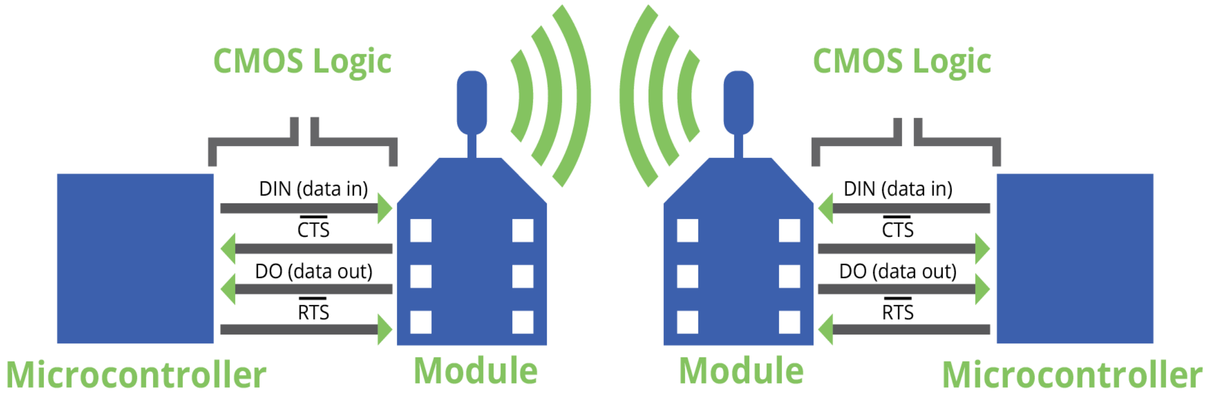
When serial data enters the device through the DIN pin, it stores the data in the serial receive buffer until the device can process it. Under certain conditions, the device may not be able to process data in the serial receive buffer immediately. If large amounts of serial data are sent to the device such that the serial receive buffer would overflow, then it discards new data. If the UART is in use, you can avoid this by the host side by honoring CTS flow control.

Serial transmit buffer

When the device receives RF data, it moves the data into the serial transmit buffer and sends it out the UART. If the serial transmit buffer becomes full and the system buffers are also full, then it drops the entire RF data packet. Whenever the device receives data faster than it can process and transmit the data out the serial port, there is a potential of dropping data.

UART data flow

Devices that have a UART interface connect directly to the pins of the XBee3 802.15.4 RF Module as shown in the following figure. The figure shows system data flow in a UART-interfaced environment. Low-asserted signals have a horizontal line over the signal name.

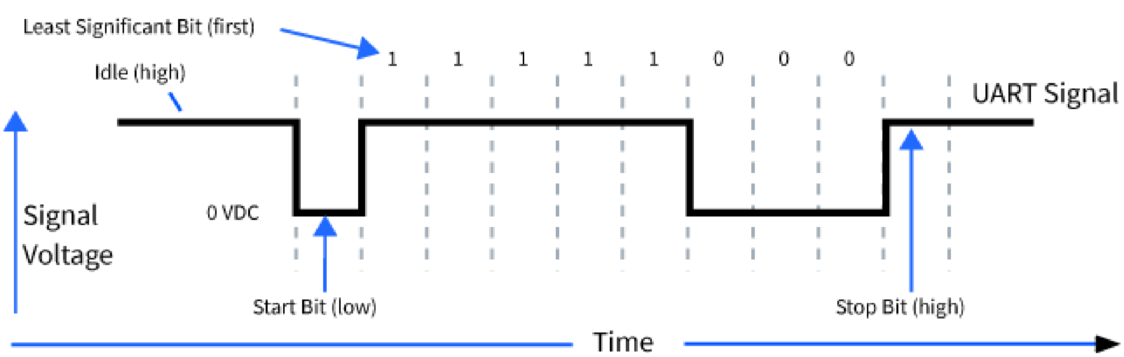


Serial data

A device sends data to the XBee3 802.15.4 RF Module's UART as an asynchronous serial signal. When the device is not transmitting data, the signals should idle high.

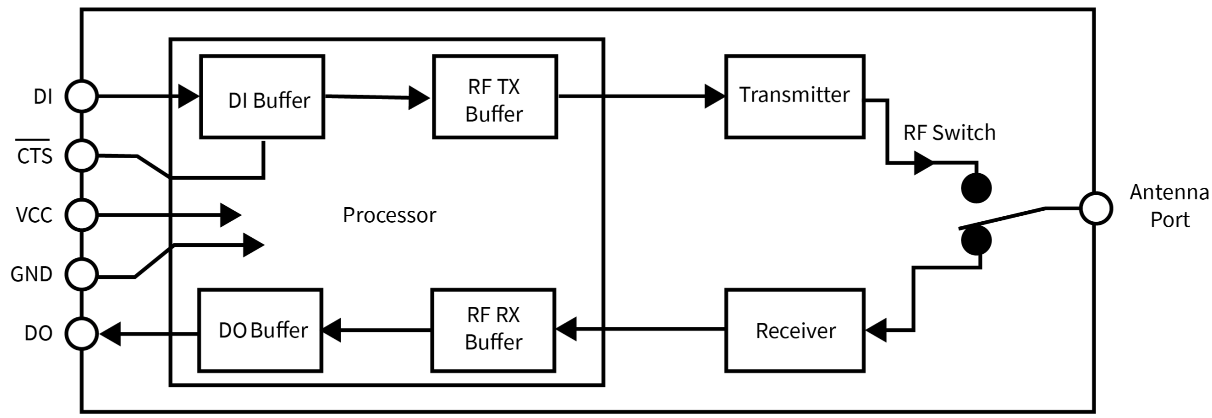
For serial communication to occur, you must configure the UART of both devices (the microcontroller and the XBee3 802.15.4 RF Module) with compatible settings for the baud rate, parity, start bits, stop bits, and data bits.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following diagram illustrates the serial bit pattern of data passing through the device. The diagram shows UART data packet 0x1F (decimal number 31) as transmitted through the device.



Flow control

The XBee3 802.15.4 RF Module maintains buffers to collect serial and RF data that it receives. The serial receive buffer collects incoming serial characters and holds them until the device can process them. The serial transmit buffer collects the data it receives via the RF link until it transmits that data out the serial port. The following figure shows the process of device buffers collecting received serial data.



CTS flow control

If you enable CTS flow control (D7 command), when the serial receive buffer is 17 bytes away from being full, the device de-asserts CTS (sets it high) to signal to the host device to stop sending serial data. The device reasserts CTS after the serial receive buffer has 34 bytes of space. See FT command for the buffer size.

In either case, CTS is not re-asserted until the serial receive buffer has **FT**-17 or less bytes in use.

RTS flow control

If you send the **D6** command to enable RTS flow control, the device does not send data in the serial transmit buffer out the DOUT pin as long as RTS is de-asserted (set high). Do not de-assert RTS for long periods of time or the serial transmit buffer will fill. If the device receives an RF data packet and the serial transmit buffer does not have enough space for all of the data bytes, it discards the entire RF data packet.

If the device sends data out the UART when RTS is de-asserted (set high) the device could send up to five characters out the UART port after RTS is de-asserted.

Cases in which the DO buffer may become full, resulting in dropped RF packets:

1. If the RF data rate is set higher than the interface data rate of the device, the device may receive data faster than it can send the data to the host. Even occasional transmissions from a large number of devices can quickly accumulate and overflow the transmit buffer.
2. If the host does not allow the device to transmit data out from the serial transmit buffer due to being held off by hardware flow control.

Asynchronous Parameters

Asynchronous communication over a UART is configured with a start bit, data bits, parity, stop bits, and baud rate. Out of these, only parity, number of stop bits, and baud rate are configurable on the device. This means that the connecting micro-controller must match the start bits (1), the data bits (8), and the stop bits (1) of the device for proper communication.

Baud rate

Use the **BD** command to configure standard and non-standard baud rates. For more information, see BD (Interface Data Rate).

Parity

Use the **NB** command to configure parity; see NB (Parity).

Stop bits

Use the **SB** command to configure the number of stop bits (1 or 2); see SB (Stop Bits).

Sleep support

This section provides information about sleep support.

Sleep modes

Sleep modes enable the device to enter states of low-power consumption when not in use. To enter Sleep mode, the following conditions must be met (in addition to the device having a non-zero **SM** parameter value):

- SLEEP_RQ/DTR is configured as a peripheral (**D8** = 1) and is asserted.
- A valid sleep mode is selected via the **SM** command.

The following table shows the sleep mode configurations.

Sleep mode	Description
SM 0	No sleep
SM 1	Pin sleep

Pin Sleep mode (SM = 1)

Pin Sleep mode minimizes quiescent power (power consumed when in a state of rest or inactivity). This mode is voltage level-activated; when SLEEP_RQ (TH pin 9/SMT pin 10) is enabled and asserted, the device finishes any transmit, receive or association activities, enters Idle mode, and then enters a state of sleep. The device does not respond to either serial or RF activity while in pin sleep. To enter pin sleep, the SLEEP_RQ/DTR line must be configured as a peripheral (**D8** =1).

To wake a sleeping device operating in Pin Sleep mode, de-assert SLEEP_RQ. The device wakes when SLEEP_RQ is de-asserted and is ready to transmit or receive when the $\overline{\text{CTS}}$ line is low. When waking the device, the pin must be de-asserted at least two 'byte times' after CTS goes low. This assures that there is time for the data to enter the DI buffer.

Sleep parameters

See the SM (Sleep Mode) for the parameter's description, range and default values.

Sleep current

The following table shows the sleep current during the XBee3 802.15.4 RF Module sleep modes.

Sleep mode	SM command setting	Sleep current
Pin sleep	1	<2 µA @ 25°C

The sleep pins are set up for sleeping as specified in the following section, Sleep pins. Additionally, pins that are outputs (other than PWM outputs) continue to output the same levels during sleep. Normally, this means that pins configured for output high or low will output high or low accordingly. However, if I/O line passing overrides the output, the output level is maintained during the sleep time.

Sleep pins

The following table describes the three external device pins associated with sleep.

Pin name	Description
DTR/SLEEP_RQ	For **SM** = 1, high puts the device to sleep and low wakes it up.
$\overline{\text{CTS}}$	If **D7** = 1, high indicates that the device is asleep and low indicates that it is awake and ready to receive serial data.
ON_$\overline{\text{SLEEP}}$	Low indicates that the device is asleep and high indicates that it is awake.

Node discovery

Node discovery has three variations as shown in the following table:

Commands	Syntax	Description
Node Discovery	**ND**	Seeks to discover all nodes in the network (on the current PAN ID).
Directed Node Discovery	**ND** <NI String>	Seeks to discover if a particular node named <NI String> is found in the network.
Destination Node	**DN** <NI String>	Sets **DH**/**DL** to point to the MAC address of the node whose <NI String> matches.

The node discovery command (without an **NI** string designated) sends out a broadcast to every node in the PAN ID. Each node in the PAN sends a response back to the requesting node after a jittered time delay to ensure reliable delivery.

Remote configuration commands

The API firmware has provisions to send configuration commands to remote devices using the Remote AT Command Request frame (0x17); see Remote AT Command Request frame - 0x17. You can use this frame to send commands to a remote device to read or set command parameters.

CAUTION! It is important to set the short address to 0xFFFE when sending to a long address. Any other value causes the long address to be ignored. This is particularly problematic in the case where nodes are set up with default addresses of 0 and the 16-bit address is erroneously left at 0. In that case, even with a correct long address the remote command goes out to all devices with the default short address of 0, potentially resulting in harmful consequences, depending on the command.

Send a remote command

To send a remote command populate the Remote AT Command Request frame (0x17) with:

1. The 64-bit address of the remote device.
2. The correct command options value.

3. The command and parameter data (optional). If (and *only* if) all nodes in the PAN have unique short addresses, then remote configuration commands can be sent to 16-bit short addresses by setting the short address in the API frame for Remote AT commands. In that case, the 64-bit address is unused and does not matter.

Apply changes on remote devices

Any changes you make to the configuration command registers using AT commands do not take effect until you apply the changes. For example, if you send the **BD** command to change the baud rate, the actual baud rate does not change until you apply the changes. To apply changes:

1. Set the Apply Changes option bit in the Remote AT Command Request frame (0x17).
2. Issue an **AC** (Apply Changes) command to the remote device.
3. Issue a **WR** + **FR** command to the remote device to save changes and reset the device.

Remote command responses

If the remote device receives a Remote AT Command Request (0x17 frame type), the remote sends an AT Command Response (0x88 frame type) back to the device that sent the remote command. The AT command response indicates the status of the command (success, or reason for failure), and in the case of a command query, it includes the parameter value.

The device that sends a remote command will not receive a remote command response frame if the frame ID in the remote command request is set to 0 , indicating that the request is sent without acknowledgment.

AT commands

Network commands

This section lists the AT commands that are used during a form and join attempt.

ID (Extended PAN ID)

Set or read the user network identifier.

Devices must have the same network identifier to communicate with each other.

Devices can only communicate with other devices that have the same network identifier and channel configured.

Setting **ID** to **0xFFFF** indicates a global transmission for all PANs. It does not indicate a global receive.

Parameter range

0 - 0xFFFF

Default

0x3332

C8 (802.15.4 Compatibility)

Sets or displays the operational compatibility with the Legacy 802.15.4 module (S1 hardware). This parameter should only be set when operating in a mixed network that contains XBee Series 1 modules.

Parameter range

0 - 3

Bit field:

Bit	Meaning	Setting	Description
0[1]	TX compatibility	0	Transmissions are optimized as follows: 1. Maximum transmission size is affected by multiple factors (**MM**, **MY**, **DH**, **DL**, and **EE**). See Maximum payload rules. In the best case, with no app header, short source and destination addresses, and no encryption, the maximum transmission size is 116 bytes. 2. Multiple messages can be present simultaneously on the active queue, providing they are all destined for different addresses. This improves performance.
		1	Transmissions operate like the Legacy 802.15.4 module, which means the following: 1. Maximum transmission size is 95 bytes for encrypted packets and 100 bytes for un-encrypted packets. These maximum transmission sizes are not adjusted upward for short addresses or for lack of an APP header. 2. Only one transmission message can be active at a time, even if other messages in the queue would go to a different destination address.
1	Node Discovery compatibility	0	Node discovery operates like other XBee devices and not like the Legacy 802.15.4 module. This means the following: 1. A directed **ND** request terminates after the single response arrives. This allows the device to process other commands without waiting for the **NT** to time out. 2. The device outputs an error response to the directed **ND** request if no response occurs within the time out.
		1	The module operates like the Legacy 802.15.4 module, which has the following effect: 1. When the expected response arrives, the command remains active until **NT** times out. (**NT** defaults to 2.5 seconds.) This prevents the device from processing any other AT command, even if the desired response occurs immediately. 2. When the timeout occurs, the command silently terminates and indicates success, whether or not a response occurred within the **NT** timeout.

[1] This bit does not typically need to be set. However, when the XBee3 802.15.4 RF Module is streaming broadcasts in transparent mode to a Legacy 802.15.4 module (S1 hardware), and **RR** > 0, set this bit to avoid a watchdog reset on the Legacy 802.15.4 module.

Default

0

NI (Node Identifier)

Stores the node identifier string for a device, which is a user-defined name or description of the device. This can be up to 20 ASCII characters.

Parameter range

A string of case-sensitive ASCII printable characters from 0 to 20 bytes in length. A carriage return or a comma automatically ends the command.

Default

0x20 (an ASCII space character)

NT (Node Discover Timeout)

Sets or displays the amount of time a base node waits for responses from other nodes when using the **ND** (Node Discover) command. The **NT** value is transmitted with the **ND** command; remote nodes set up a random hold-off time based on this time.

Sets or displays the network discovery back-off parameter for a device. This sets the maximum value for the random delay that the device uses to send network discovery responses.

Parameter range

0x1 - 0xFC (x 100 ms)

Default

0x19 (2.5 decimal seconds)

ND (Network Discover)

This command reports the following information after a jittered time delay.

Node discover response when issued in Command mode:

16-bit Short Address (**MY** command)<CR>

Upper portion of the Long 64-bit Address (**SH** command)<CR>

Lower portion of the Long 64-bit Address (**SL** command)<CR>

Signal Strength in -dBm (**DB** command)<CR>

Node Identifier String (**NI** command)<CR>

<CR> (This is part of the response and not the end of command indicator.)

A second carriage return indicates the network discovery timeout (**NT**) has expired.

When operating in API mode and a Network Discovery is issued as a 0x08 or 0x09 frame, the response contains binary data except for the NI string in the following format:

2 bytes for Short Source Address

4 bytes for Upper Long Address

4 bytes for Lower Long Address

1 byte for the signal strength in -dBm (two's complement representation)

NULL-terminated string for NI (Node Identifier) value (maximum 20 bytes without NULL terminator)

Each device that responds to the request will generate a separate AT Command Response frame - 0x88.

Broadcast an **ND** command to the network. If the command includes an optional node identifier string parameter, only those devices with a matching **NI** string respond without a random offset delay. If the command does not include a node identifier string parameter, all devices respond with a random offset delay.

The **NT** setting determines the maximum timeout (13 seconds by default), this value is sent along with the discovery broadcast and determines the random delay the remote nodes use to prevent the responses from colliding.

For more information about the options that affect the behavior of the **ND** command, see NO (Node Discovery Options).

WARNING! If the **NT** setting is small relative to the number of devices on the network, responses may be lost due to channel congestion. Regardless of the **NT** setting, because the random offset only mitigates transmission collisions, getting responses from all devices in the network is not guaranteed.

Parameter range

20-byte printable ASCII string

Default

N/A

NO (Node Discovery Options)

Use **NO** to suppress or include a self-response to **ND** (Node Discover) commands. When **NO** bit 1 is set, a device performing a Node Discover includes a response entry for itself.

Parameter range

0 - 1

Default

0x0

NP (Maximum Packet Payload Bytes)

Reads the maximum number of RF payload bytes that you can send in a transmission.

Note **NP** returns a hexadecimal value. For example, if **NP** returns 0x54, this is equivalent to 84 bytes.

Parameter range

[read-only]

Default

N/A

Addressing commands

SH (Serial Number High)

Displays the upper 32 bits of the unique IEEE 64-bit extended address assigned to the XBee in the factory.

The 64-bit source address is always enabled. This value is read-only and it never changes.

Parameter range

0x0013A200 - 0x0013A2FF [read-only]

Default

Set in the factory

SL (Serial Number Low)

Displays the lower 32 bits of the unique IEEE 64-bit RF extended address assigned to the XBee in the factory.

The device's serial number is set at the factory and is read-only.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

MY (16-bit Source Address)

Sets or displays the device's 16-bit source address. Set **MY** = 0xFFFF to disable reception of packets with 16-bit addresses. Regardless of **MY**, messages addressed to the 64-bit long address of the device are always delivered.

Parameter range

0 - 0xFFFF

Default

0

DH (Destination Address High)

Set or read the upper 32 bits of the 64-bit destination address. When you combine **DH** with **DL**, it defines the destination address that the device uses for transmissions in Transparent mode.

To transmit using a 16-bit address, set **DH** to 0 and **DL** less than 0xFFFF.

0x000000000000FFFF is the broadcast address.

Parameter range

0 - 0xFFFFFFFF

Default

0

DL (Destination Address Low)

Set or display the lower 32 bits of the 64-bit destination address. When you combine **DH** with **DL**, it defines the destination address that the device uses for transmissions in Transparent mode.

0x000000000000FFFF is the broadcast address.

Parameter range

0 - 0xFFFFFFFF

Default

0

RR (XBee Retries)

Set or reads the number of application-layer retries the device executes. Application-layer retries are only enabled if a Digi header is present via the **MM** command.

Every transmitted unicast transmission utilizes up to three MAC-Layer retries (if enabled via the **MM** command). If **RR** > 0, a failed unicast transmission will be attempted **RR** times (each application-layer retry will exhaust the three MAC-layer retries).

When transmitting a broadcast message, if **RR** = 0, only one packet is broadcast. If **RR** is > 0, then **RR** + 2 packets are sent on each broadcast. No acknowledgments are returned on a broadcast.

The **RR** value does not need to be set on all devices for retries to work. If retries are enabled, the transmitting device sets a bit in the Digi RF Packet header that requests the receiving device to send an ACK. If the transmitting device does not receive an ACK within 200 ms, it re-sends the packet within a random period up to 48 ms. Each device retry can potentially result in the MAC sending the packet four times (one try plus three retries).

Parameter range

0 - 6

Default

0

TO (Transmit Options)

Set/read transmit options for Transparent mode.

Bit	Meaning
0	Disable MAC ACKs.
2	Send to broadcast PAN ID.

Parameter range

0 - 5

Default

0

MM (MAC Mode)

Use the **MM** command to specify the operating MAC Mode.

The MAC Mode serves two purposes:

- Enable/disable the use of a Digi header, which enables advanced features.
- Enable/disable MAC-Layer acknowledgments.

The default configuration enables a Digi-specific header to every RF packet. This header includes information that allows for some advanced features:

- Network discovery support
- Application-layer retries
- Duplicate packet detection
- Remote AT command support

The presence of the Digi header prevents interoperability with third-party devices. When the Digi header is disabled, encrypted data that is not valid is sent out of the UART and not filtered out. The Digi header can be disabled by setting **MM** to **1** or **2**.

When **MM** is set **1** or **3**, MAC-layer retries are disabled.

Parameter range

0 - 3

Parameter	Configuration	ACKs
0	Digi mode	With ACKs
1	802.15.4	No ACKs
2	802.15.4	With ACKs
3	Digi mode	No ACKs

Default

0

DD (Device Type Identifier)

Stores the Digi device type identifier value. Use this value to differentiate between multiple types of devices.

If you change **DD**, RE (Restore Defaults) will not restore defaults. The only way to get **DD** back to default values is to explicitly set it to defaults.

Parameter range

0 - 0xFFFFFFFF

Default

0x120000

Note 0x120000 denotes Digi XBee3 hardware.

RF interfacing commands

The following AT commands affect the RF interface of the device.

PL (TX Power Level)

Sets or displays the power level at which the device transmits conducted power.

Note If operating on channel 26 (**CH** = 0x1A), output power will be capped and cannot exceed 8 dBm regardless of the **PL** setting.

Parameter range

0 - 4

The following table shows the TX power versus the **PL** setting.

PL setting	XBee3 TX power	XBee3-PRO TX power
4	8 dBm	19 dBm
3	5 dBm	15 dBm
2	2 dBm	8 dBm
1	-1 dBm	3 dBm
0	-5 dBm	-5 dBm

Default

4

PP (Output Power in dBm)

Display the operating output power based on the current configuration (Channel and **PL** setting). The values returned are in dBm, and negative values are represented in two's complement; for example, -5 dBm = 0xFB.

Parameter range

0 - 0xFF [read-only]

Default

N/A

CH (Operating Channel)

Set or read the operating channel devices used to transmit and receive data.

In order for devices to communicate with each other, they must share the same channel number. A network can use different channels to prevent devices in one network from listening to the transmissions of another.

The command uses 802.15.4 channel numbers.

Parameter range

0xB - 0x1A

Default

0xC (IEEE 802.15.4 channel 12)

CA (CCA Threshold)

Defines the Clear Channel Assessment (CCA) threshold. Prior to transmitting a packet, the device performs a CCA to detect energy on the channel. If the device detects energy above the CCA threshold, it will not transmit the packet.

The **CA** parameter is measured in units of -dBm. The CCA threshold is set upon device initialization, any change to the CCA threshold must be written to flash with the **WR** command and the module reset (power cycle or **FR** command) before the new threshold is observed.

You can set **CA** to 0 to disable CCA; this can improve latency but may cause interference with other 2.4GHz devices when transmitting. You can disable and enable CCA at runtime, which does not require a power cycle.

Note If you are deploying an XBee3-PRO 802.15.4 device in Europe and EIRP output power exceeds 10dBm, an adequate CCA threshold must be set to meet compliance requirements. Refer to EN 300 328 Listen Before Talk requirements for information on how to calculate a proper CCA threshold based on power level and antenna choice.

Parameter range

0, 0x28 - 0x64

Default

0x41 (-65 decimal dBm)

RN (Random Delay Slots)

Defines the minimum value of the back-off exponent in the CSMA-CA algorithm. The Carrier Sense Multiple Access - Collision Avoidance (CSMA-CA) algorithm was engineered for collision avoidance (random delays are inserted to prevent data loss caused by data collisions.

If **RN** = 0, there is no delay between a request to transmit and the first iteration of CSMA-CA.

Unlike CSMA-CD, which reacts to network transmissions after collisions have been detected, CSMA-CA acts to prevent data collisions before they occur. As soon as a device receives a packet that is to be transmitted, it checks if the channel is clear (no other device is transmitting). If the channel is clear, the packet is sent over-the-air. If the channel is not clear, the device waits for a randomly selected period of time, then checks again to see if the channel is clear. After a time, the process ends and the data is lost.

Parameter range

0 - 5 (exponent)

Default

0

DB (Last Packet RSSI)

Reports the RSSI in -dBm of the last received RF data packet. **DB** returns a hexadecimal value for the -dBm measurement.

For example, if **DB** returns 0x60, then the RSSI of the last packet received was -96 dBm.

If the XBee3 802.15.4 RF Module has been reset and has not yet received a packet, **DB** reports **0**.

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFF [read-only]

Default

N/A

UART serial interfacing

The following AT commands configure the UART interface on the device.

BD (Interface Data Rate)

This command configures the serial interface baud rate for communication between the UART port of the device and the host. Standard baud rates can be set using a parameter value of 0 - 8.

Non-standard interface data rates

The firmware interprets any value from 0x4B0 through 0x3D090 as an actual baud rate. When the firmware cannot configure the exact rate specified, it configures the closest approximation to that rate. For example, to set a rate of 57600 b/s send the following command line: **ATBDE100**. Then, to find out the closest approximation, send **ATBD** to the console window. It sends back a response of 0xE0D1, which is the closest approximation to 57600 b/s attainable by the hardware.

Note When using XCTU, you can only set and read non-standard interface data rates using the XCTU **Terminal** tab. You cannot access non-standard rates through the **Modem Configuration** tab.

The following table provides some example **BD** parameters sent versus the parameters stored.

BD parameter sent (HEX)	Interface data rate (b/s)	BD parameter stored (HEX)
0	1200 (standard)	0
4	19,200 (standard)	4
7	115,200 (standard)	7
E100	57,600	E0D1
1C200	115,200	1C2B8

Parameter range

Standard baud rates: 0 - 8

Non-standard baud rates: 0x12C - 0x0EC400

Parameter	Description
0	1200 b/s
1	2400 b/s

Parameter	Description
2	4800 b/s
3	9600 b/s
4	19200 b/s
5	38400 b/s
6	57600 b/s
7	115200 b/s
8	230400 b/s

Default

3 (9600 baud)

NB (Parity)

Set or read the serial parity settings for UART communications.

The device does not actually calculate and check the parity. It only interfaces with devices at the configured parity and stop bit settings for serial error detection.

Parameter range

0 - 2

Parameter	Description
0	No parity
1	Even parity
2	Odd parity

Default

0

SB (Stop Bits)

Sets or displays the number of stop bits for UART communications.

Parameter range

0 - 1

Parameter	Configuration
0	One stop bit
1	Two stop bits

Default

0

AP (API Enable)

Set or read the API mode setting. The device can format the RF packets it receives into API frames and sends them out the serial port.

When you enable API, you must format the serial data as API frames because Transparent operating mode is disabled.

Parameter range

0 - 2

Parameter	Description
0	API disabled (operate in Transparent mode)
1	API enabled
2	API enabled (with escaped control characters)

Default

0

RO (Packetization Timeout)

Set or read the number of character times of inter-character silence required before transmission begins when operating in Transparent mode.

Set **RO** to 0 to transmit characters as they arrive instead of buffering them into one RF packet.

The **RO** command is only supported when operating in Transparent mode.

Parameter range

0 - 0xFF (x character times)

Default

3

FT command

Set or display the flow control threshold.

The device de-asserts $\overline{\text{CTS}}$ when **FT** bytes are in the UART receive buffer. It re-asserts $\overline{\text{CTS}}$ when less than **FT**-16 bytes are in the UART receive buffer.

Parameter range

0x0C - 0xA2 bytes

Default

0x81

D6 (DIO6/RTS)

Sets or displays the DIO6/RTS configuration (Micro pin 27/SMT pin 29).

Parameter range

0, 1, 4 - 5

Parameter	Description
0	Disabled
1	RTS flow control
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

D7 (DIO7/CTS)

Sets or displays the DIO7/CTS configuration (Micro pin 24/SMT pin 25).

Parameter range

0, 1, 4 - 5

Parameter	Description
0	Disabled
1	CTS flow control
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

Command mode options

The following commands are Command mode option commands.

CN (Exit Command mode)

Executable command. This command immediately exits Command mode and applies pending changes.

Parameter range

N/A

Default

N/A

CT (Command Mode Timeout)

Sets or displays the Command mode timeout parameter. If a device does not receive any valid commands within this time period, it returns to Idle mode from Command mode.

Parameter range

2 - 0x1770 (x 100 ms)

Default

0x64 (10 seconds)

GT (Guard Times)

Set the required period of silence before and after the command sequence characters of the Command mode sequence, **GT** + **CC** + **GT** (including spaces). The period of silence prevents inadvertently entering Command mode. For more information, see Enter Command mode.

Parameter range

0x2 - 0x6D3 (x 1 ms)

Default

0x3E8 (one second)

CC (Command Character)

The character value the device uses to enter Command mode.

The default value (**0x2B**) is the ASCII code for the plus (**+**) character. You must enter it three times within the guard time to enter Command mode. To enter Command mode, there is also a required period of silence before and after the command sequence characters of the Command mode sequence (**GT** + **CC** + **GT**). The period of silence prevents inadvertently entering Command mode. For more information, see Enter Command mode.

Parameter range

0 - 0xFF

Default

0x2B (the ASCII plus character: **+**)

Sleep settings

The following AT commands are sleep commands.

SM (Sleep Mode)

Sets or displays the sleep mode of the device.

By default, Sleep Modes are disabled (**SM** = 0) and the device remains in Idle/Receive mode. When in this state, the device is constantly ready to respond to either serial or RF activity.

When operating in Pin Sleep (**SM** = 1), **D8** must be set as a peripheral (**D8**=1) in order for the device to sleep.

Parameter range

0 - 1

Parameter	Description
0	No sleep (disabled)
1	Pin sleep

Default

0

D8 (DIO8/DTR/SLP_RQ)

Sets or displays the DIO8/$\overline{\text{DTR}}$/SLP_RQ configuration (Micro pin 9/SMT pin 10).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	$\overline{\text{DTR}}$/Sleep_Request (used with pin sleep)
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

D9 (DIO9/ON_SLEEP)

Sets or displays the DIO9/ON_$\overline{\text{SLEEP}}$ configuration (Micro pin 25/SMT pin 26).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	ON/$\overline{\text{SLEEP}}$ output
3	NA
4	Digital output, low
5	Digital output, high

Default

1

I/O settings commands

The following AT commands are I/O settings commands.

D0 (DIO0 Configuration)

Sets or displays the DIO0 (Micro pin 31/SMT pin 33).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

D1 (DIO1 Configuration)

Sets or displays the DIO1 configuration (Micro pin 30/SMT pin 32).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

D2 (DIO2 Configuration)

Sets or displays the DIO2 configuration (Micro pin 29/SMT pin 31).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

D3 (DIO3 Configuration)

Sets or displays the DIO3 configuration (Micro pin 28/SMT pin 30).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A

Parameter	Description
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

D4 (DIO4 Configuration)

Sets or displays the DIO4 configuration (Micro pin 23/SMT pin 24).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

D5 (DIO5/Associate Configuration)

Sets or displays the DIO5 configuration (Micro pin 26/SMT pin 28).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	Associate LED indicator
2	N/A
3	N/A

Parameter	Description
4	Digital output, default low
5	Digital output, default high

Default

1

P0 (DIO10/PWM0 Configuration

Sets or displays the DIO10/RSSI configuration (Micro pin 7/SMT pin 7).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	RSSI PWM output
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

P1 (DIO11 Configuration)

Sets or displays the DIO11 configuration (Micro pin 8/SMT pin 8).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

P5 (DIO15 Configuration)

Sets or displays the DIO15 configuration (Micro pin 16/SMT pin 17).

Parameter range

0, 4, 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

0

PR (Pull-up/Down Resistor Enable)

The bit field that configures the internal pull-up/down resistor status for the I/O lines.

- If you set a **PR** bit to 1, it enables the pull-up/down resistor
- If you set a **PR** bit to 0, it specifies no internal pull-up/down resistor.

The **PD** (Pull Direction) parameter determines the direction of the internal pull-up/down resistor.

PR and **PD** only affect lines that are configured as digital inputs or disabled.

By default, pull-up resistors are enabled on all disabled I/O lines.

The following table defines the bit-field map for **PR** and **PD** commands.

Bit	I/O line
0	DIO4
1	DIO3
2	DIO2
3	DIO1
4	DIO0
5	DIO6/$\overline{\text{RTS}}$
6	DIO8/DTR/Sleep_Rq

Bit	I/O line
7	UART_DIN
8	DIO5/Associate
9	DIO9/Awake_nSleep
10	DIO12
11	DIO10/PWM-RSSI
12	DIO11
13	DIO7/$\overline{\text{CTS}}$
14	UART_DOUT
15	DIO15
16	N/A
17	N/A
18	N/A
19	N/A

Parameter range

0 - 0xFFFFF (bit field)

Default

0xFFFF

Example

Sending the command ATPR 6F turn bits 0, 1, 2, 3, 5 and 6 ON, and bits 4 and 7 OFF. The binary equivalent of 0x6F is 01101111. Bit 0 is the right-most digit in the binary bit field.

PD (Pull Up/Down Direction)

See PR (Pull-up/Down Resistor Enable) for the bit mappings.

Parameter range

0 - 0xFFFFF (bit field)

Default

0xFFFF

LT command

Set or read the Associate LED blink time. If you use D5 (DIO5/Associate Configuration) to enable the Associate LED functionality (DIO5/Associate pin), this value determines the on and off blink times for the LED when the device has joined the network.

If **LT = 0**, the device uses the default blink rate: 500 ms for a sleep coordinator, 250 ms for all other nodes.

If **LT** = **0**, the device uses the default blink rate of 250 ms.

Parameter range

0xA - 0xFF

Default

0

Diagnostic commands

The following AT commands are diagnostic commands.

AI (Association Indication)

Reads the Association status code to monitor association progress.

The following table provides the status codes and their meanings.

Status code	Meaning
0x00	Operating in peer to peer mode where no association is needed.
0xFF	Initialization time; no association status has been determined yet.

Parameter range

0 - 0xFF [read-only]

Default

N/A

EA (ACK Failures)

Resets or displays the count of acknowledgment failures. This value increments when the device expires the retries without receiving an ACK on a packet transmission. This count saturates at its maximum value. Set **EA** to zero to reset the count.

Parameter range

0 - 0xFFFF

Default

N/A

EC (CCA Failures)

Resets or displays the count of Clear Channel Assessment (CCA) failures. This value increments when the device does not transmit a packet because it detected energy above the CCA threshold level set with **CA** command. This count saturates at its maximum value. Set **EC** to zero to reset the count.

Parameter range

0 - 0xFFFF

Default

N/A

VR (Firmware Version)

Reads the firmware version on a device.

Parameter range

0x2000 - 0x2FFF

Default

Set in the firmware

VL (Version Long)

Shows detailed version information including the application build date and time.

Parameter range

N/A

Default

N/A

VH command

Reads the bootloader version of the device.

Range

N/A

Default

N/A

HV (Hardware Version)

Display the hardware version number of the device.

Parameter range

0 - 0xFFFF [read-only]

Default

Set in firmware

%V command

Reads the voltage on the Vcc pin in mV.

Parameter range

0 - 0xFFFF (in mV) [read only]

Default

N/A

TP command

The current module temperature in degrees Celsius. The temperature is represented in two's complement, as shown in the following example:

1 °C = 0x0001 and -1°C = 0xFFFF

Parameter range

0 - 0xFFFF (Celsius)

Default

N/A

CK (Configuration CRC)

Reads the cyclic redundancy check (CRC) of the current AT command configuration settings to determine if the configuration has changed.

After a firmware update this command may return a different value.

Parameter range

0 - 0xFFFF

Default

N/A

FR (Software Reset)

Resets the device. The device responds immediately with an **OK** and performs a reset 100 ms later.

If you issue **FR** while the device is in Command mode, the reset effectively exits Command mode.

Parameter range

N/A

Default

N/A

Memory access commands

This section details the executable commands that provide memory access to the device.

AC (Apply Changes)

This command applies changes to all command parameters configured in Command mode.

Any of the following also applies changes the same as issuing an **AC** command:

- Exiting Command mode with a **CN** command.
- Exiting Command mode via timeout.
- Receiving a 0x08 API command frame.

- Issuing a 0x08 Local AT Command API frame.
- Issuing a remote 0x17 AT Command API frame with option bit 1 set.

Example: Altering the UART baud rate with the **BD** command does not change the operating baud rate until after an **AC** command is received; at this point, the interface immediately changes baud rates.

Parameter range

N/A

Default

N/A

WR (Write)

Immediately writes parameter values to non-volatile flash memory so they persist through a power cycle. Operating network parameters are persistent and do not require a **WR** command for the device to reattach to the network.

Note Once you issue a **WR** command, do not send any additional characters to the device until after you receive the **OK** response. Use the **WR** command sparingly; the device's flash supports a limited number of write cycles.

Parameter range

N/A

Default

N/A

RE (Restore Defaults)

Restore device parameters to factory defaults.

Does not exit out of Command mode.

Parameter range

N/A

Default

N/A

Operate in API mode

API mode overview

As an alternative to Transparent operating mode, you can use API operating mode. API mode provides a structured interface where data is communicated through the serial interface in organized packets and in a determined order. This enables you to establish complex communication between devices without having to define your own protocol. The API specifies how commands, command responses and device status messages are sent and received from the device using the serial interface or the SPI interface.

We may add new frame types to future versions of the firmware, so we recommend building the ability to filter out additional API frames with unknown frame types into your software interface.

API frame specifications

The firmware supports two API operating modes: without escaped characters and with escaped characters. Use the **AP** command to enable either mode. To configure a device to one of these modes, set the following **AP** parameter values:

AP command setting	Description
AP = 0	Transparent operating mode, UART serial line replacement with API modes disabled. This is the default option.
AP = 1	API operation without escaped characters.
AP = 2	API operation with escaped characters (only possible on UART).

Software flow control (XON and XOFF) uses API mode 2. The XBee3 802.15.4 RF Module does not support software flow control and only supports API mode 2 for compatibility with other XBee devices. We recommend using API mode 1.

The API data frame structure differs depending on what mode you choose.

The firmware silently discards any data it receives prior to the start delimiter. If the device does not receive the frame correctly or if the checksum fails, the device discards the frame.

API operation (AP parameter = 1)

We recommend this API mode for most applications. The following table shows the data frame structure when you enable this mode:

Frame fields	Byte	Description
Start delimiter	1	0x7E
Length	2 - 3	Most Significant Byte, Least Significant Byte
Frame data	4 - n	API-specific structure
Checksum	n + 1	1 byte

API operation-with escaped characters (AP parameter = 2)

Set API to 2 to allow escaped control characters in the API frame. Due to its increased complexity, we only recommend this API mode in specific circumstances. API 2 may help improve reliability if the serial interface to the device is unstable or malformed frames are frequently being generated.

When operating in API 2, if an unescaped 0x7E byte is observed, it is treated as the start of a new API frame and all data received prior to this delimiter is silently discarded. For more information on using this API mode, refer to the following knowledge base article:

http://knowledge.digi.com/articles/Knowledge_Base_Article/Escaped-Characters-and-API-Mode-2

The following table shows the structure of an API frame with escaped characters:

Frame fields	Byte	Description	
Start delimiter	1	0x7E	
Length	2 - 3	Most Significant Byte, Least Significant Byte	Characters escaped if needed
Frame data	4 - n	API-specific structure	
Checksum	n + 1	1 byte	

Escape characters

When sending or receiving a UART data frame, you must escape (flag) specific data values so they do not interfere with the data frame sequencing. To escape an interfering data byte, insert 0x7D and follow it with the byte to be escaped XOR'd with 0x20. If not escaped, 0x11 and 0x13 are sent as is.

Data bytes that need to be escaped:

- 0x7E – Frame delimiter
- 0x7D – Escape
- 0x11 – XON
- 0x13 – XOFF

Example - Raw UART data frame (before escaping interfering bytes): 0x7E 0x00 0x02 0x23 0x11 0xCB

0x11 needs to be escaped which results in the following frame: 0x7E 0x00 0x02 0x23 0x7D 0x31 0xCB

Note In the previous example, the length of the raw data (excluding the checksum) is 0x0002 and the checksum of the non-escaped data (excluding frame delimiter and length) is calculated as:
0xFF - (0x23 + 0x11) = (0xFF - 0x34) = 0xCB.

API frame format

An API frame consists of the following:

- Start delimiter
- Length
- Frame data
- Checksum

Start delimiter

This field indicates the beginning of a frame. It is always 0x7E. This allows the device to easily detect a new incoming frame.

Length

The length field specifies the total number of bytes included in the frame's data field. Its two-byte value excludes the start delimiter, the length, and the checksum.

Frame data

This field contains the information that a device receives or will transmit. The structure of frame data depends on the purpose of the API frame:

Start delimiter	Length		Frame data								Checksum
			Frame type	Data							
1	2	3	4	5	6	7	8	9	...	n	n+1
0x7E	MSB	LSB	API frame type	Data							Single byte

- **Frame type** is the API frame type identifier. It determines the type of API frame and indicates how the Data field organizes the information.
- **Data** contains the data itself. This information and its order depend on the type of frame that the Frame type field defines.

Checksum

Checksum is the last byte of the frame and helps test data integrity. It is calculated by taking the hash sum of all the API frame bytes that came before it, except the first three bytes (start delimiter and length).

The device does not process frames sent through the serial interface with incorrect checksums, and ignores their data.

Calculate and verify checksums

To calculate the checksum of an API frame:

1. Add all bytes of the packet, except the start delimiter 0x7E and the length (the second and third bytes).
2. Keep only the lowest 8 bits from the result.
3. Subtract this quantity from 0xFF.

To verify the checksum of an API frame:

1. Add all bytes including the checksum; do not include the delimiter and length.
2. If the checksum is correct, the last two digits on the far right of the sum equal 0xFF.

Example

Consider the following sample data packet: **7E 00 0A 01 01 50 01 00 48 65 6C 6C 6F B8**

Byte(s)	Description
7E	Start delimiter
00 0A	Length bytes
01	API identifier
01	API frame ID
50 01	Destination address low
00	Option byte
48 65 6C 6C 6F	Data packet
B8	Checksum

To calculate the check sum you add all bytes of the packet, excluding the frame delimiter **7E** and the length (the second and third bytes):

7E 00 0A 01 01 50 01 00 48 65 6C 6C 6F B8

Add these hex bytes:

01 + 01 + 50 + 01 + 00 + 48 + 65 + 6C + 6C + 6F = 247

Now take the result of 0x247 and keep only the lowest 8 bits which, in this example, is 0x47 (the two far right digits). Subtract 0x47 from 0xFF and you get 0xB8 (0xFF - 0x47 = 0xB8). 0xB8 is the checksum for this data packet.

If an API data packet is composed with an incorrect checksum, the XBee3 802.15.4 RF Module will consider the packet invalid and will ignore the data.

To verify the check sum of an API packet add all bytes including the checksum (do not include the delimiter and length) and if correct, the last two far right digits of the sum will equal FF.

01 + 01 + 50 + 01 + 00 + 48 + 65 + 6C + 6C + 6F + B8 = 2FF

Frame descriptions

The following sections describe the API frames.

API frames

The device sends multi-byte values in big-endian format. The XBee 802.15.4 RF Module supports API frames in the following table. Request frames are less than 0x80 and responses are always 0x80 or higher.

API frame name	API ID
Transmit (TX) Request: 64-bit address	0x00
Transmit (TX) Request: 16-bit Address	0x01
AT Command	0x08
AT Command - Queue Parameter Value	0x09
Remote AT Command Request	0x17
Receive (RX) Packet: 64-bit address	0x80
Receive (RX) Packet: 16-bit address	0x81
AT Command Response	0x88
Transmit (TX) Status	0x89
Modem Status	0x8A
Remote AT Command Response	0x97

.

TX Request: 64-bit address frame - 0x00

Description

This frame causes the device to send payload data as an RF packet.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x00

Frame data fields	Offset	Description
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK, which is a 0x89 (Tx status) frame that indicates the packet was transmitted successfully. If set to **0**, the device does not send a response.
64-bit destination address	5-12	Set to the 64-bit address of the destination device. If set to 0x000000000000FFFF, the broadcast address is used.
Options	13	0x01 = Disable ACK 0x04 = Send packet with Broadcast PAN ID. Set all other bits to 0.
RF data	14-n	The RF data length can be up to 110 bytes, but may be less depending on other factors discussed in Maximum payload.

TX Request: 16-bit address - 0x01

Description

A TX Request message causes the device to transmit data as an RF Packet.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x01
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x89). If set to **0**, the device does not send a response.
16-bit destination address	5-6	Set to the 16-bit address of the destination device. Broadcast = 0xFFFF.
Options	7	0x01 = Disable ACK. 0x04 = Send packet with Broadcast PAN ID. Set all other bits to 0.
RF data	8-n	The RF data length can be up to 116 bytes, but may be less depending on other factors discussed in Maximum payload.

AT Command Frame - 0x08

Description

Use this frame to query or set command parameters on the local device. This API command applies changes after running the command. You can query parameter values by sending the 0x08 AT Command frame with no parameter value field (the two-byte AT command is immediately followed by the frame checksum). Any parameter that is set with this frame type will apply the change immediately. If you wish to queue multiple parameter changes and apply them later, use the AT Command - Queue Parameter Value frame - 0x09 instead.

When an AT command is queried, a 0x88 response frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x88 response is the same one set by the command in the 0x08 frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x08
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent response (0x88). If set to 0, the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the AT command.
Parameter value	7-n	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the register.

Example

The following example illustrates an AT Command frame where the device's **SL** parameter value is queried.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x04
Frame type	3	0x08
Frame ID	4	0x13

Frame data fields	Offset	Example
AT command	5	0x53 (S)
	6	0x4C (L)
Parameter value (optional)		
Checksum	8	0x45

The following example illustrates an AT Command frame when you modify the device's **DL** parameter value to a broadcast address of 0xFFFF. A non-zero Frame ID can be used to correlate the AT command request with the corresponding response frame.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x08
Frame type	3	0x08
Frame ID	4	0x4D
AT command	5	0x44 (D)
	6	0x4C (L)
Parameter value	7-10	0xFF 0xFF
Checksum	11	0x1C

AT Command - Queue Parameter Value frame - 0x09

Description

This frame allows you to query or set device parameters. In contrast to the AT Command (0x08) frame, this frame queues new parameter values and does not apply them until you issue either:

- The **AT** Command (0x08) frame (for API type)
- The **AC** command

When querying parameter values, the 0x09 frame behaves identically to the 0x08 frame; the response for this command is also an **AT** Command Response frame (0x88).

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x09
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent response (0x88). If set to **0**, the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the AT command.
Parameter value (**BD7** = 115200 baud) (optional)	7-n	If present, indicates the requested parameter value to set the given register. If no characters are present, queries the register.

Remote AT Command Request frame - 0x17

Description

Used to query or set device parameters on a remote device. For parameter changes on the remote device to take effect, you must apply changes, either by setting the Apply Changes options bit, or by sending an **AC** command to the remote.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x17
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent response (0x97). If set to **0**, the device does not send a response.
64-bit destination address	5-12	Broadcast = 0x000000000000FFFF. This field is ignored if the 16-bit network address field equals anything other than 0xFFFF.
16-bit destination address	13-14	Set to match the 16-bit network address of the destination, MSB first, LSB last. Set to 0xFFFF if 64-bit addressing is being used.
AT command	16-17	Command name: two ASCII characters that identify the command.
Command parameter	18-n	If present, indicates the parameter value you request for a given register. If no characters are present, it queries the register.

RX Packet: 64-bit Address frame - 0x80

Description

When a device receives an RF data packet from a device configured to use 64-bit addressing (**MY** = FFFF), it sends this frame out the serial interface.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x80
64-bit source address	4-11	The sender's 64-bit address.
RSSI	12	Received Signal Strength Indicator. The Hexadecimal equivalent of (-dBm) value. For example if RX signal strength is -40 dBm, then 0x28 (40 decimal) is returned.
Options	13	Bit field: 0 = [reserved]. 1 = Packet was a broadcast packet. 2 = Packet was broadcast across all PANs. 3-7 = [reserved].
Received data	14-n	The RF data that the device receives.

Receive Packet: 16-bit address frame - 0x81

Description

When the device receives an RF packet from a device configured to use 16 bit addressing (**MY** < FFFE), it sends this frame out the serial interface.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x81
Source address	4-5	MSB first LSB last
RSSI	6	RSSI = hexadecimal equivalent of -dBm value. For example, if RX signal strength = -40 dBm, it returns 0x28 (40 decimal).
Options	7	Bit 0 = [reserved]. Bit 1 = Packet was a broadcast packet. Bit 2 = Packet was broadcast across all PANs. Bits 3 - 7 = [reserved].
RF data	8-n	The RF data that the device receives.

AT Command Response frame - 0x88

Description

A device sends this frame in response to an AT Command (0x08) frame and a queued AT command (0x09). Some commands send back multiple frames; for example, the **ND** command. This command ends by sending a frame with a status of **0** (OK) and no value. In the particular case of **ND**, a frame is received via a remote node in the network and when the process is finished, the AT command response is received. For details on the behavior of **ND**, see ND (Network Discover).

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x88
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent request (0x08 or 0x09). If set to **0** in the request frame, the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the command.
Command status	7	0 = OK 1 = ERROR 2 = Invalid command 3 = Invalid parameter 4 = Tx failure
Command data		The register data in binary format. If the host sets the register, the device does not return this field.

Example

If you change the **BD** parameter on a local device with a frame ID of 0x01, and the parameter is valid, the user receives the following response.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x05
Frame type	3	0x88
Frame ID	4	0x01

Frame data fields	Offset	Example
AT command	5	0x42 (B)
	6	0x44 (D)
Command status	7	0x00
Command data		(No command data implies the parameter was set rather than queried)
Checksum	8	0xF0

TX Status frame - 0x89

Description

When a TX request: 64-bit address (0x00) or 16-bit address (0x01) is complete, the device sends a TX Status frame. This message indicates if the packet transmitted successfully or if there was a failure.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x89
Frame ID	4	Identifies the TX Request frame being reported. If the Frame ID = 0 in the TX Request, no TX Status frame is given.
Status	5	0x00 = standard 0x01 = no ACK received 0x02 = CCA failure 0x21 = Network ACK failure 0x31 = Internal error 0x32 = Transmission failed due to resource depletion; for example, out of buffers 0x74 = The payload in the frame was larger than allowed

Notes:

- A status of 0x01 occurs when all MAC and Application-Layer retries have expired and no ACK is received.
- If the transmitter sends an outgoing transmission as a broadcast (destination address = 0x000000000000FFFF), status 0x01 and 0x21 will never be returned because broadcasts are sent unacknowledged.

Example

The following example shows a successful status received.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x03
Frame type	3	0x89

Frame data fields	Offset	Example
Frame ID	4	0x01
Status	5	0x00
Checksum	6	0x75

Modem Status frame - 0x8A

Description

Devices send the status messages in this frame in response to specific conditions.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x8A
Status	4	0x00 Hardware reset 0x01 Watchdog timer reset 0x0D Input voltage is too high, which prevents transmissions

Example

When a device powers up, it returns the following API frame.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
LSB 2	LSB 2	0x02
Frame type	3	0x8A
Status	4	0x00
Checksum	5	0x75

Remote Command Response frame - 0x97

Description

If a device receives this frame in response to a Remote Command Request (0x17) frame, the device sends an AT Command Response (0x97) frame out the serial interface.

Some commands, such as the **ND** command, may send back multiple frames. For details on the behavior of **ND**, see ND (Network Discover).

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x97
Frame ID	4	This is the same value that is passed into the request. The request is a 0x17 frame.
64-bit source (remote) address	5-12	The long address of the remote device returning this response.
16-bit source (remote) address	13 - 14	The short address of the remote device returning this response.
AT commands	15-16	The name of the command.
Command status	17	0 = OK 1 = ERROR 2 = Invalid Command 3 = Invalid Parameter 4 = Remote Command Transmission Failed
Command data	18-n	The value of the requested register in hexadecimal notation (non-ASCII).