XBee-PRO PKG-R® RS-232 RF Modem

802.15.4

User Guide

Revision history—90000829

Revision	Date	Description
A	September 2006	Initial release.
B	May 2007	Updated document to fix minor errors.
C	August 2017	Updated branding and made editorial enhancements. Modified regulatory and certification information as required by RED (Radio Equipment Directive).
D	May 2018	Added a note on range estimates.

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    Product serial number (s)
    Firmware version
    Operating system/browser (if applicable)
    Logs (from time of reported issue)
    Trace (if possible)
    Description of issue
    Steps to reproduce

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Include the document title and part number (XBee-PRO PKG-R RS-232 RF Modem User Guide, 90000829 D) in the subject line of your email.

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XBee-PRO RS-232 modem

The XBee-PRO PKG-R RS-232 RF Modem is an IEEE 802.15.4 compliant solution that features an RS-232 interface. Out-of-box, the modem is equipped to sustain outstanding range (2-3x the range of typical 802.15.4 solutions) and requires no additional configuration for immediate RF communications. Simply feed data into one modem, then the data is sent out the other end of the wireless link.

The modem transfers a standard asynchronous serial data stream between two or more devices. Its built-in RS-232 interface allows for rapid integration into existing data systems.

Technical specifications

Physical specifications

Specification	Value
Size	4.500" x 2.750" x 1.125" (11.4cm x 7.0cm x 2.9cm)
Weight	5.25 oz. (150 g)
Data connection	Female DB-9
Operating temperature	-40 - 85º C (industrial)

Performance specifications

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	Value
Indoor/urban range (w/2.1 dB dipole antenna)	Up to 300 feet (90 m)
Outdoor/urban range (w/2.1 dB dipole antenna)	Up to 4000 feet (1200 m)
Transmit power output	60 mW, 100 mW (20 dBm) EIRP
RF data rate	250 Kbps
Interface data rate	1200 bps - 115.2 Kbps (non-standard baud rates also supported
Receiver sensitivity	-100 dBm (1% packet error rate)

Networking and security specifications

Specification	Value
Frequency	ISM 2.4 GHz
Modulation	DSSS (direct sequence spread spectrum), OQPSK (offset quadrature phase shift keying)
Supported network topologies	Point-to-point, point-to-multipoint, peer-to-peer and mesh
Number of channels (software selectable)	12 direct sequence channels
Addressing layers	PAN ID, channel and source/destination addresses

Antenna specifications

Specification	Value
Connector	RPSMA (reverse polarity SMA)
Impedance	50 ohms unbalanced

Power requirements

Specification	Value
Power supply	5 - 14 V
Receive current	80 mA (@ 9 Volts)
Transmit current	300 mA (Average current when streaming data (@9600 bps) = 86 mA)
Power-down current	<6 mA

Regulatory approvals

Specification	Value
United States (FCC Part 15.247)	OUR-XBEEPRO
Industry Canada (IC)	4214A-XBEEPRO
Europe (CE)	Maximum 10 mW transmit power output[1]

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[1]When the radio is set to **PL0**, using the command **ATPL0**.

Hardware

External interface

1-01c. Serial Port

1-01d. RSSI LEDs

1-01b. I/O & Power LEDs

1-01e. Power Connector
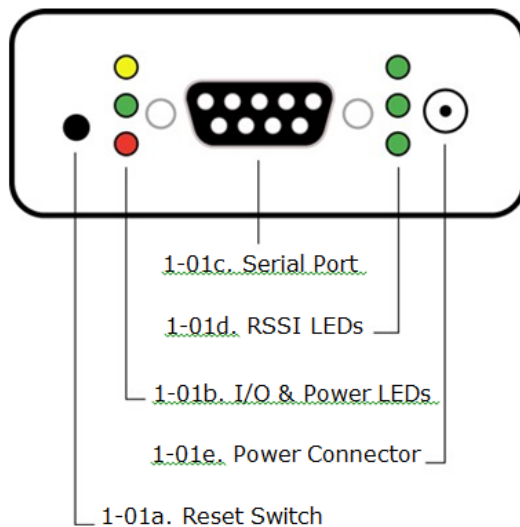
1-01a. Reset Switch

Reset switch

The reset switch is used to reset (re-boot) the XBee-PRO PKG-R RS-232 RF Modem. This switch only applies when using the configuration tabs of Digi's XCTU software.

I/O and power LEDs

LEDs indicate RF modem activity as follows:

- Yellow (top LED) = serial Data Out (to host).
- Green (middle) = serial Data In (from host).
- Red (bottom) = Power/association indicator (refer to D5 (DIO5 Configuration) command).

host   RF modems   host

Serial port

Standard female DB-9 (RS-232) connector.

RSSI LEDs

RSSI LEDs indicate the amount of fade margin present in an active wireless link. Fade margin is defined as the difference between the incoming signal strength and the modem's receiver sensitivity.

- 3 LEDs ON = very strong signal (> 30 dB fade margin)
- 2 LEDs ON = strong signal (> 20 dB fade margin)
- 1 LED ON = moderate signal (> 10 dB fade margin)
- 0 LED ON = weak Signal (< 10 dB fade margin)

Power connector

5-14 VDC power connector

Back view

1-02a. DIP Switch
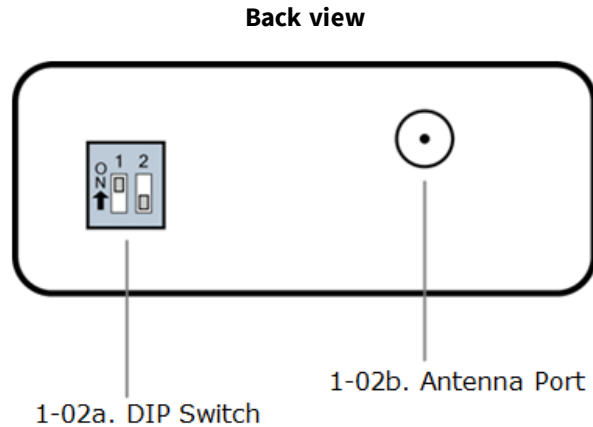
1-02b. Antenna Port

DIP switch

DIP switch functions are not supported in this release. Future downloadable firmware versions will support DIP switch configurations.

Antenna port

Port is a 50Ω RF signal connector for connecting to an external antenna. The connector type is RPSMA (reverse polarity SMA) female. The connector has threads on the outside of a barrel and a male center conductor.

Interfacing protocol

RS-232 operation

Pin signals

Pins used on the female RS-232 (DB-9) serial connector
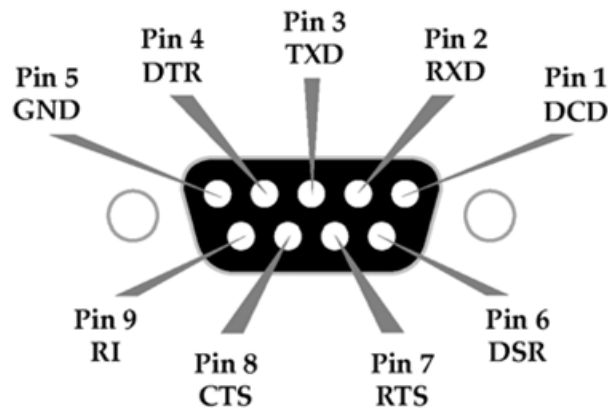
Pin assignments and implementations

DB-9 pin	RS-232 name	Description	Implementation[1]
1	DCD	Data-carrier-detect	Connected to DSR (pin6)
2	RXD	Received data	Serial data exiting the RF modem (to host)
3	TXD	Transmitted data	Serial data entering into the RF modem (from host)
4	DTR	Data-terminal-ready	Can enable power-down on the RF modem
5	GND	Ground signal	Ground
6	DSR	Data-set-ready	Connected to DCD (pin1)
7	RTS / CMD	Request-to-send/command mode	Provides RTS flow control or enables "command mode" on the RF modem Refer to Flow control and the D6 (DIO6 Configuration) command.
8	CTS	Clear-to-send	Provides CTS flow control Refer to Flow control and D7 (DIO7 Configuration) command.
9	RI	Ring indicator	Optional power input that is connected internally to the positive lead of the front power connector

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[1]Functions listed in the implementation column may not be available at the time of release.

Wiring diagrams

DTE RS-232 device to a DCE RF Modem

        RS-232 device (DTE-male connector) wired to an XBee-PRO RF Modem (DCE-female)
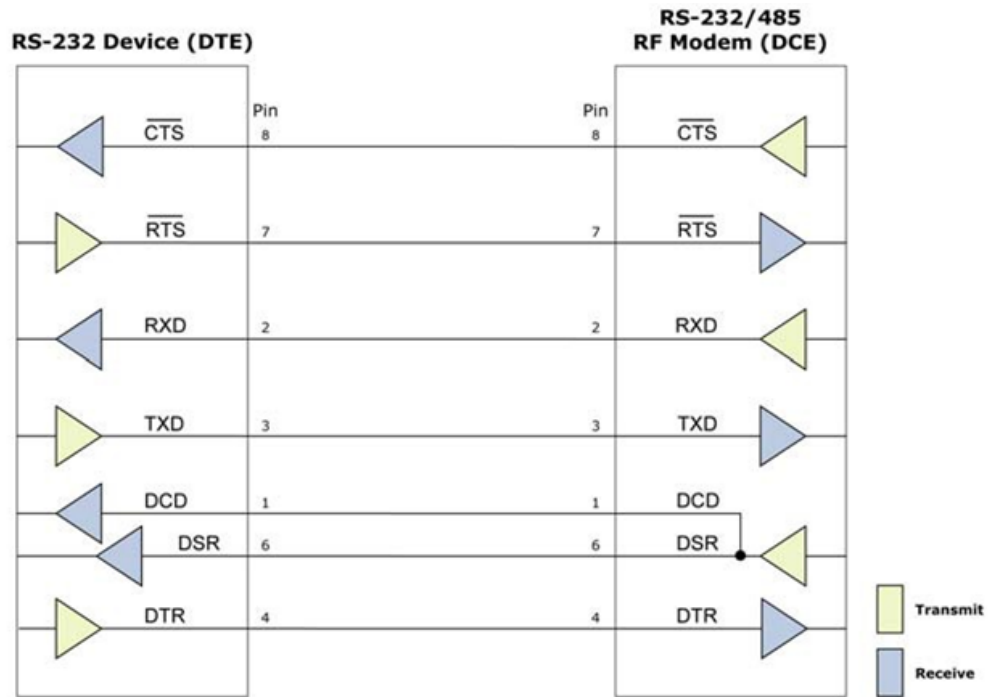
DCE RF Modem to an DCE RS-232 device

XBee-PRO RF Modem (DCE - female connector) wired to an RS-232 device (DCE)
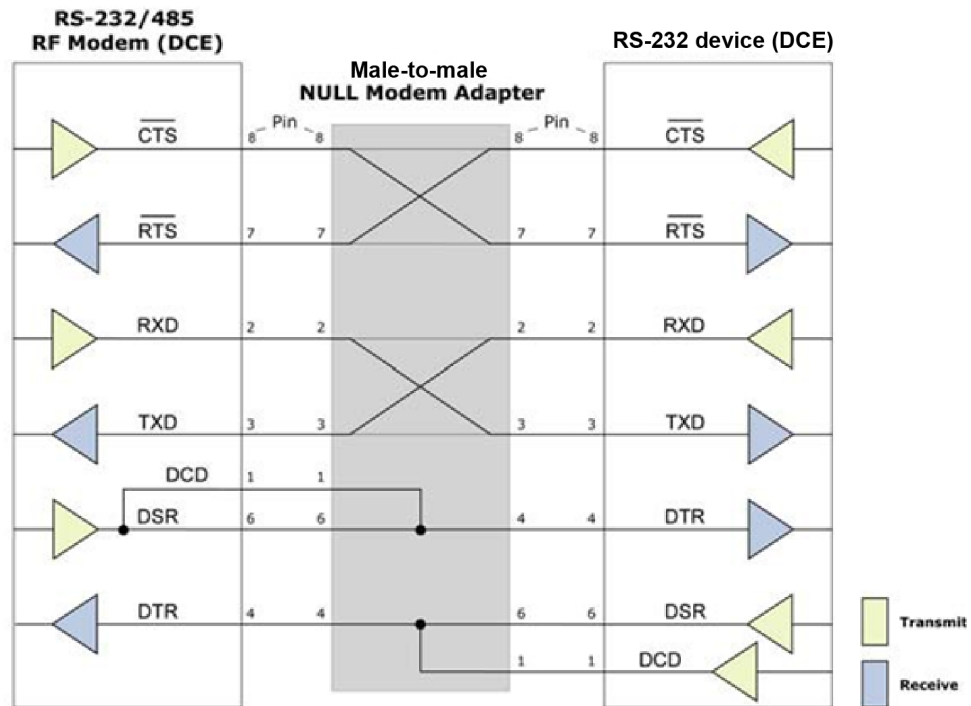
Sample wireless connection: DTE <--> DCE ⚡ DCE <--> DCE

Typical wireless link between DTE and DCE devices

Serial communications

RS-232 data flow

The XBee-PRO PKG-R RS-232 RF Modem interfaces to a host device through a standard RS-232 (DB-9) connector. Devices that have a standard RS-232 serial port can connect directly through the pins of the RF modem as shown in the following figure.

System data flow in an RS 232 environment
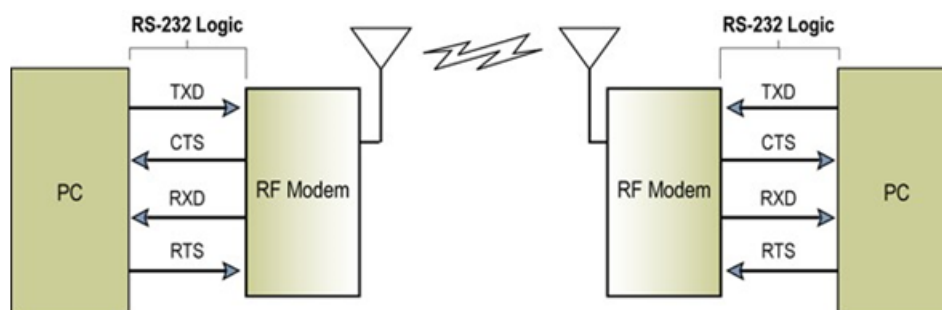
Host and RF modem settings

Serial communications between a host and an XBee-PRO RF modem are dependent upon having matching baud rate, parity, stop bit and number of data bits settings. Refer to the table below to ensure host serial port settings match those of the XBee-PRO RF modem.

Parameter values critical to serial communications between the RF modem and host

Parameter setting	Default parameter value
Baud (serial data rate)	9600 bps (BD parameter = 3)
Number of data bits	8
Parity	None
Number of stop bits	1

Both the XBee-PRO RF modem and host (PC) settings can be viewed and adjusted using Digi's proprietary XCTU software. Use the **PC settings** tab to configure host settings. Use the **terminal** or **RF modem configuration** tabs to configure the RF modem settings.

Note Failure to enter AT command mode is most commonly due to baud rate mismatch. Ensure the **baud** setting on the **PC settings** tab matches the BD (interface data rate) setting of the RF modem (by default, BD parameter = 3, which is associated to 9600 baud).

Transparent operation

By default, XBee-PRO RF modems operate in transparent mode. When operating in this mode, the modems act as a serial line replacement - all UART data received through the DI pin is queued up for RF transmission. When RF data is received, the data is sent out the DO pin.

Serial-to-RF packetization

Data is buffered in the DI 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 (100) is received.
3. The command mode sequence (GT + CC + GT) is received. Any character buffered in the DI buffer before the sequence is transmitted.

If the modem cannot immediately transmit (for instance, if it is already receiving RF data), the serial data is stored in the DI buffer. The data is packetized and sent at any RO timeout or when 100 bytes (maximum packet size) are received.

If the DI buffer becomes full, hardware or software flow control must be implemented in order to prevent overflow (loss of data between the host and modem).

API operation

API (application programming interface) operation is an alternative to the default transparent operation. The frame-based API extends the level to which a host application can interact with the networking capabilities of the modem.

When in API mode, all data entering and leaving the modem is contained in frames that define operations or events within the modem.

Transmit data frames (received through the DI (Data In) pin) include:

- RF transmit data frame
- Command frame (equivalent to AT commands)

Receive data frames (sent out the data out) include:

- RF-received data frame
- Command response
- Event notifications such as reset, associate, and disassociate

The API provides alternative means of configuring modems and routing data at the host application layer. A host application can send data frames to the modem that contain address and payload information instead of using command mode to modify addresses. The modem will send data frames to the application containing status packets; as well as source, RSSI and payload information from received data packets.

The API operation option facilitates many operations such as the examples cited below:

- Transmitting data to multiple destinations without entering command mode.
- Receive success/failure status of each transmitted RF packet.
- Identify the source address of each received packet.

Flow control

Internal data flow diagram
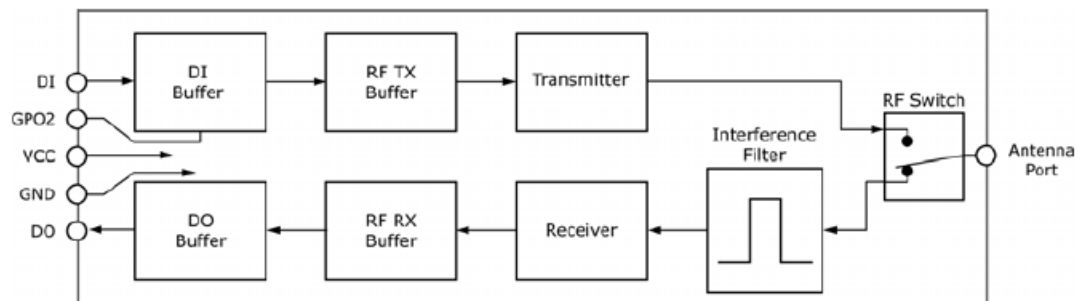
DI (Data In) buffer

When serial data enters the RF modem through the DI (Data In) pin, the data is stored in the DI Buffer until it can be processed.

Hardware flow control (CTS). When the DI buffer is 17 bytes away from being full; by default, the modem de-asserts CTS (high) to signal to the host device to stop sending data (refer to D7 (DIO7 Configuration) command. CTS is re-asserted after the DI Buffer has 34 bytes of memory available.

How to eliminate the need for flow control:

1. Send messages that are smaller than the DI buffer size.
2. Interface at a lower baud rate (BD (interface data rate) parameter) than the throughput data rate.

Case in which the DI buffer may become full and possibly overflow

If the modem is receiving a continuous stream of RF data, any serial data that arrives on the DI pin is placed in the DI Buffer. The data in the DI buffer will be transmitted over-the-air when the modem is no longer receiving RF data in the network.

Refer to RO (Packetization Timeout) command, BD (Interface Data Rate) command, and D7 (DIO7 Configuration) command command descriptions for more information.

Refer to BD (Interface Data Rate) command and RO (Packetization Timeout) command command descriptions for more information.

DO (Data Out) buffer

When RF data is received, the data enters the DO buffer and is sent out the serial port to a host device. Once the DO buffer reaches capacity, any additional incoming RF data is lost.

Hardware flow control (RTS). If RTS is enabled for flow control (D6 (DIO6 configuration) parameter = 1), data will not be sent out the DO buffer as long as RTS (DIO6) is de-asserted.

Two cases in which the DO buffer may become full and possibly overflow:

1. If the RF data rate is set higher than the interface data rate of the modem, the modem will receive data from the transmitting modem faster than it can send the data to the host.
2. If the host does not allow the modem to transmit data out from the DO buffer because of being held off by hardware or software flow control.

To implement API operations, refer to API operation.

IEEE 802.15.4 networks

The following IEEE 802.15.4 network types are available to the RF modem:

- NonBeacon
- NonBeacon (w/coordinator)

The following terms will be used to explicate the network system types:

Terms and definitions (Applicable networking network types are designated within <brackets>.)

Term	Definition
Association	<NonBeacon (w/coordinator) systems only> The establishment of membership between end devices and a coordinator.
Coordinator	<NonBeacon (w/coordinator) systems only> A central RF modem that is configured to provide synchronization services through the transmission of beacons.
End device	When in the same network as a coordinator - RF modems that rely on a coordinator for synchronization and can be put into states of sleep for low-power applications.
PAN	Personal Area Network - A data communication network that includes one or more end devices and optionally a coordinator.

NonBeacon

By default, XBee-PRO RF modems are configured to support NonBeacon communications (no coordinator). NonBeacon systems operate within a peer-to-peer network topology and are not dependent upon master/slave relationships. This means that modems remain synchronized without use of master/server configurations and each modem in the network shares both roles of master and slave. Digi's peer-to-peer architecture features fast synchronization times and fast cold start times. This default configuration accommodates a wide range of RF data applications.

NonBeacon peer-to-peer architecture
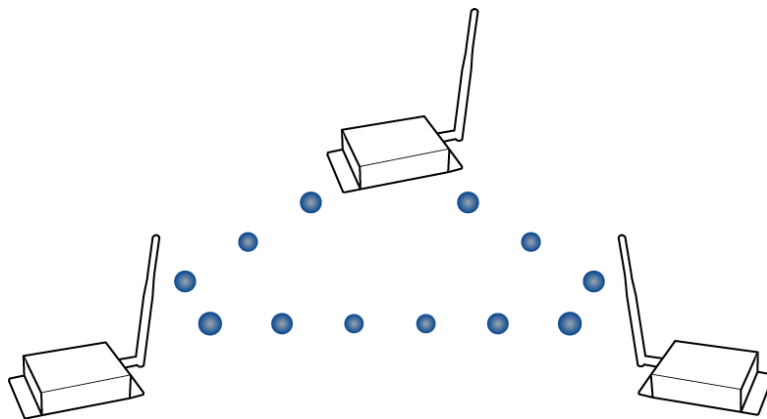
A peer-to-peer network can be established by configuring each modem to operate as an end device (CE = 0), disabling end device association on all modems (A1 = 0) and setting ID and CH parameters to be identical across the network.

NonBeacon (with coordinator)

A device is configured as a coordinator by setting the CE (Coordinator Enable) parameter to "1." Coordinator power-up is governed by the A2 (Coordinator Association) command.

In a NonBeacon (with coordinator) system, the coordinator can be configured to use direct or indirect transmissions. If the SP (Cyclic Sleep Period) parameter is set to "0," the coordinator sends data immediately. Otherwise, the SP parameter determines the length of time the coordinator will retain the data before discarding it. Generally, SP (Cyclic Sleep Period) and ST (Time before Sleep) parameters should be set to match the SP and ST settings of the end devices.

Association plays a critical role in the implementation of a NonBeacon (with coordinator) system. Refer to Association for more information.

Association

Association is the establishment of membership between end devices and a coordinator and is only applicable in NonBeacon (w/coordinator) networks. The establishment of membership is useful in scenarios that require a central unit (coordinator) to relay messages or to gather data from several remote units (end devices), assign channels or assign PAN IDs.

An RF data network that consists of one coordinator and one or more end devices forms a PAN (Personal Area Network). Each device in a PAN has a PAN identifier (ID (PAN ID) parameter). PAN IDs must be unique to prevent miscommunication between PANs. The coordinator PAN ID is set using the ID (PAN ID) and A2 (coordinator association) commands.

An end device can associate to a coordinator without knowing the address, PAN ID or channel of the coordinator. The A1 (End Device Association) parameter bit fields determine the flexibility of an end device during association. The A1 parameter can be used for an end device to dynamically set its destination address, PAN ID and/or channel.

For example, If the PAN ID of a coordinator is known, but the operating channel is not, the A1 command on the end device should be set to enable the Auto_Associate and Reassign_Channel bits. Additionally, the ID parameter should be set to match the PAN ID of the associated coordinator.

Coordinator/end device setup and operation

To configure a modem to operate as a coordinator, set the **CE (Coordinator Enable)** parameter to **1**. Set the CE parameter of end devices to **0** (default). Coordinator and end devices should contain matching firmware versions.

NonBeacon (with coordinator) systems

In a NonBeacon (w/coordinator) system, the coordinator can be configured to use direct or indirect transmissions. If the SP (Cyclic Sleep Period) parameter is set to **0**, the coordinator will send data immediately. Otherwise, the SP parameter determines the length of time the coordinator will retain the data before discarding it. Generally, SP (Cyclic Sleep Period) and ST (Time before Sleep) parameters should be set to match the SP and ST settings of the end devices.

Coordinator power-up

Coordinator power-up is governed by the A2 (Coordinator Association) command. On power-up, the coordinator undergoes the following sequence of events:

1. **Check A2 parameter- reassign_PANID flag**

   Set (bit 0 = 1) - The coordinator issues an active scan. The active scan selects one channel and transmits a BeaconRequest command to the broadcast address (0xFFFF) and broadcast PAN ID (0xFFFF). It then listens on that channel for beacons from any coordinator operating on that channel. The listen time on each channel is determined by the SD (Scan Duration) parameter value.

Once the time expires on that channel, the active scan selects another channel and again transmits the BeaconRequest as before. This process continues until all channels have been scanned, or until 5 PANs have been discovered. When the active scan is complete, the results include a list of PAN IDs and channels that are being used by other PANs. This list is used to assign an unique PAN ID to the new coordinator. The ID parameter will be retained if it is not found in the active scan results. Otherwise, the ID (PAN ID) parameter setting will be updated to a PAN ID that was not detected.

Not Set (bit 0 = 0) - The coordinator retains its ID setting. No active scan is performed.

2. **Check A2 parameter - reassign_channel flag (bit 1)**

   Set (bit 1 = 1) - The coordinator issues an energy scan. The energy scan selects one channel and scans for energy on that channel. The duration of the scan is specified by the SD (Scan Duration) parameter. Once the scan is completed on a channel, the energy scan selects the next channel and begins a new scan on that channel. This process continues until all channels have been scanned.

   When the energy scan is complete, the results include the maximal energy values detected on each channel. This list is used to determine a channel where the least energy was detected. If an active scan was performed (reassign_PANID flag set), the channels used by the detected PANs are eliminated as possible channels. Thus, the results of the energy scan and the active scan (if performed) are used to find the best channel (channel with the least energy that is not used by any detected PAN). Once the best channel has been selected, the CH (Channel) parameter value is updated to that channel.

   Not set (bit 1 = 0) - The coordinator retains its CH setting. An energy scan is not performed.

3. **Start coordinator**

   The coordinator starts on the specified channel (CH parameter) and PAN ID (ID parameter). Note, these may be selected in steps 1 and/or 2 above. The coordinator will only allow end devices to associate to it if the A2 parameter "AllowAssociation" flag is set. Once the coordinator has successfully started, the Associate LED will blink one time per second. (The LED is solid if the coordinator has not started.)

4. **Coordinator modifications**

   Once a coordinator has started:

   Modifying the A2 (Reassign_Channel or Reassign_PANID bits), ID, CH or MY parameters will cause the coordinator's MAC to reset (The coordinator RF modem (including volatile RAM) is not reset). Changing the A2 AllowAssociation bit will not reset the coordinator's MAC. In a non-beaconing system, end devices that are associated to the coordinator prior to a MAC reset will have knowledge of the new settings on the coordinator. Thus, if the coordinator were to change its ID, CH or MY settings, the end devices would no longer be able to communicate with the non-beacon coordinator. Once a coordinator has started, the ID, CH, MY or A2 (Reassign_ Channel or Reassign_PANID bits) should not be changed.

End device power-up

End device power-up is governed by the A1 (End Device Association) command. On power-up, the end device undergoes the following sequence of events:

1. **Check A1 parameter -11 AutoAssociate bit.**

   Set (bit 2 = 1) - End device attempts to associate to a coordinator. (Refer to steps 2-3.)

   Not Set (bit 2 = 0) - End device will not attempt to associate to a coordinator. The end device will operate as specified by its ID, CH and MY parameters. Association is considered complete

and the **Associate LED** blinks quickly (5 times per second). When the AutoAssociate bit is not set, the remaining steps (2-3) do not apply.

2. **Discover coordinator (if AutoAssociate bit set).**

The end device issues an active scan. The active scan selects one channel and transmits a BeaconRequest command to the broadcast address (0xFFFF) and broadcast PAN ID (0xFFFF).

It then listens on that channel for beacons from any coordinator operating on that channel. The listen time on each channel is determined by the SD parameter.

Once the time expires on that channel, the active scan selects another channel and again transmits the BeaconRequest command as before. This process continues until all channels have been scanned, or until 5 PANs have been discovered. When the active scan is complete, the results include a list of PAN IDs and channels that are being used by detected PANs.

The end device selects a coordinator to associate with according to the A1 parameter (Reassign_PANID) and (Reassign_Channel) flags:

- **Reassign_PANID Bit Set (bit 0 = 1)**- end device can associate with a PAN with any ID value.
- **Reassign_PANID Bit Not Set (bit 0 = 0)** - end device will only associate with a PAN whose ID setting matches the ID setting of the end device.
- **Reassign_Channel bit set (bit 1 = 1)** - end device can associate with a PAN with any CH value.
- **Reassign_Channel bit not set (bit 1 = 0)**- end device will only associate with a PAN whose CH setting matches the CH setting of the end device.

After applying these filters to the discovered coordinators, if multiple candidate PANs exist, the end device will select the PAN whose transmission link quality is the strongest. If no valid coordinator is found, the end device will either go to sleep (as dictated by its SM (Sleep Mode) parameter) or retry association.

Note An end device will also disqualify coordinators if they are not allowing association (A2 - AllowAssociation bit); or, if the coordinator is not using the same NonBeacon scheme as the end device. (They must both be programmed with NonBeacon code.)

3. **Associate to valid coordinator.**

Once a valid coordinator is found (step 2), the end device sends an AssociationRequest message to the coordinator. It then waits for an AssociationConfirmation to be sent from the coordinator. Once the confirmation is received, the end device is associated and the **Associate LED** blinks rapidly (2 times per second). The LED is solid if the end device has not associated.

4. **End device changes once an end device has associated.**

Changing A1, ID or CH parameters will cause the end device to disassociate and restart the association procedure.

If the end device fails to associate, the AI command can give some indication of the failure.

Addressing

Every RF data packet sent over-the-air contains a source address and destination address field in its header. The RF modem 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. Short

addressing must be configured manually. A modem will use its unique 64-bit address as its source address if its MY (16-bit Source Address) value is **0xFFFF** or **0xFFFE**.

To send a packet to a specific modem using 64-bit addressing: set destination address (DL + DH) to match the source address (SL + SH) of the intended destination modem.

To send a packet to a specific modem using 16-bit addressing: Set DL (Destination Address Low) parameter to equal the MY parameter and set the DH (Destination Address High) parameter to **0**.

Unicast mode

By default, the RF modem operates in Unicast mode. Unicast mode is the only mode that supports retries. While in this mode, receiving modems send an ACK (acknowledgment) of RF packet reception to the transmitter. If the transmitting modem does not receive the ACK, it will re-send the packet up to three times or until the ACK is received.

Short 16-bit addresses

The modem can be configured to use short 16-bit addresses as the source address by setting (MY < 0xFFFE). Setting the DH parameter (DH = 0) will configure the destination address to be a short 16-bit address (if DL < 0xFFFE). For two modems to communicate using short addressing, the destination address of the transmitter modem must match the MY parameter of the receiver.

The following table shows a sample network configuration that would enable Unicast mode communications using short 16-bit addresses.

Sample Unicast network configuration
(using 16-bit addressing)

Parameter	RF modem 1	RF modem 2
MY (Source Address)	0x01	0x02
DH (Destination Address High)	0	0
DL (Destination Address Low)	0x02	0x01

Long 64-bit addresses

The RF modem's serial number (SL parameter concatenated to the SH parameter) can be used as a 64-bit source address when the MY (16-bit Source Address) parameter is disabled. When the MY parameter is disabled (set MY = 0xFFFF or 0xFFFE), the modem's source address is set to the 64-bit IEEE address stored in the SH and SL parameters.

When an end device associates to a coordinator, its MY parameter is set to 0xFFFE to enable 64- bit addressing. The 64-bit address of the modem is stored as SH and SL parameters. To send a packet to a specific modem, the destination address (DL + DH) on one modem must match the source address (SL + SH) of the other.

Broadcast mode

Any RF modem within range will accept a packet that contains a broadcast address. When configured to operate in Broadcast mode, receiving modems do not send ACKs (acknowledgements) and transmitting modems do not automatically re-send packets as is the case in Unicast mode.

To send a broadcast packet to all modems regardless of 16-bit or 64-bit addressing, set the destination addresses of all the modems as shown below.

Sample network configuration (All modems in the network):

- DL (Destination Low Address) = 0x0000FFFF
- DH (Destination High Address) = 0x00000000 (default value)

Note When programming the modem, parameters are entered in hexadecimal notation (without the "0x" prefix). Leading zeros may be omitted.

Modes of operation

XBee-PRO RF modems operate in five modes.
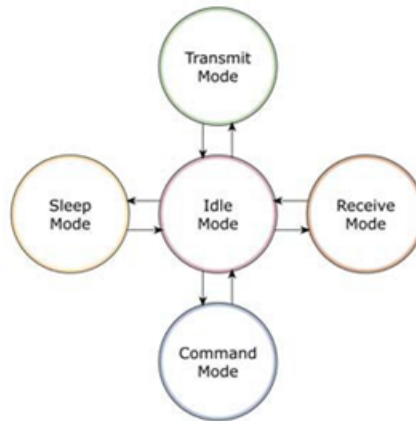
Idle mode

When not receiving or transmitting data, the RF modem is in idle mode. The modem shifts into the other modes of operation under the following conditions:

- Transmit mode (serial data is received in the DI buffer).
- Receive mode (valid RF data is received through the antenna).
- Sleep mode (sleep mode condition is met).
- Command mode (command mode sequence is issued).

Transmit/receive modes

RF data packets

Each transmitted data packet contains a source address and destination address field. The source address matches the address of the transmitting modem as specified by the MY (Source Address) parameter (if MY >= 0xFFFE), the SH (Serial Number High) parameter or the SL (Serial Number Low) parameter. The <Destination Address> field is created from the DH (Destination Address High) and DL (Destination Address Low) parameter values. The source address and/or destination address fields will either contain a 16-bit short or long 64-bit long address.

The RF data packet structure follows the 802.15.4 specification.

Refer to Addressing for more information.

Direct and indirect transmission

There are two methods to transmit data:

- Direct transmission - data is transmitted immediately to the destination address.
- Indirect transmission - A packet is retained for a period of time and is only transmitted after the destination modem (source address = destination address) requests the data.

Indirect transmissions can only occur on a coordinator. Thus, if all nodes in a network are end devices, only direct transmissions will occur. Indirect transmissions are useful to ensure packet delivery to a sleeping node. The coordinator currently is able to retain up to two indirect messages.

Direct transmission

A NonBeaconing coordinator can be configured to use only direct transmission by setting the SP (Cyclic Sleep Period) parameter to **0**. Also, a NonBeaconing coordinator using indirect transmissions will revert to direct transmission if it knows the destination modem is awake.

To enable this behavior, the ST (Time before Sleep) value of the coordinator must be set to match the ST value of the end device. Once the end device either transmits data to the coordinator or polls the coordinator for data, the coordinator uses direct transmission for all subsequent data transmissions to that modem address until ST time (or number of beacons) occurs with no activity (at which point it will revert to using indirect transmissions for that modem address). **No activity** means no transmission or reception of messages with a specific address. Global messages will not reset the ST timer.

Indirect transmission

To configure indirect transmissions in a PAN (Personal Area Network), the SP (Cyclic Sleep Period) parameter value on the coordinator must be set to match the longest sleep value of any end device. The SP parameter represents time in NonBeacon systems and beacons in Beacon-enabled systems. The sleep period value on the coordinator determines how long (time or number of beacons) the coordinator will retain an indirect message before discarding it.

In NonBeacon networks, an end device must poll the coordinator once it wakes from sleep to determine if the coordinator has an indirect message for it. For cyclic sleep modes, this is done automatically every time the modem wakes (after SP time). For pin sleep modes, the A1 (End Device Association) parameter value must be set to enable coordinator polling on pin wake-up. Alternatively, an end device can use the FP (Force Poll) command to poll the coordinator as needed.

CCA (Clear Channel Assessment)

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.

Also, a delay is inserted before a transmission takes place. This delay is settable using the RN (Backoff Exponent) parameter. If RN is set to "0", then 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 modem will attempt to re- send the packet up to two additional times.

When in Unicast packets with RR (Retries) = 0, the modem will execute two CCA retries. Broadcast packets always get two CCA retries.

Acknowledgment

If the transmission is not a broadcast message, the modem will expect to receive an acknowledgment from the destination node. If an acknowledgment is not received, the packet will be resent up to three more times. If the acknowledgment is not received after all transmissions, an ACK failure is recorded.

Sleep mode

Sleep modes enable the RF modem to enter states of low-power consumption when not in use. In order to enter sleep mode, one of the following conditions must be met (in addition to the modem having a non-zero SM parameter value):

- DTR (data terminal ready) is de-asserted.
- The modem is idle (no data transmission or reception) for the amount of time defined by the ST (Time before Sleep) parameter. **Note** ST is only active when SM = 4-5.

Sleep mode configurations

Sleep mode setting	Transition into sleep mode	Transition out of sleep mode (wake)	Characteristics	Related commands	Power consumption
Pin hibernate (SM = 1)	De-assert DTR (data terminal ready)	Assert DTR	Pin/host-controlled / NonBeacon systems only / lowest power	(SM)	< 6 mA
Pin doze (SM = 2)	De-assert DTR (data terminal ready)	Assert DTR	Pin/host-controlled / NonBeacon systems only / fastest wake-up	(SM)	< 6 mA
Cyclic sleep (SM = 4 - 5)	Automatic transition to sleep mode as defined by the SM (Sleep Mode) and ST (Time before Sleep) parameters.	Transition occurs after the cyclic sleep time interval elapses. The time interval is defined by the SP (Cyclic Sleep Period) parameter.	RF modem wakes in pre-determined time intervals to detect if RF data is present / When SM = 5, NonBeacon systems only	(SM), SP, ST	< 25 mA when sleeping

The SM command is central to setting sleep mode configurations. By default, sleep modes are disabled (SM = 0) and the modem remains in idle/receive mode. When in this state, the modem is constantly ready to respond to serial or RF activity.

Higher voltages

Sleep mode current consumption is highly sensitive to voltage. Voltages above 3.0V will cause much higher current consumption.

Sample sleep mode currents

XBee				XBee-PRO		
Vcc (V)	SM=1	SM=2	SM=4,5	SM=1	SM=2	SM=4,5

	XBee			XBee-PRO		
2.8–3.0	<3 µA	<35uA	<34uA	<4uA	<34uA	<34uA
3.1	8uA	37mA	36uA	12uA	39uA	37uA
3.2	32uA	48uA	49uA	45uA	60uA	55uA
3.3	101uA	83uA	100uA	130uA	115uA	120uA
3.4	255uA	170uA	240uA	310uA	260uA	290uA

Pin/host-controlled sleep modes

The transient current when waking from pin sleep (SM = 1 or 2) does not exceed the idle current of the modem. The current ramps up exponentially to its idle current.

Pin hibernate (SM = 1)

- Pin/host-controlled
- Typical power-down current: < 6 mA
- Typical wake-up time: 10.2 milliseconds

Pin hibernate mode minimizes quiescent power (power consumed when in a state of rest or inactivity). This mode is voltage level-activated; when DTR is de-asserted, the modem will finish any transmit, receive or association activities, enter idle mode and then enter a state of sleep. The modem will not respond to either serial or RF activity while in pin sleep.

To wake a sleeping modem operating in Pin hibernate mode, assert DTR (data terminal ready). The modem will wake when DTR is asserted and is ready to transmit or receive when the CTS line is low. When waking the modem, the pin must be asserted at least two 'byte times' after CTS goes low. This assures that there is time for the data to enter the DI buffer.

Pin doze (SM = 2)

- Pin/host-controlled
- Typical power-down current: < 6 mA
- Typical wake-up time: 2.6 milliseconds

Pin doze mode functions like does Pin hibernate mode; however, Pin doze features faster wake-up time and higher power consumption.

To wake a sleeping modem operating in Pin doze mode, assert DTR (data terminal ready). The modem will wake when DTR is asserted and is ready to transmit or receive when the CTS line is low. When waking the modem, the pin must be asserted at least two 'byte times' after CTS goes low. This assures that there is time for the data to enter the DI buffer.

Cyclic sleep modes

Cyclic sleep remote (SM = 4)

- Typical power-down current: < 25 mA (when asleep)
- Typical wake-up time: 2.6 milliseconds

The cyclic sleep modes allow modems to periodically check for RF data. When the SM parameter is set to '4', the modem is configured to sleep, then wakes once a cycle to check for data from a modem configured as a cyclic sleep coordinator (SM = 0, CE = 1). The cyclic sleep remote sends a poll request

to the coordinator at a specific interval set by the SP (Cyclic Sleep Period) parameter. The coordinator will transmit any queued data addressed to that specific remote upon receiving the poll request.

If no data is queued for the remote, the coordinator will not transmit and the remote will return to sleep for another cycle. If queued data is transmitted back to the remote, it will stay awake to allow for back and forth communication until the ST (Time before Sleep) timer expires.

Also note that CTS will go low each time the remote wakes, allowing for communication initiated by the remote host if desired.

Cyclic sleep remote with pin wake-up (SM = 5)

Use this mode to wake a sleeping remote modem through either the RF interface or by the assertion of DTR for event-driven communications. The cyclic sleep mode works as described above (cyclic sleep remote) with the addition of a pin-controlled wake-up at the remote modem. The DTR pin is edge-triggered, not level-triggered. The modem will wake when a low is detected then set CTS low as soon as it is ready to transmit or receive.

Any activity will reset the ST (Time before Sleep) timer so the modem will go back to sleep only after there is no activity for the duration of the timer. Once the module wakes (pin-controlled), further pin activity is ignored. The modem transitions back into sleep according to the ST time regardless of the state of the pin.

(Cyclic sleep coordinator (SM = 6))

- Typical current = receive current
- Always awake

Note The SM=6 parameter value exists solely for backwards compatibility with firmware version 1.x60. If backwards compatibility with the older firmware version is not required, always use the CE (Coordinator Enable) command to configure a modem as a coordinator.

This mode configures a modem to wake cyclic sleeping remotes through RF interfacing. The coordinator will accept a message addressed to a specific remote 16 or 64-bit address and hold it in a buffer until the remote wakes and sends a poll request. Messages not sent directly (buffered and requested) are called indirect messages. The coordinator only queues one indirect message at a time. The coordinator will hold the indirect message for a period 2.5 times the sleeping period indicated by the SP (Cyclic Sleep Period) parameter. The coordinator's SP parameter should be set to match the value used by the remotes.

Command mode

To modify or read RF modem parameters, the modem must first enter into Command mode - a state in which incoming characters are interpreted as commands. Two command mode types are supported: AT command mode and API command mode.

AT command mode

To enter AT command mode:

Send the 3-character command sequence "+++" and observe guard times before and after the command characters.

Default AT Command Mode Sequence (for transition to Command mode):

- No characters sent for one second GT (Guard Times) parameter = 0x3E8.
- Input three plus characters ("+++") within one second (CC (Command Sequence Character)

parameter = 0x2B.

- No characters sent for one second GT (Guard Times) parameter = 0x3E8.

All of the parameter values in the sequence can be modified to reflect user preferences.

Note Failure to enter AT Command mode is most commonly due to baud rate mismatch. Ensure the **baud** setting on the **PC Settings** tab matches the interface data rate of the RF modem. By default, the BD parameter = 3 (9600 bps).

To send AT commands:

Send AT commands and parameters using the syntax shown below.

Syntax for sending AT commands

Example: ATDL 1F<CR>
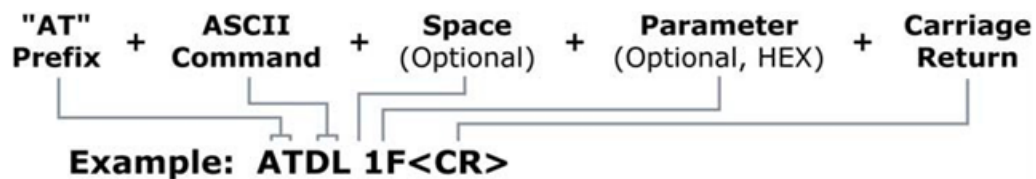
To read a parameter value stored in the RF modem's register, omit the parameter field.

The preceding example would change the RF modem destination address (Low) to "0x1F." To store the new value to non-volatile (long term) memory, subsequently send the WR (Write) command.

For modified parameter values to persist in the modem's registry after a reset, changes must be saved to non-volatile memory using the WR (Write) command. Otherwise, parameters are restored to previously saved values after the modem is reset.

System response

When a command is sent to the modem, the modem will parse and execute the command. Upon successful execution of a command, the modem returns an "**OK**" message. If execution of a command results in an error, the modem returns an "**ERROR**" message.

To exit AT Command mode:

1. Send the ATCN (Exit Command Mode) command (followed by a carriage return).
   OR

2. If no valid AT commands are received within the time specified by CT (Command Mode Timeout) Command, the RF modem automatically returns to Idle Mode.

For an example that illustrates programming the RF modem using AT commands, refer to RF modem configuration.

Programming the RF Modem

Refer to the Command mode section for more information about entering command mode, sending AT commands and exiting command mode. For information regarding modem programming using API mode, refer to the API operation.

Configure the device using XCTU

(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.

Setup

The programming examples in this section require the installation of Digi's XCTU software and an RS-232 connection to a PC.

1. Download and install XCTU at https://www.digi.com/products/xbee-rf-solutions/xctu-software/xctu.

2. Connect the RF modem to a PC using their respective serial ports.

3. Launch the XCTU software and select the **Configuration working mode** tab. Verify that the baud and parity settings of the Com port match those of the RF modem.

Note Failure to enter AT Command mode is most commonly due to baud rate mismatch. Ensure the **baud** setting on the **Configuration working mode** tab matches the interface data rate of the RF modem (by default, BD parameter = 3 (which corresponds to 9600 bps)).

Sample configuration: modify RF modem destination address

Example: Use the XCTU **Consoles working mode** tab to change the RF modem's DL (Destination Address Low) parameter and save the new address to non-volatile memory.

After establishing a serial connection between the RF modem and a PC, select the **Consoles working mode** tab of XCTU and enter the following command lines (CR stands for carriage return):

Method 1 (one line per command).

Send AT command	System response
+++	OK <CR> (enter into Command mode)
ATDL <Enter>	{current value} <CR> (Read Destination Address Low)
ATDL1A0D <Enter>	OK <CR> (Modify Destination Address Low)
ATWR <Enter>	OK <CR> (Write to non-volatile me mory)
ATCN <Enter>	OK <CR> (Exit Command mode)

Method 2 (multiple commands on one line).

Send AT command	System response
+++	OK <CR> (enter into Command mode)
ATDL <Enter>	{current value} <CR> (Read Destination Address Low)
ATDL1A0D,WR,CN <Enter>	OK<CR> OK<CR> OK<CR>

Sample configuration: restore RF modem defaults

Example: Use the XCTU **Configuration** tab to restore default parameter values.

After establishing a connection between the modem and a PC, select the **Configuration** tab of XCTU.

1. Click the **Read** button.
2. Click the **Restore** button.

Command reference

XBee-PRO RF modems expect numerical values in hexadecimal. Hexadecimal values are designated by a "0x" prefix. Decimal equivalents are designated by a "d" suffix. Table rows are sorted by command category, then by logic of most commonly used.

All modems operating within the same network should contain the same firmware version.

Special commands

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

WR command

Write: Write parameter values to non-volatile memory so that parameter modifications persist through subsequent power-up or reset.

Note Once WR is issued, no additional characters should be sent to the modem until after the response "OK\r" is received.

Parameter range

-

Default

-

RE command

Restore Defaults: Restore modem parameters to factory defaults

Parameter range

-

Default

-

FR command (v1.x80)

Software reset: Responds immediately with an OK then performs a hard reset ~100ms later.

Parameter range

-

Default

-

Networking commands: addressing

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

CH command

Channel: Set/read the channel number used for transmitting and receiving data between RF modems (uses 802.15.4 protocol channel numbers).

Parameter range

0x0C - 0x17

Default

0x0C (12d)

ID command

PAN ID: Set/read the PAN (Personal Area Network) ID. Use 0xFFFF to broadcast messages to all PANs.

Parameter range

0 - 0xFFFF

Default

0x3332 (13106d)

DH command

Destination address high: Set/read the upper 32 bits of the 64-bit destination address. When combined with DL, it defines the destination address used for transmission. To transmit using a 16-bit address, set DH parameter to zero and DL less than 0xFFFF. 0x000000000000FFFF is the broadcast address for the PAN.

Parameter range

0 - 0xFFFFFFFF

Default

0

DL command

Destination address low: Set/read the lower 32 bits of the 64-bit destination address. When combined with DH, DL defines the destination address used for transmission. To transmit using a 16-bit address, set DH parameter to zero and DL less than 0xFFFF. 0x000000000000FFFF is the broadcast address for the PAN.

Parameter range

0 - 0xFFFFFFFF

Default

0

MY command

16-bit source address: Set/read the RF modem 16-bit source address. Set MY = 0xFFFF to disable reception of packets with 16-bit addresses. 64-bit source address (serial number) and broadcast address (0x000000000000FFFF) is always enabled.

Parameter range

0 - 0xFFFF

Default

0

SH command

Serial number high: Read high 32 bits of the RF modem's unique IEEE 64-bit address. 64-bit source address is always enabled.

Parameter

0 - 0xFFFFFFFF (read-only)

Default

Factory-set

SL command

Serial number low: Read low 32 bits of the RF modem's unique IEEE 64-bit address. 64-bit source address is always enabled.

Parameter

0 - 0xFFFFFFFF (read-only)

Default

Factory-set

RR command (v1.xA0)

XBee retries: Set/read the maximum number of retries the modem will execute in addition to the 3 retries provided by the 802.15.4 MAC. For each XBee retry, the 802.15.4 MAC can execute up to 3 retries.

Parameter range

0 - 6

Default

9

RN command

Random delay slots: Set/read the minimum value of the back-off exponent in the CSMA-CA algorithm that is used for collision avoidance. If RN = 0, collision avoidance is disabled during the first iteration of the algorithm (802.15.4 - macMinBE).

Parameter range

0 - 3 (exponent)

Default

0

MM command (v1.x80)

MAC mode: Set/read MAC Mode value. MAC Mode enables/disables the use of a Digi header in the 802.15.4 RF packet.
When Mode 0 is enabled (MM=0), duplicate packet detection is enabled as well as certain AT commands. Modes 1 and 2 are strict 802.15.4 modes.

Parameter range

0 - 2

> 0 = Digi Mode
> 1 = 802.15.4 (no ACKs)
> 2 = 802.15.4 (with ACKs)

Default

0

Networking commands: identification

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

NI command (v1.x80)

Node identifier: Stores a string identifier. The register only accepts printable ASCII data. A string cannot start with a space. Carriage return ends command. Command will automatically end when maximum bytes for the string have been entered. This string is returned as part of the ND (Node Discover) command. This identifier is also used with the DN (Destination Node) command.

Parameter range

20-character ASCII string

Default

-

ND command (v1.x80)

Node discover: Discovers and reports all RF modems found. The following information is reported for each modem discovered (the example cites use of Transparent operation (AT command format) - refer to the long ND command description regarding differences between Transparent and API operation).

> MY<CR>
> SH<CR>
> SL<CR>
> DB<CR>
> NI<CR><CR>

The amount of time the modem allows for responses is determined by the NT parameter. In Transparent operation, command completion is designated by a <CR> (carriage return). ND also accepts a Node Identifier as a parameter. In this case, only a modem matching the supplied identifier will respond.

Parameter range

Optional 20-character NI value

NT command (v1.xA0)

Node discover time: Set/read the amount of time a node will wait for responses from other nodes when using the ND (Node Discover) command.

Parameter range

0x01 - 0xFC

Default

0x19

DN command (v1.x80)

Destination Node. Resolves an NI (node identifier) string to a physical address.
The following events occur upon successful command execution:

1. DL and DH are set to the address of the modem with the matching Node Identifier.
2. "OK" is returned.
3. RF modem automatically exits AT command mode.

If there is no response from a modem within 200 msec or a parameter is not specified (left blank), the command is terminated and an "ERROR" message is returned.

Parameter range

20-character ASCII string

Default

-

Networking commands: association

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

CE command (v1.x80)

Coordinator enable: Set/read the coordinator setting.

Parameter range

0 - 1

> 0 = End device
> 1 = Coordinator

Default

0

SC command (v1.x80)

Scan channels: Set/read list of channels to scan for all active and energy scans as a bitfield. This affects scans initiated in command mode (AS, ED) and during end device association and coordinator startup:

> bit 0 - 0x0B bit 4 - 0x0F bit 8 - 0x13 bit12 - 0x17
> bit 1 - 0x0C bit 5 - 0x10 bit 9 - 0x14 bit13 - 0x18
> bit 2 - 0x0D bit 6 - 0x11 bit 10 - 0x15 bit14 - 0x19
> bit 3 - 0x0E bit 7 - 0x12 bit 11 - 0x16 bit 15 - 0x1A

Parameter

0 - 0xFFFF (bitfield) (bits 0, 14, 15 not allowed on the XBee-PRO)

Default

0x1FFE (all XBee- PRO Channels)

SD command (v1.x80)

Scan duration: Set/read the scan duration exponent.

End device - Duration of active scan during association. On a beacon system, set SD = BE of coordinator. SD must be set at least to the highest BE parameter of any Beaconing Coordinator which an end device or coordinator will discover.

Coordinator - If 'ReassignPANID' option is set on Coordinator (refer to A2 parameter), SD determines the length of time the Coordinator will scan channels to locate existing PANs. If 'ReassignChannel' option is set, SD determines how long the Coordinator will perform an Energy Scan to determine which channel it will operate on.

'Scan time' is measured as (# of channels to scan) * (2 ^ SD) * 15.36ms). The number of channels to scan is set by the SC command. The XBee can scan up to 16 channels (SC = 0xFFFF). The XBee PRO can scan up to 13 channels (SC = 0x3FFE).

Example: The values below show results for a 13 channel scan:

> If SD = 0, time = 0.18 sec SD = 8, time = 47.19 sec
> SD = 2, time = 0.74 sec SD = 10, time = 3.15 min
> SD = 4, time = 2.95 sec SD = 12, time = 12.58 min
> SD = 6, time = 11.80 sec SD = 14, time = 50.33 min

Parameter range

0-0x0F (exponent)

Default

4

A1 command (v1.x80)

End device association: Set/read end device association options.

bit 0 - ReassignPanID

> 0 - Will only associate with Coordinator operating on PAN ID that matches modem ID
> 1 - May associate with coordinator operating on any PAN ID.

bit 1 - ReassignChannel

> 0 - Will only associate with coordinator operating on matching CH channel setting
> 1 - May associate with Coordinator operating on any channel.

bit 2 - AutoAssociate

> 0 - Device will not attempt association
> 1 - Device attempts association until success

Note This bit is used only for Non-Beacon systems. End devices in a Beacon-enabled system must always associate to a coordinator.

---

bit 3 - PollCoordOnPinWake

> 0 - Pin wake will not poll the coordinator for indirect (pending) data
> 1 - Pin wake will send poll request to coordinator to extract any pending data

bits 4 - 7 are reserved

Parameter range

0 - 0x0F (bitfield)

Default

0

A2 command (v1.x80)

Coordinator association: Set/read coordinator association options.
bit 0 - ReassignPanID.

> 0 - Coordinator will not perform active scan to locate available PAN ID. It will operate on ID (PAN ID).

> 1 - Coordinator will perform active scan to determine an available ID (PAN ID). If a PAN ID conflict is found, the ID parameter will change.

bit 1 - ReassignChannel -

> 0 - Coordinator will not perform energy scan to determine free channel. It will operate on the channel determined by the CH parameter.

> 1 - Coordinator will perform energy scan to find a free channel, then operate on that channel.

bit 2 - AllowAssociation -

> 0 - Coordinator will not allow any devices to associate to it.

> 1 - Coordinator will allow devices to associate to it.

bits 3 - 7 are reserved

Parameter range

0 - 7 (bitfield)

Default

0

AI command (v1.x80)

Association indication: Read errors with the last association request:

0x00 - Successful completion - coordinator successfully started or end device association complete.

0x01 - Active scan timeout.

0x02 - Active scan found no PANs.

0x03 - Active scan found PAN, but the CoordinatorAllowAssociation bit is not set 0x04 - active scan found PAN, but coordinator and end device are not configured to support beacons.

0x05 - Active scan found PAN, but the coordinator ID parameter does not match the ID parameter of the end device.

0x06 - Active scan found PAN, but the coordinator CH parameter does not match the CH parameter of the end device.

0x07 - Energy scan timeout.

0x08 - Coordinator start request failed.

0x09 - Coordinator could not start due to invalid parameter 0x0A - coordinator realignment is in progress.

0x0B - Association request not sent.

0x0C - Association request timed out - no reply was received 0x0D - association request had an Invalid Parameter.

0x0E - Association request channel access failure. Request was not transmitted - CCA failure.

0x0F - Remote coordinator did not send an ACK after association request was sent 0x10 - remote coordinator did not reply to the association request, but an ACK was received after sending the request 0x11 - (reserved).

0x12 - Sync-loss - Lost synchronization with a Beaconing Coordinator

0x13 - Disassociated - No longer associated to coordinator.

Parameter range

0 - 0x13 (read-only)

DA command (v1.x80)

Force disassociation: End device will immediately disassociate from a coordinator (if associated) and reattempt to associate.

Parameter range

-

Default

-

FP command (v1.x80)

Force poll: Request indirect messages being held by a coordinator.

Parameter range

-

Default

-

AS command (v1.x80)

Active scan: Send beacon request to broadcast address (0xFFFF) and broadcast PAN (0xFFFF) on every channel. The parameter determines the time the radio will listen for Beacons on each channel. A PanDescriptor is created and returned for every Beacon received from the scan. Each PanDescriptor contains the following information:

CoordAddress (SH, SL)<CR>

CoordPanID (ID)<CR>

CoordAddrMode <CR>

        0x02 = 16-bit Short Address

        0x03 = 64-bit Long Address Channel (CH parameter) <CR>

SecurityUse<CR>

ACLEntry<CR>

SecurityFailure<CR>

SuperFrameSpec<CR> (2 bytes):

        bit 15 - Association permitted (MSB)

        bit 14 - PAN coordinator

        bit 13 - Reserved

        bit 12 - Battery life extension

　　　　　bits 8-11 - final CAP slot

　　　　　bits 4-7 - Superframe Order

　　　　　bits 0-3 - Beacon order

GtsPermit<CR>

RSSI<CR> (RSSI is returned as -dBm)

TimeStamp<CR> (3 bytes)

<CR>

A carriage return <CR> is sent at the end of the AS command. The active scan is capable of returning up to 5 PanDescriptors in a scan. The actual scan time on each channel is measured as Time = ((2 ^SD PARAM) * 15.36) ms. Note the total scan time is this time multiplied by the number of channels to be scanned (16 for the XBee and 13 for the XBee-PRO). Refer to SD (Scan Duration) command.

Parameter range

0-6

Default

-

ED command (v1.x80)

Energy scan: Send an energy detect scan.

This parameter determines the length of scan on each channel. The maximal energy on each channel is returned and each value is followed by a carriage return. An additional carriage return is sent at the end of the command. The values returned represent the detected energy level in units of -dBm. The actual scan time on each channel is measured as Time = ((2 ^ED) * 15.36) ms. Note the total scan time is this time multiplied by the number of channels to be scanned (refer to SD parameter).

Parameter range

0-6

Default

-

Networking commands: security

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

EE command (v1.xA0)

AES encryption enable: Disable/enable 128-bit AES encryption support. Use in conjunction with the KY command.

Parameter

0-1

Default

0 (disabled)

KY command (v1.xA0)

AES encryption key: Set the 128-bit AES (Advanced Encryption Standard) key for encrypting/decrypting data. The KY register cannot be read.

Parameter range

0 - (any 16-Byte value)

RF interfacing commands

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

PL command

Power level: Select/read the power level at which the RF modem transmits conducted power.

Note XBee-PRO RF modems optimized for use in Japan contain firmware that limits transmit power output to 10 dBm. If PL=4 (default), the maximum power output level is fixed at 10 dBm.

Parameter range

0 - 4 (XBee / XBee-PRO)

> 0 = -10 / 10 dBm
> 1 = -6 / 12 dBm
> 2 = -4 / 14 dBm
> 3 = -2 / 16 dBm
> 4 = 0 / 18 dBm

Default

4

CA command (v1.x80)

CCA threshold: Set/read the CCA (Clear Channel Assessment) threshold. Prior to transmitting a packet, a CCA is performed to detect energy on the channel. If the detected energy is above the CCA threshold, the modem will not transmit the packet.

Parameter range

0 - 0x50 (-dBm)

Default

0x2C (-44d dBm)

Sleep (low power) commands

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

SM command

Sleep mode: <NonBeacon firmware> Set/read sleep mode configurations.

Parameter range

0 - 5

       0 = No sleep

       1 = Pin hibernate 2 = Pin doze

       3 = Reserved

       4 = Cyclic sleep remote 5 = cyclic sleep remote w/ pin wake-up

       6 = (sleep coordinator) for backwards compatibility w/ v1.x6 only; otherwise, use CE command

Default

0

ST command

Time before sleep: <NonBeacon firmware> Set/read time period of inactivity (no serial or RF data is sent or received) before activating sleep mode. ST parameter is only valid with cyclic sleep settings (SM = 4 - 5).

Coordinator and end device ST values must be equal.

Also note, the GT parameter value must always be less than the ST value. (If GT > ST, the configuration will render the modem unable to enter into command mode.) If the ST parameter is modified, also modify the GT parameter accordingly.

Parameter range

1 - 0xFFFF (x 1 ms)

Default

0x1388 (5000d)

SP command

Cyclic sleep period: <NonBeacon firmware> Set/read sleep period for cyclic sleeping remotes. Coordinator and end device SP values should always be equal. To send direct messages, set SP = 0.

End device - SP determines the sleep period for cyclic sleeping remotes. Maximum sleep period is 268 seconds (0x68B0).

Coordinator - If non-zero, SP determines the time to hold an indirect message before discarding it. A coordinator will discard indirect messages after a period of (2.5 * SP).

Parameter range

0 - 0x68B0 (x 10 ms)

Default

0

DP command (v1.x80)

Disassociated cyclic sleep period: <NonBeacon firmware>

End device - Set/read time period of sleep for cyclic sleeping remotes that are configured for association but are not associated to a coordinator. (i.e. If a device is configured to associate, configured as a cyclic sleep remote, but does not find a coordinator, it will sleep for DP time before reattempting association.) Maximum sleep period is 268 seconds (0x68B0). DP should be > 0 for NonBeacon systems.

Parameter range

1 - 0x68B0 (x 10 ms)

Default

0x3E8 (1000d)

Serial interfacing commands

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

BD command

Interface data rate: Set/read the serial interface data rate for communications between the RF modem serial port and host.

Request non-standard baud rates with values above 0x80 using a terminal window. Read the BD register to find actual baud rate achieved.

Parameter range

0 - 7 (standard baud rates)

> 0 = 1200 bps
> 1 = 2400
> 2 = 4800
> 3 = 9600
> 4 = 19200
> 5 = 38400
> 6 = 57600
> 7 = 115200

0x80 - 0x1C200

(non-standard baud rates)

Default

3

RO command

Packetization timeout: Set/read number of character times of inter-character delay required before transmission. Set to zero to transmit characters as they arrive instead of buffering them into one RF packet.

Parameter range

0 - 0xFF (x character times)

Default

3

AP command (v1.x80)

API enable: Disable/enable API Mode.

Parameter range

0 - 2

> 0 = Disabled
>
> 1 = API enabled
>
> 2 = API enabled (w/escaped control characters)

Default

0

PR command (v1.x80)

Pull-up resistor enable: Set/read bitfield to configure internal pull-up resistor status for I/O lines.
Bitfield map:

> bit 0 - AD4/DIO4 (pin11)
>
> bit 1 - AD3/DIO3 (pin17)
>
> bit 2 - AD2/DIO2 (pin18)
>
> bit 3 - AD1/DIO1 (pin19)
>
> bit 4 - AD0/DIO0 (pin20)
>
> bit 5 - RTS/AD6/DIO6 (pin16)
>
> bit 6 - DTR/SLEEP_RQ/DI8 (pin9)
>
> bit 7 - DIN/CONFIG (pin3)

Bit set to "1" specifies pull-up enabled; "0" specifies no pull-up

Parameter range

0 - 0xFF

Default

0xFF

I/O settings commands

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

Note The "I/O settings" commands listed below refer to the I/O lines of the OEM RF module embedded inside the boxed RF modem. Implementation of these commands requires board-level development and is not supported when using the DB-9 serial connection of the RF modem.

D8 command

DI8 configuration: Select/read options for the DI8 line (pin 9) of the RF modem.

Parameter range

0 - 1

> 0 = Disabled
>
> 3 = DI

(1,2,4 and 5 n/a)

Default

0

D7 command (v1.x80)

DIO7 configuration: Select/read settings for the DIO7 line (pin 12) of the RF modem. Options include CTS flow control and I/O line settings.

Parameter range

0 - 1

> 0 = Disabled
> 1 = CTS Flow Control
> 2 = (n/a)
> 3 = DI
> 4 = DO low
> 5 = DO high

Default

1

D6 command (v1.x80)

DIO6 configuration: Select/read settings for the DIO6 line (pin 16) of the RF modem. Options include RTS flow control and I/O line settings.

Parameter range

0 - 1

> 0 = Disabled
> 1 = RTS flow control
> 2 = (n/a)
> 3 = DI
> 4 = DO low
> 5 = DO high

Default

0

D5 command (v1.x80)

DIO5 configuration: Configure settings for the DIO5 line (pin 15) of the RF modem. Options include associated LED indicator (blinks when associated) and I/O line settings.

Parameter range

0 - 1

> 0 = Disabled
> 1 = Associated indicator
> 2 = ADC
> 3 = DI
> 4 = DO low

5 = DO high

Default

1

D0 to D4 commands (v1.xA0)

(DIO0 -DIO4) configuration: Select/read settings for the following lines: AD0/DIO0 (pin 20), AD1/DIO1 (pin 19), AD2/DIO2 (pin 18), AD3/DIO3 (pin 17), AD4/DIO4 (pin 11).

Options include: Analog-to-digital converter, digital input and digital output.

Parameter range

0 - 1

0 = Disabled

1 = (n/a)

2 = ADC

3 = DI

4 = DO low

5 = DO high

Default

0

IU command (v1.xA0)

I/O output enable: Disables/enables I/O data received to be sent out UART. The data is sent using an API frame regardless of the current AP parameter value.

Parameter range

0 - 1

0 = Disabled

1 = Enabled

Default

1

IT command (v1.xA0)

Samples before TX: Set/read the number of samples to collect before transmitting data. Maximum number of samples is dependent upon the number of enabled inputs.

Parameter range

1 - 0xFF

Default

1

IS command (v1.xA0)

Force sample: Force a read of all enabled inputs (DI or ADC). Data is returned through the UART. If no inputs are defined (DI or ADC), this command will return error.

Parameter range

8-bit bitmap (each bit represents the level of an I/O line setup as an output)

Default

-

IO command (v1.xA0)

Digital output level: Set digital output level to allow DIO lines that are setup as outputs to be changed through command mode.

Parameter range

-

Default

-

IC command (v1.xA0)

DIO change detect: Set/read bitfield values for change detect monitoring. Each bit enables monitoring of DIO0 - DIO7 for changes. If detected, data is transmitted with DIO data only. Any samples queued waiting for transmission will be sent first.

Parameter range

0 - 0xFF (bitfield)

Default

0 (disabled

IR command (v1.xA0)

Sample rate: Set/read sample rate. When set, this parameter causes the modem to sample all enabled inputs at a specified interval.

Parameter range

0 - 0xFFFF (x 1 msec)

Default

0

AV command (v1.xA0)

ADC voltage reference: <XBee-PRO only> Set/read ADC reference voltage switch.

Parameter range

0 - 1

      0 = VREF pin

      1 = Internal

Default

0

I/O settings commands: I/O line passing

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

IA command (v1.xA0)

I/O input address: Set/read addresses of modem to which outputs are bound. Setting all bytes to 0xFF will not allow any received I/O packet to change outputs. Setting address to 0xFFFF will allow any received I/O packet to change outputs.

Parameter range

0 - 0xFFFFFFFFFFFFFFFF

Default

0 - 0xFFFFFFFFFFFFFFFF

T0 to T7 commands (v1.xA0)

(D0 - D7) Output timeout: Set/read output timeout values for lines that correspond with the D0 - D7 parameters. When output is set (due to I/O line passing) to a non- default level, a timer is started which when expired will set the output to it default level. The timer is reset when a valid I/O packet is received.

Parameter range

0 - 0xFF (x 100 ms)

Default

0xFF

P0 command

PWM0 configuration: Select/read function for PWM0 pin.

Parameter range

0 - 2

> 0 = Disabled
> 1 = RSSI
> 2 = PWM Output

Default

1

P1 command (v1.xA0)

PWM1 configuration: Select/read function for PWM1 pin.

Parameter range

0 - 2

> 0 = Disabled
> 1 = RSSI
> 2 = PWM Output

Default

0

M0 command (v1.xA0)

PWM0 output level: Set/read the PWM0 output level.

Parameter range

0 - 0x03FF

Default

-

M1 command (v1.xA0)

PWM1 output level: Set/read the PWM0 output level.

Parameter range

0 - 0x03FF

Default

-

PT command (v1.xA0)

PWM output timeout: Set/Read output timeout value for both PWM outputs. When PWM is set to a non-zero value: Due to I/O line passing, a time is started which when expired will set the PWM output to zero. The timer is reset when a valid I/O packet is received.

Parameter range

0 - 0xFF (x 100 ms)

Default

0xFF

RP command (v1.xA0)

RSSI PWM timer: Set/read PWM timer register. Set the duration of PWM (pulse width modulation) signal output on the RSSI pin. The signal duty cycle is updated with each received packet and is shut off when the timer expires.)

Parameter range

0 - 0xFF (x 100 ms)

Default

0x28 (40d)

Diagnostics commands

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

VR command

Firmware version: Read firmware version of the RF modem.

Parameter range

0 - 0xFFFF (read-only)

Default

Factory-set

VL command (v1.x80)

Firmware version - verbose: Read detailed version information (including application build date, MAC, PHY and bootloader versions).

Parameter range

-

Default

-

HV command (v1.x80)

Hardware version: Read hardware version of the RF modem.

Parameter range

0 - 0xFFFF (read-only)

Default

Factory-set

DB command

Received signal strength: Read signal level (in dB) of last good packet received (RSSI). Absolute value is reported. (For example: 0x58 = -88 dBm). Reported value is accurate between -40 dBm and RX sensitivity.

Parameter range

0 - 0x64 (read-only)

Default

-

EC command (v1.x80)

CCA failures: Reset/read count of CCA (clear channel assessment) failures. This parameter value increments when the modem 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 count to "0" to reset count.

Parameter range

0 - 0xFFFF

Default

-

EA command (v1.x80)

ACK failures: Reset/read count of acknowledgment failures. This parameter value increments when the modem expires its transmission retries without receiving an ACK on a packet transmission. This count saturates at its maximum value. Set the parameter to "0" to reset count.

Parameter range

0 - 0xFFFF

Default

-

ED command (v1.x80)

Energy scan: Send energy detect scan. ED parameter determines the length of scan on each channel. The maximal energy on each channel is returned and each value is followed by a carriage return. Values returned represent detected energy levels in units of -dBm. Actual scan time on each channel is measured as Time = $((2 \wedge SD) * 15.36)$ ms. Total scan time is this time multiplied by the number of channels to be scanned.

Parameter range

0-6

Default

-

AT command options

Some of the following commands include a note about the firmware version where the command was first introduced, such as v1.x80. Firmware versions are numbered in hexadecimal notation.

CT command

Command mode timeout: Set/read the period of inactivity (no valid commands received) after which the RF modem automatically exits AT command mode and returns to idle mode.

Parameter range

2 - 0xFFFF (x 100 ms)

Default

0x64 (100d)

CNV command

Exit command mode: Explicitly exit the modem from AT command mode.

Parameter range

--

Default

--

AC command (v1.xA0)

Apply changes: Explicitly apply changes to queued parameter value(s) and re-initialize modem. Explicitly apply changes to queued parameter value(s) and re-initialize modem.

Parameter range

--

Default

--

GT command

Guard times: Set required period of silence before and after the command sequence characters of the AT command mode sequence (GT+ CC + GT). The period of silence is used to prevent inadvertent entrance into AT command mode.

Parameter range

2 - 0x0CE4 (x 1 ms)

Default

0x3E8 (1000d)

CC command

Command sequence character: Set/read the ASCII character value to be used between guard times of the AT command mode sequence (GT+CC+GT). The AT command mode sequence enters the RF modem into AT command mode.

Parameter range

0 - 0xFF

Default

0x2B ('+' ASCII)

Command descriptions

Command descriptions in this section are listed alphabetically. Command categories are designated within "< >" symbols that follow each command title. XBee-PRO RF modems expect parameter values in hexadecimal (designated by the "0x" prefix).

All modems operating within the same network should contain the same firmware version.

A1 (End Device Association) command

<Networking {Association}> The A1 command is used to set and read association options for an end device.

Use the table below to determine end device behavior in relation to the A1 parameter.

Bit number	End device association option
0 - ReassignPanID	0 - Will only associate with coordinator operating on PAN ID that matches node identifier.
	1 - May associate with coordinator operating on any PAN ID.
1 - ReassignChannel	0 - Will only associate with coordinator operating on channel that matches CH setting.
	1 - May associate with coordinator operating on any channel.
2 - AutoAssociate	0 - Device will not attempt association.
	1 - Device attempts association until success. **Note** This bit is used only for Non-Beacon systems. End devices in a Beaconing system must always associate to a coordinator.
3 - PollCoordOnPinWake	0 - Pin wake will not poll the coordinator for pending (indirect) Data.
	1 - Pin wake will send poll request to coordinator to extract any pending data.
4 - 7	(reserved)

AT command: ATA1

Parameter range

0 - 0x0F (bitfield)

Default parameter value

0

Related commands

ID (PAN ID), NI (Node Identifier), CH (Channel), CE (Coordinator Enable), A2 (Coordinator Association)

Minimum firmware version required

v1.x80

A2 (Coordinator Association) command

<Networking {Association}> The A2 command is used to set and read association options of the coordinator.

Use the table below to determine end device behavior in relation to the A1 parameter.

Bit number	End device association option
0-ReassignPanID	0 - Coordinator will not perform active scan to locate available PAN ID. It will operate on ID (PAN ID).
	1 - Coordinator will perform active scan to determine an available ID (PAN ID). If a PAN ID conflict is found, the ID parameter will change.
1-ReassignChannel	0 - Coordinator will not perform energy scan to determine free channel. It will operate on the channel determined by the CH parameter.
	1 - Coordinator will perform energy scan to find a free channel, then operate on that channel.
2 - AllowAssociate	0 - Coordinator will not allow any devices to associate to it.
	1 - Coordinator will allow devices to associate to it.
3 - 7	(reserved)

The binary equivalent of the default value (0x06) is 00000110. 'Bit 0' is the last digit of the sequence.

AT command: ATA2

Parameter range

0 - 7 (bitfield)

Default parameter value

0

Related commands

ID (PAN ID), NI (Node Identifier), CH (Channel), CE (Coordinator Enable), A1 (End Device Association), AS Active Scan), ED (Energy Scan)

Minimum firmware version required

v1.x80

AC (Apply Changes) command

<AT Command Mode Options> The AC command is used to explicitly apply changes to modem parameter values. Applying changes means that the modem is re-initialized based on changes made to its parameter values.
Once changes are applied, the modem immediately operates according to the new parameter values.

This behavior is in contrast to issuing the WR (Write) command. The WR command saves parameter values to non-volatile memory, but the modem still operates according to previously saved values until the modem is re-booted or the CN (Exit AT Command Mode) command is issued.

Refer to AT command - queue parameter value for more information.

AT command: ATAC

Minimum firmware version required

v1.xA0

AI (Association Indication) command

<Networking {Association}> The AI command is used to indicate occurrences of errors during the last association request.

Use the table below to determine meaning of the returned values.

Returned value (HEX)	Association indication
0x00	Successful completion - coordinator successfully started or end device association complete.
0x01	Active scan timeout.
0x02	Active scan found no PANs.
0x03	Active scan found PAN, but the coordinator allow association bit is not set.
0x04	Active scan found PAN, but coordinator and end device are not configured to support beacons.
0x05	Active scan found PAN, but coordinator ID (PAN ID) value does not match the ID of the end device.
0x06	Active scan found PAN, but coordinator CH (Channel) value does not match the CH of the end device.
0x07	Energy scan timeout.
0x08	Coordinator start request failed.
0x09	Coordinator could not start due to invalid parameter.
0x0A	Coordinator realignment is in progress.
0x0B	Association request not sent.
0x0C	Association request timed out - no reply was received.
0x0D	Association request had an invalid parameter.
0x0E	Association request channel access failure - request was not transmitted - CCA failure.
0x0F	Remote coordinator did not send an ACK after association request was sent.
0x10	Remote coordinator did not reply to the association request, but an ACK was received after sending the request.
0x11	(reserved)
0x12	Sync-loss - lost synchronization with a beaconing coordinator.
0x13	Disassociated - no longer associated to coordinator.

AT command: ATAI

Parameter range

0 - 0x13 (read-only)

Related commands

AS (Active Scan), ID (PAN ID), CH (Channel), ED (Energy Scan), A1 (End Device Association), A2 (Coordinator Association), CE (Coordinator Enable)

Minimum firmware version required

v1.x80

AP (API Enable) command

<Serial Interfacing> The AP command is used to enable the RF modem to operate using a frame-based API instead of using the default transparent (UART) mode.

Refer to API operation when API operation is enabled (AP = 1 or 2).

AT command: ATAP

Parameter range

0 - 2

Parameter

0

Parameter	Configuration
0	Disabled (transparent operation)
1	API enabled
2	API enabled (with escaped characters)

Default parameter value

0

Minimum firmware version required

v1.x80

AS (Active Scan) command

<AT Command Mode Options> The AS command is used to send a beacon request to a broadcast.

Address (0xFFFF) and broadcast PAN (0xFFFF) on every channel. The parameter determines the amount of time the RF modem will listen for beacons on each channel. A 'PanDescriptor' is created and returned for every beacon received from the scan.

Each PanDescriptor contains the following information:

CoordAddress (SH + SL parameters)<CR> CoordPanID (ID parameter)<CR> CoordAddrMode <CR>

 0x02 = 16-bit short address

 0x03 = 64-bit long address

Channel (CH parameter) <CR>

SecurityUse<CR> ACLEntry<CR>

SecurityFailure<CR>

SuperFrameSpec<CR> (2 bytes):

bit 15 - association permitted (MSB)

bit 14 - PAN coordinator

bit 13 - Reserved

bit 12 - Battery life extension

bits 8-11 - Final CAP slot

bits 4-7 - Superframe order

bits 0-3 - Beacon order

GtsPermit<CR>

RSSI<CR> (- RSSI is returned as -dBm)

TimeStamp<CR> (3 bytes)

<CR> (A carriage return <CR> is sent at the end of the AS command.

The active scan is capable of returning up to 5 PanDescriptors in a scan. The actual scan time on each channel is measured as Time = ((2 ^ (SD Parameter)) * 15.36) ms. Total scan time is this time multiplied by the number of channels to be scanned (16 for the XBee, 12 for the XBee-PRO).

Note Refer the scan table in the SD description to determine scan times. If using API mode, no <CR>'s are returned in the response. Refer to API operation.

AT command: ATAS

Parameter range

0 - 6

Related command

SD (Scan Duration), DL (Destination Low Address), DH (Destination High Address), ID (PAN ID), CH (Channel)

Minimum firmware version required

v1.x80

AV (ADC Voltage Reference) command

<Serial Interfacing> The AV command is used to AT command: ATAV

set/read the ADC reference voltage switch. The XBee-PRO has an ADC voltage reference switch which allows the modem to select between an on- board voltage reference or to use the VREF pin on the connector.

This command only applies to XBee-PRO RF modems and will return error on an XBee RF modem.

AT command: ATAV

Parameter range

0 - 1

Parameter	Configuration
0	VREF pin
1	Internal (on-board reference - VCC)

Default parameter value

0

Minimum firmware version required

v1.xAO

BD (Interface Data Rate) command

<Serial Interfacing> The AV command is used to set/read the ADC reference voltage switch. The XBee-PRO has an ADC voltage reference switch which allows the modem to select between the RF modem and host. This parameter determines the rate at which serial data is sent to the modem from the host. Modified interface data rates do not take effect until the CN (Exit AT Command Mode) command is issued and the system returns the **OK** response.

When parameters 0-7 are sent to the modem, the respective interface data rates are used (as shown in the table on the right).

The RF data rate is not affected by the BD parameter. If the interface data rate is set higher than the RF data rate, a flow control configuration may need to be implemented.

Non-standard interface data rates:

Any value above 0x07 will be interpreted as an actual baud rate. When a value above 0x07 is sent, the closest interface data rate represented by the number is stored in the BD register. For example, a rate of 19200 bps can be set by sending the following command line "ATBD4B00."

Note When using Digi's XCTU Software, non-standard interface data rates can only be set and read using the XCTU 'Terminal' tab. Non-standard rates are not accessible through the Modem Configuration tab.

When the BD command is sent with a non-standard interface data rate, the UART will adjust to accommodate the requested interface rate. In most cases, the clock resolution will cause the stored BD parameter to vary from the parameter that was sent (refer to the table below). Reading the BD command (send "ATBD" command without an associated parameter value) will return the value actually stored in the modem's BD register.

Parameters sent versus parameters stored

BD parameter sent (HEX)	Interface data rate (bps)	BD parameter stored (HEX)
0	1200	0
4	19,200	4
7	115,200	7
12C	300	12B
1C200	115,200	1B207

AT command: ATBD

Parameter range

0 - 7 (standard rates) 0x80-0x1C200 (non-standard rates)

Parameter	Configuration (bps)
0	1200
1	2400
2	4800
3	9600
4	1200
5	38400
6	57600
7	115200

Default parameter value

3

CA (CCA Threshold) command

<RF Interfacing> CA command is used to set and read CCA (Clear Channel Assessment) thresholds.

Prior to transmitting a packet, a CCA is performed to detect energy on the transmit channel. If the detected energy is above the CCA threshold, the RF modem will not transmit the packet.

AT command: ATCA

Parameter range

0 - 0x50 (-dBm)

Default parameter value

0x2C (-44 decimal dBm)

Minimum firmware version required

v1.x80

CC (Command Sequence Character) command

<AT Command Mode Options> The CC command is used to set and read the ASCII character used between guard times of the AT command mode sequence (GT + CC + GT). This sequence enters the RF modem into AT command mode so that data entering the modem from the host is recognized as commands instead of payload.

The AT command sequence is explained further in the AT command options section.

AT command: ATCC

Parameter range

0 - 0xFF

Default parameter value

0x2B (ASCII "+")

Related command

GT (Guard Times)

CE (Coordinator Enable) command

<Serial Interfacing> The CE command is used to set and read the behavior (end device vs. coordinator) of the RF modem.

AT command: ATCE

Parameter range

0 - 1

Parameter	Configuration
0	End device
1	Coordinator

Default parameter value

0

Minimum firmware version required

v1.x80

CH (Channel) command

<Networking {Addressing}> The CH command is used to set/read the operating channel on which RF connections are made between RF modems. The channel is one of three addressing options available to the modem. The other options are the PAN ID (ID command) and destination addresses (DL and DH commands).

For modems to communicate with each other, the modems must share the same channel number. Different channels can be used to prevent modems in one network from listening to transmissions of another. Adjacent channel rejection is 23 dB.

The modem uses channel numbers of the 802.15.4 standard.

Center frequency = 2.405 + (CH - 11d) * 5 MHz (d = decimal)

Refer to Addressing for more information.

AT command: ATCH

Parameter range

0x0C - 0x17

Default parameter value

0x0C (12 decimal)

Related commands

ID (PAN ID), DL (Destination Address Low, DH (Destination Address High)

CN (Exit Command Mode) command

<AT Command Mode Options> The CN command is used to explicitly exit the RF modem from At command mode.

AT command: ATCN

CT (Command Mode Timeout) command

<AT Command Mode Options> The CT command is used to set and read the amount of inactive time that elapses before the RF modem automatically exits from AT command mode and returns to idle mode.

Use the CN (Exit Command Mode) command to exit AT command mode manually.

AT command: ATCT

Parameter range

2 - 0xFFFF (x 100 milliseconds)

Default parameter value

0x64 (100 decimal (which equals 10 decimal seconds)).

Number of bytes returned

2

Related command

CN (Exit Command Mode)

D0 - D4 (DIOn Configuration) commands

<I/O Settings> The D0, D1, D2, D3 and D4 commands are used to select/read the behavior of their respective AD/DIO lines (pins 20, 19, 18, 17 and 11 respectively).

Options include:

- Analog-to-digital converter
- Digital input
- Digital output

AT commands

ATD0, ATD1, ATD2, ATD3, ATD4

Parameter range

0 - 5

Parameter	Configuration
0	Disabled
1	n/a
2	ADC
3	DI
4	D0 low
5	D0 high

Default parameter value

0

Minimum firmware version required

1.x.A0

D5 (DIO5 Configuration) command

<I/O Settings> The D5 command is used to select/read the behavior of the DIO5 line (pin 15).

Options include:

- Associated indicator (LED blinks when the modem is associated)
- Analog-to-digital converter
- Digital input
- Digital output

AT command: ATD5

Parameter range

0 - 5

Parameter	Configuration
0	Disabled
1	Associated indicator
2	ADC
3	DI
4	DO low
5	DO high

Default parameter value

1

Parameters 2-5 supported as of firmware version 1.xA0

D6 (DIO6 Configuration) command

<I/O Settings> The D6 command is used to select/read the behavior of the DIO6 line (pin 16).

Options include:

- RTS flow control
- Analog-to-digital converter
- Digital input
- Digital output

AT command: ATD6

Parameter range

0 - 5

Parameter	Configuration
0	Disabled
1	RTS flow control
2	n/a
3	DI
4	DO low
5	DO high

Default parameter value

0

Parameters 3-5 supported as of firmware version 1.xA0

D7 (DIO7 Configuration) command

<I/O Settings> The D7 command is used to select/read the behavior of the DIO7 line (pin 12).

Options include:

- CTS flow control
- Analog-to-digital converter
- Digital input
- Digital output

AT command: ATD7

Parameter range

0 - 5

Parameter	Configuration
0	Disabled
1	CTS flow control
2	n/a
3	DI
4	DO low
5	DO high

Default parameter value

1

Parameters 3-5 supported as of firmware version 1.x.A0

D8 (DI8 Configuration) command

<I/O Settings> The D8 command is used to select/read the behavior of the DI8 line (pin 9).

This command enables configuring the pin to function as a digital input. This line is also used with pin sleep.

AT command: ATD8

Parameter range

0 - 5 (1, 2, 4 and 5 n/a)

Parameter	Configuration
0	Disabled
3	DI

Default parameter value

0

Minimum firmware version required

1.xA0

DA (Force Disassociation) command

<(Special)> The DA command is used to immediately disassociate an end device from a coordinator and reattempt to associate.

AT command: ATDA

Minimum firmware version required

v1.x80

DB (Received Signal Strength) command

<Diagnostics> DB parameter is used to read the received signal strength (in dBm) of the last RF packet received. Reported values are accurate between -40 dBm and the RF modem's receiver sensitivity.

Absolute values are reported. For example: 0x58 = -88 dBm (decimal). If no packets have been received (since last reset, power cycle or sleep event), "0" will be reported.

AT command: ATDB

Parameter range

0 - 0x64 (read-only)

DH (Destination Address High) command

<Networking {Addressing}> The DH command is used to set and read the upper 32 bits of the RF modem's 64-bit destination address. When combined with the DL (Destination Address Low) parameter, it defines the destination address used for transmission.

A modem will only communicate with other modems having the same channel (CH

parameter), PAN ID (ID parameter) and destination address (DH + DL parameters).

To transmit using a 16-bit address, set the DH parameter to zero and the DL parameter less than 0xFFFF. The broadcast address for the PAN is 0x000000000000FFFF (DL concatenated to DH) is the broadcast address for the PAN.

Refer to Addressing for more information.

AT command: ATDH

Parameter range

0 - 0xFFFFFFFF

Related commands

DL (Destination Address Low), CH (Channel), ID (PAN VID), MY (Source Address)

DL (Destination Address Low) command

<Networking {Addressing}> The DL command is used to set and read the lower 32 bits of the RF modem's 64-bit destination address. When combined with the DH (Destination Address High) parameter, it defines the destination address used for transmission.

A modem will only communicate with other modems having the same channel (CH parameter), PAN ID (ID parameter) and destination address (DH + DL parameters).

To transmit using a 16-bit address, set the DH parameter to zero and the DL parameter less than 0xFFFF. The broadcast for the PAN is 0x000000000000FFFF (DL concatenated to DH).

Refer to Addressing for more information.

AT command: ATDL

Parameter range

0 - 0xFFFFFFFF

Default parameter value

0

Related commands:

DH (Destination Address High), CH (Channel), ID (PAN VID), MY (Source Address)

DN (Destination Node) command

<Networking {Identification}> The DN command is used to resolve a NI (Node Identifier) string to a physical address. The following events occur upon successful command execution:

1. DL and DH are set to the address of the modem with the matching NI (Node Identifier).
2. **OK** is returned.
3. RF modem automatically exits AT command mode.

If there is no response from a modem within 200 milliseconds or a parameter is not specified (left blank), the command is terminated and an ERROR message is returned.

AT command: ATDN

Parameter range

20-character ASCII String

Minimum firmware version required

v1.x80

DP (Disassociation Cyclic Sleep Period) command

<Sleep Mode (Low Power)>

NonBeacon firmware

End device - The DP command is used to set and read the time period of sleep for cyclic sleeping remotes that are configured for Association but are not associated to a coordinator. For example, If a device is configured to associate, configured as a cyclic sleep remote, but does not find a coordinator, it will sleep for DP time before reattempting association.) Maximum sleep period is 268 seconds (0x68B0). DP should be > 0 for NonBeacon systems.

AT command: ATDP

Parameter range

1 - 0x68B0 (x 10 milliseconds)

Default parameter value

0x3E8 (1000 decimal)

Related commands

SM (Sleep Mode), SP (Cyclic Sleep Period), ST (Time before Sleep)

Minimum firmware version required

v1.x80

EA (ACK Failures) command

<Diagnostics> The EA command is used to reset and read the count of ACK (acknowledgment) failures. This parameter value increments when the modem expires its transmission retries without receiving an ACK on a packet transmission. This count saturates at its maximum value. Set the parameter to "0" to reset count.

AT command: ATEA

Parameter range

0 - 0xFFFF

Minimum firmware version required

v1.x80

EC (CCA Failures) command

<Diagnostics> The EC command is used to read and reset the count of CCA (Clear Channel Assessment) failures. This parameter value increments when the RF modem does not transmit a packet due to the detection of energy that is above the CCA threshold level (set with the CA command). This count saturates at its maximum value. Set the EC parameter to "0" to reset count.

AT command: ATEC

Parameter range

0 - 0xFFFF

Related command

CA (CCA Threshold)

Minimum firmware version required

v1.x80

ED (Energy Scan) command

<Networking {Association}> The ED command is used to send an "Energy Detect Scan." This parameter determines the length of scan on each channel. The maximal energy on each channel is returned and each value is followed by a carriage return. An additional carriage return is sent at the end of the command.

The values returned represent the detected energy level in units of -dBm. The actual scan time on each channel is measured as Time = ((2 ^ ED PARAM) * 15.36) ms.

Note Total scan time is this time multiplied by the number of channels to be scanned. Also refer to SD scan table. Use the SC (Scan Channel) command to choose which channels to scan.

AT command: ATED

Parameter range

0 - 6

Related command

SD (Scan Duration), SC (Scan Channel)

Minimum firmware version required

v1.x80

EE (AES Encryption Enable) command

<Networking {Security}> The EE command is used to set/read the parameter that disables/enables 128-bit AES encryption.

The XBee-PRO firmware uses the 802.15.4 Default Security protocol and uses AES encryption with a 128-bit key. AES encryption dictates that all modems in the network use the same key and the maximum RF packet size is 95 bytes.

When encryption is enabled, the modem will always use its 64-bit long address as the source address for RF packets. This does not affect how the MY (Source Address), DH (Destination Address High) and DL (Destination Address Low) parameters work.

If MM (MAC Mode) > 0 and AP (API Enable) parameter > 0:

With encryption enabled and a 16-bit short address set, receiving modems will only be able to issue RX (Receive) 64-bit indicators. This is not an issue when MM = 0.

If a modem with a non-matching key detects RF data, but has an incorrect key: When encryption is enabled, non-encrypted RF packets received will be rejected and will not be sent out the UART.

Transparent operation --> All RF packets are sent encrypted if the key is set.

API operation --> Receive frames use an option bit to indicate that the packet was encrypted.

AT command: ATEE

Parameter range

0 - 1

Parameter	Configuration
0	Disabled
1	Enabled

Default parameter value

0

Related commands

KY (Encryption Key), AP (API Enable), MM (MAC Mode)

Minimum firmware version required

v1.xA0

FP (Force Poll) command

<Networking (Association)> The FP command issued to request indirect messages being held by a coordinator.

AT command: ATFP

Minimum firmware version required

v1.x80

FR (Software Reset) command

<Special> The FR command is used to force a software reset on the RF modem. The reset simulates powering off and then on again the modem.

AT command: ATFR

Minimum firmware version required

v1.x80

GT (Guard Times) command

<AT Command Mode Options> GT Command is used to set the DI (Data In from host) time-of-silence that surrounds the AT command sequence character (CC Command) of the AT command mode sequence (GT + CC + GT).

The DI time-of-silence is used to prevent inadvertent entrance into AT Command Mode.

Refer to Command mode for more information regarding the AT command mode sequence.

AT command: ATGT

Parameter range

2 - 0x0CE4 (x 1 millisecond)

Default parameter value

0x3E8 (1000 decimal)

Related command

CC (Command Sequence Character)

HV (Hardware Version) command

<Diagnostics> The HV command is used to read the hardware version of the RF modem.

AT command: ATHV

Parameter range

0 - 0xFFFF (read-only)

Minimum firmware version required

v1.x80

IA (I/O Input Address) command

<I/O Settings {I/O Line Passing}> The IA command is used to bind a modem output to a specific address. Outputs will only change if received from this address. The IA command can be used to set/read both 16 and 64-bit addresses.

Setting all bytes to 0xFF will not allow the reception of any I/O packet to change outputs. Setting the IA address to 0xFFFF will cause the modem to accept all I/O packets.

AT command: ATIA

Parameter range

0 - 0xFFFFFFFFFFFFFFFF

Default parameter value

0xFFFFFFFFFFFFFFFF (will not allow any received I/O packet to change outputs)

Minimum firmware version required

v1.xA0

IC (DIO Change Detect) command

<I/O Settings> Set/read bitfield values for change detect monitoring. Each bit enables monitoring of DIO0 - DIO7 for changes.

If detected, data is transmitted with DIO data only. Any samples queued waiting for transmission will be sent first.

Refer to ADC and Digital I/O line support in the RF modem operation chapter for more information.

AT command: ATIC

Parameter range

0 - 0xFF (bitfield)

Default parameter value

0 (disabled)

Minimum firmware version required

1.xA0

ID (PAN ID) command

<Networking {Addressing}> The ID command is used to set and read the PAN (Personal Area Network) ID of the RF modem. Only modems with matching PAN IDs can communicate with each other. Unique PAN IDs enable control of which RF packets are received by a modem.

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

AT command: ATID

Parameter range

0 - 0xFFFF

Default parameter value

0x3332 (13106 decimal)

IO (Digital Output Level) command

<I/O Settings> The IO command is used to set digital output levels. This allows DIO lines set up as outputs to be changed through command mode.

AT command: ATIO

Parameter range

8-bit bitmap (where each bit represents the level of an I/O line that is setup as an output).

Minimum firmware version required

v1.xA0

IR (Sample Rate) command

<I/O Settings> The IR command is used to set/read the sample rate. When set, the module will sample all enabled IO/ADC lines at a specified interval. This command allows periodic reads of the ADC and DIO lines in a non-Sleep Mode setup.

Example: When IR = 0x0A, the sample rate is 10 ms (or 100 Hz).

AT command: ATIR

Parameter range

8-bit bitmap (where each bit represents the level of an I/O line that is setup as an output).

Default parameter value

0

Related command

IT (Samples before TX)

Minimum firmware version required

v1.xA0

IS (Force Sample) command

<I/O Settings> The IS command is used to force a read of all enabled DIO/ADC lines. The data is returned through the UART.

When operating in Transparent Mode (AP=0), the data is returned in the following format:

All bytes are converted to ASCII:

> Number of samples<CR> channel mask<CR>
>
> DIO data<CR> (If DIO lines are enabled<CR>
>
> ADC channel Data<cr> <-This will repeat for every enabled ADC channel<CR>
>
> <CR> (end of data noted by extra <CR>)

When operating in API mode (AP > 0), the command will immediately return an 'OK' response. The data will follow in the normal API format for DIO data.

AT command: ATIS

Parameter range

1 - 0xFF

Default parameter value

1

Minimum firmware version required

v1.xA0

IT (Samples before TX) command

<I/O Settings> The IT command is used to set/read the number of DIO and ADC samples to collect before transmitting data.

One ADC sample is considered complete when all enabled ADC channels have been read. The modem can buffer up to 93 bytes of sample data.

Since the modem uses a 10-bit A/D converter, each sample uses two bytes. This leads to a maximum buffer size of 46 samples or IT=0x2E.

When sleep modes are enabled and IR (Sample Rate) is set, the modem will remain awake until IT samples have been collected.

AT command: ATIT

Parameter range

1 - 0xFF

Default parameter value

1

Minimum firmware version required

v1.xA0

IU (I/O Output Enable) command

<I/O Settings> The IU command is used to disable/enable I/O UART output. When enabled (IU = 1), received I/O line data packets are sent out the UART. The data is sent using an API frame regardless of the current AP parameter value.

AT command: ATIU

Parameter range

0 - 1

Parameter	Configuration
0	Disabled - Received I/O line data packets will NOT sent out UART.
1	Enabled - Received I/O line data will be sent out UART

Default parameter value

1
Minimum firmware version required

1.xA0

KY (AES Encryption Key) command

<Networking {Security}> The KY command is used to set the 128-bit AES (advanced encryption standard) key for encrypting/decrypting data. Once set, the key cannot be read out of the module by any means.

The entire payload of the packet is encrypted using the key and the CRC is computed across the ciphertext. When encryption is enabled, each packet carries an additional 16 Bytes to convey the random CBC initialization vector (IV) to the receiver(s). The KY value may be "0" or any 128-bit value. Any other value, including entering ATKY by itself with no parameters, will cause an error. A module with the wrong key (or no key) will receive encrypted data, but the data driven out the serial port will be meaningless. Likewise, a module with a key will receive unencrypted data sent from a module without a key, but the output will be meaningless. Because CBC mode is utilized, repetitive data appears differently in different transmissions due to the randomly-generated IV.

When queried, the system will return an 'OK' message and the value of the key will not be returned.

AT command: ATKY

Parameter range

0 - (any 16-Byte value)

Default parameter value

0

Related command

EE (Encryption Enable)

Minimum firmware version required

v1.xA0

M0 (PWM0 Output Level) command

<I/O Settings> The M0 command is used to set/read the output level of the PWM0 line (pin 6).

Before setting the line as an output:

1. Enable PWM0 output (P0 = 2).
2. Apply settings (use CN or AC).

The PWM period is 64 μsec and there are 0x03FF (1023 decimal) steps within this period.

When M0 = 0 (0% PWM), 0x01FF (50% PWM), 0x03FF (100% PWM), and so on.

AT command: ATM0

Parameter range

0 - 0x03FF (steps)

Default parameter value

0

Related commands

P0 (PWM0 Enable), AC (Apply Changes), CN (Exit Command Mode)

Minimum firmware version required

v1.xA0

M1 (PWM1 Output Level) command

<I/O Settings> The M1 command is used to set/read the output level of the PWM1 line (pin 7). Before setting the line as an output:

1. Enable PWM1 output (P1 = 2).
2. Apply settings (use CN or AC).

AT command: ATM1

Parameter range

0 - 0x03FF

Parameter range

0 - 0x03FF

Related commands

P1 (PWM1 Enable), AC (Apply Changes), CN (Exit Command Mode)

Minimum firmware version required

v1.xA0

MM (MAC Mode) command

<Networking {Addressing}> The MM command is used to set and read the MAC Mode value. The MM command disables/enables the use of a Digi header contained in the 802.15.4 RF packet. By default (MM = 0), Digi Mode is enabled and the modem adds an extra header to the data portion of the 802.15.4 packet. This enables the following features:

- ND and DN command support
- Duplicate packet detection when using ACKs

The MM command allows users to turn off the use of the extra header. Modes 1 and 2 are strict 802.15.4 modes. If the Digi header is disabled, ND and DN parameters are also disabled.

Note When MM > 0, application and CCA failure retries are not supported.

AT command: ATMM

Parameter range

0 - 2

Parameter	Configuration
0	MaxStream Mode (802.15.4 + MaxStream header)
1	802.15.4 (no ACKs)
2	802.15.4 (with ACKs)

Default parameter value

0

Related commands

ND (Node Discover), DN (Destination Node)

Minimum firmware version required

v1.x80

MY (16-bit Source Address) command

<Networking {Addressing}> The MY command is used to set and read the 16-bit source address of the RF modem.

By setting MY to 0xFFFF, the reception of RF packets having a 16-bit address is disabled. The 64-bit address is the modem's serial number and is always enabled.

AT command: ATMY

Parameter range

0 - 0xFFFF

Default parameter value

0

Related commands

DH (Destination Address High), DL (Destination Address Low), CH (Channel), ID (PAN ID)

NB (Parity) command

<Serial Interfacing> The NB command is used to select/read the parity settings of the RF module for UART communications.

Note The module does not actually calculate and check the parity. It only interfaces with devices at the configured parity and stop bit settings.

AT command: ATNB

Parameter range

0 - 4

Parameter	Configuration
0	8-bit no parity
1	8-bit even
2	8-bit odd
3	8-bit mark
4	8-bit space

Default parameter value

0

Number of bytes returned

1

ND (Node Discover) command

<Networking {Identification}> The ND command is used to discover and report all modems on its current operating channel (CH parameter) and PAN ID (ID parameter). ND also accepts an NI (Node Identifier) value as a parameter. In this case, only a modem matching the supplied identifier will respond.

ND uses a 64-bit long address when sending and responding to an ND request. The ND command causes a modem to transmit a globally addressed ND command packet. The amount of time allowed for responses is determined by the NT (Node Discover Time) parameter.

In AT command mode, command completion is designated by a carriage return (0x0D). Since two carriage returns end a command response, the application will receive three carriage returns at the end of the command. If no responses are received, the application should only receive one carriage return. When in API mode, the application should receive a frame (with no data) and status (set to 'OK') at the end of the command. When the ND command packet is received, the remote sets up a random time delay (up to 2.2 sec) before replying as follows:

Node discover response (AT command mode format - transparent operation):

> MY (Source Address) value<CR>
>
> SH (Serial Number High) value<CR>
>
> SL (Serial Number Low) value<CR>
>
> DB (Received Signal Strength) value<CR>
>
> NI (Node Identifier) value<CR>
>
> <CR> (This is part of the response and not the end of command indicator.)

Node discover response (API format - data is binary (except for NI)):

> 2 bytes for MY (Source Address) value
>
> 4 bytes for SH (Serial Number High) value
>
> 4 bytes for SL (Serial Number Low) value
>
> 1 byte for DB (Received Signal Strength) value
>
> NULL-terminated string for NI (Node Identifier) value (max 20 bytes w/out NULL terminator)

AT command: ATND

Parameter Range

Optional 20-character NI value

Related commands

CH (Channel), ID (Pan ID), MY (Source Address), SH (Serial Number High), SL (Serial Number Low), NI (Node Identifier), NT (Node Discover Time)

Minimum firmware version required

v1.x80

NI (Node Identifier) command

<Networking {Identification}> The NI command is used to set and read a string for identifying a particular node.

Rules:

- Register only accepts printable ASCII data.
- A string cannot start with a space.
- A carriage return ends command
- Command will automatically end when maximum bytes for the string have been entered.

This string is returned as part of the ND (Node Discover) command. This identifier is also used with the DN (Destination Node) command.

AT command: ATNI

Parameter range

20-character ASCII string

Related commands

ND (Node Discover), DN (Destination Node)

Minimum firmware version required

v1.x80

NT (Node Discover Time) command

<Networking {Identification}> The NT command is used to set the amount of time a base node will wait for responses from other nodes when using the ND (Node Discover) command. The NT value is transmitted with the ND command.

Remote nodes will set up a random hold-off time based on this time. The remotes will adjust this time down by 250 ms to give each node the ability to respond before the base ends the command. Once the ND command has ended, any response received on the base would be discarded.

AT command: ATNT

Parameter range

0x01 - 0xFC (x 100 milliseonds)

Default

0x19 (2.5 decimal seconds)

Related commands

ND (Node Discover)

Minimum firmware version required

1.xA0

P0 (PWM0 Configuration) command

<I/O Setting {I/O Line Passing}> The P0 command is used to select/read the function for PWM0 (Pulse Width Modulation output 0). This command enables the option of translating incoming data to a PWM so that the output can be translated back into analog form.

With the IA (I/O Input Address) parameter correctly set, AD0 values can automatically be passed to PWM0.

AT command: ATP0

Parameter range

0 - 2

Parameter	Configuration
0	Disabled
1	RSSI
2	PWM0 output

Default parameter value

1

P1 (PWM1 Configuration) command

<I/O Setting {I/O Line Passing}> The P1 command is used to select/read the function for PWM1 (Pulse Width Modulation output 1). This command enables the option of translating incoming data to a PWM so that the output can be translated back into analog form.

With the IA (I/O Input Address) parameter correctly set, AD1 values can automatically be passed to PWM1.

AT command: ATP1

Parameter range

0 - 2

Parameter	Configuration
0	Disabled
1	RSSI
2	PWM1 output

Default parameter value

0

Minimum firmware version required

v1.xA0

PL (Power Level) command

<RF Interfacing> The PL command is used to select and read the power level at which the RF modem transmits conducted power.

When operating in Europe:

XBee-PRO 802.15.4 RF Modems must be configured to operate at or below a transmit power output level of 10 dBm.

The PL parameter must equal "0" (10 dBm). Customers have two choices for transmitting at or below 10 dBm:

  ■ Order the standard XBee-PRO module and change the PL command to "0" (10dBm).

AT command: ATPL

Parameter range

Parameter	XBee	XBee-PRO
0	-10 dBm	10 dBm
1	-6 dBm	12 dBm
2	-4 dBm	14 dBm
3	-2 dBm	16 dBm
4	0 dBm	18 dBm

0 - 4

Default parameter value

4

PR (Pull-up Resistor Enable) command

<Serial Interfacing> The PR command is used to set and read the bit field that is used to configure internal the pull-up resistor status for I/O lines. "1" specifies the pull-up resistor is enabled. "0" specifies no pull up.

> bit 0 - AD4/DIO4 (pin 11)
> bit 1 - AD3/DIO3 (pin 17)
> bit 2 - AD2/DIO2 (pin 18)
> bit 3 - AD1/DIO1 (pin 19)
> bit 4 - AD0/DIO0 (pin 20)
> bit 5 - AD6/DIO6 (pin 16)
> bit 6 - DI8 (pin 9)
> bit 7 - DIN/CONFIG (pin 3)

For example: Sending the command "ATPR 6F" will turn bits 0, 1, 2, 3, 5 and 6 ON; and bits 4 and 7 will be turned OFF. (The binary equivalent of "0x6F" is "01101111". Note that 'bit 0' is the last digit in the bitfield.

AT command: ATPR

Parameter range

0 - 0xFF

Default parameter value

0xFF (all pull-up resistors are enabled)

Minimum firmware version required

v1.x80

PT (PWM Output Timeout) command

<I/O Settings {I/O Line Passing}> The PT command is used to set/read the output timeout value for both PWM outputs.

When PWM is set to a non-zero value: Due to I/O line passing, a time is started which when expired will set the PWM output to zero. The timer is reset when a valid I/O packet is received.

AT command: ATPT

Parameter range

0 - 0xFF (x 100 milliseconds)

Default parameter value

0xFF

Minimum firmware version required

1.xA0

RE (Restore Defaults) command

<(Special)> The RE command is used to restore all configurable parameters to their factory default settings. The RE command does not write restored values to non-volatile (persistent) memory. Issue the WR (Write) command subsequent to issuing the RE command to save restored parameter values to non-volatile memory.

AT command: ATRE

RN (Random Delay Slots) command

<Networking and Security> The RN command is used to set and read the minimum value of the back-off exponent in the CSMA-CA algorithm. The CSMA-CA algorithm was engineered for collision avoidance (random delays are inserted to prevent data loss caused by data collisions).

If RN = 0, collision avoidance is disabled during the first iteration of the algorithm (802.15.4 - macMinBE).

CSMA-CA stands for carrier sense multiple access - collision avoidance." Unlike CSMA-CD (reacts to network transmissions after collisions have been detected), CSMA-CA acts to prevent data collisions before they occur. As soon as a modem receives a packet that is to be transmitted, it checks if the channel is clear (no other modem is transmitting).

If the channel is clear, the packet is sent over-the-air. If the channel is not clear, the modem 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.

AT command: ATTN

Parameter range

0 - 3 (exponent)

Default parameter value

0

RO (Packetization Timeout) command

<Serial Interfacing> RO command is used to set and read the number of character times of inter-character delay required before transmission.

RF transmission commences when data is detected in the DI (data in from host) buffer and RO character times of silence are detected on the UART receive lines (after receiving at least 1 byte).

RF transmission will also commence after 100 Bytes (maximum packet size) are received in the DI buffer.

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

AT command: ATRO

Parameter range

0 - 0xFF (x character times)

Default parameter value

3

RP (RSSI PWM Timer) command

<I/O Settings {I/O Line Passing}> The RP command is used to enable PWM (pulse width modulation) output on the RF modem. The output is calibrated to show the level a received RF signal is above the sensitivity level of the modem. The PWM pulses vary from 24 to 100%. Zero percent means PWM output is inactive. One to 24% percent means the received RF signal is at or below the published sensitivity level of the modem. The following table shows levels above sensitivity and PWM values.

The total period of the PWM output is 64 µs. Because there are 445 steps in the PWM output, the minimum step size is 144 ns.

PWM percentages

dB above Sensitivity	PWM percentage (high period / total period)
10	41%
20	58%
30	75%

A non-zero value defines the time that the PWM output will be active with the RSSI value of the last received RF packet. After the set time when no RF packets are received, the PWM output will be set low (0 percent PWM) until another RF packet is received. The PWM output will also be set low at power-up until the first RF packet is received. A parameter value of 0xFF permanently enables the PWM output and it will always reflect the value of the last received RF packet.

AT command: ATRP

Parameter range

0 - 0xFF (x 100 msec)

Default parameter value

0x28 (40 decimal)

RR (XBee Retries) command

<Networking {Addressing}> The RR command is used set/read the maximum number of retries the modem will execute in addition to the three retries provided by the 802.15.4 MAC. For each XBee retry, the 802.15.4 MAC can execute up to three retries.

This values does not need to be set on all modems for retries to work. If retries are enabled, the transmitting modem will set a bit in the Digi RF Packet header which requests the receiving modem to send an ACK (acknowledgment). If the transmitting modem does not receive an ACK within 200 milliseconds, it will re-send the packet within a random period up to 48 msec. Each XBee retry can potentially result in the MAC sending the packet four times (one try plus three retries). Note that retries are not attempted for packets that are purged when transmitting with a cyclic sleep coordinator.

AT command: ATRR

Parameter Range

0 - 6

Default

0

Minimum firmware version required

1.xA0

SC (Scan Channels) command

<Networking {Association}> The SC command is used to set and read the list of channels to scan for all active and energy scans as a bit field.

This affects scans initiated in command mode AS (Active Scan) and ED (Energy Scan) commands and during end device association and coordinator startup.

bit 0 - 0x0B	bit 4 - 0x0F	bit 8 - 0x13	bit 12 - 0x17
bit 1 - 0x0C	bit 5 - 0x10	bit 9 - 0x14	bit 13 - 0x18
bit 2 - 0x0D	bit 6 - 0x11	bit 10 - 0x15	bit 14 - 0x19
bit 3 - 0x0E	bit 7 - 0x12	bit 11 - 0x16	bit 15 - 0x1A

AT command: ATSC

Parameter range

0 - 0xFFFF (Bitfield) (bits 0, 14, 15 are not allowed when using the XBee-PRO)

Default parameter value

0x1FFE (all XBee- PRO channels)

Related commands

ED (Energy Scan), SD (Scan Duration)

Minimum firmware version required

v1.x80

SD (Scan Duration) command

<Networking {Association}> The SD command is used to set and read the exponent value that determines the duration (in time) of a scan.

End device - (Duration of active scan during association) - In a Beacon system, set SD = BE of the coordinator. SD must be set at least to the highest BE parameter of any beaconing coordinator with which an end device or coordinator wish to discover.

Coordinator - If the 'ReassignPANID' option is set on the coordinator (refer to A2 parameter), the SD parameter determines the length of time the coordinator will scan channels to locate existing PANs. If the 'ReassignChannel' option is set, SD determines how long the coordinator will perform an energy scan to determine which channel it will operate on.

Scan time is measured as ((# of Channels to Scan) * (2 ^ SD) * 15.36ms). The number of channels to scan is set by the SC command. The XBee RF modem can scan up to 16 channels (SC = 0xFFFF). The XBee PRO RF modem can scan up to 12 channels (SC = 0x1FFE).

SD scan table

Examples: Values below
show results for a 12 channel scan

If SD = 0, time = 0.18 sec	SD = 8, time = 47.19 sec
SD = 2, time = 0.74 sec	SD = 10, time = 3.15 min
SD = 4, time = 2.95 sec	SD = 12, time = 12.58 min
SD = 6, time = 11.80 sec	SD = 14, time = 50.33 min

AT command: ATSD

Parameter range

0 - 0x0F

Default parameter value

4

Related commands

ED (Energy Scan), SC (Scan Channel)

Minimum firmware version required

v1.x80

SH (Serial Number High) command

<Diagnostics> The SH command is used to read the high 32 bits of the RF modem's unique IEEE 64-bit address.

The modem serial number is set at the factory and is read-only.

AT command: ATSH

Parameter range

0 - 0xFFFFFFFF (read-only)

Related commands

SL (Serial Number Low), MY (Source Address)

SL (Serial Number Low) command

<Diagnostics> The SL command is used to read the low 32 bits of the RF modem's unique IEEE 64-bit address.

The modem serial number is set at the factory and is read-only.

AT command: ATSL

Parameter range

0 - 0xFFFFFFFF (read-only)

Related commands

SH (Serial Number High), MY (Source Address)

SM (Sleep Mode) command

<Sleep Mode (Low Power)> The SM command is used to set and read sleep mode settings. By default, sleep modes are disabled (SM = 0) and the RF modem remains in idle/receive mode.

When in this state, the modem is constantly ready to respond to either serial or RF activity.

SM command options vary according to the networking system type. By default, the modem is configured to operate in a NonBeacon system.

* The sleep coordinator option (SM=6) only exists for backwards compatibility with firmware version 1.x06 only. In all other cases, use the CE command to enable a coordinator.

AT command: ATSM

Parameter range

0 - 6

Parameter	Configuration
0	Disabled
1	Pin hibernate
2	Pin doze
3	(reserved)
4	Cyclic sleep remote
5	Cyclic sleep remote (with pin wakeup)
6	Sleep coordinator*

Default parameter value

0

Related commands

SP (Cyclic Sleep Period), ST (Time before Sleep)

SP (Cyclic Sleep Period) command

<Sleep Mode (Low Power)> The SP command is used to set and read the duration of time in which a remote RF modem sleeps. After the cyclic sleep period is over, the modem wakes and checks for data. If data is not present, the modem goes back to sleep. The maximum sleep period is 268 seconds (SP = 0x68B0).

The SP parameter is only valid if the modem is configured to operate in cyclic sleep (SM = 4-6). Coordinator and end device SP values should always be equal.

To send direct messages, set SP = 0.

NonBeacon firmware

End device - SP determines the sleep period for cyclic sleeping remotes. Maximum sleep period is 268 seconds (0x68B0).

Coordinator - If non-zero, SP determines the time to hold an indirect message before discarding it. A coordinator will discard indirect messages after a period of (2.5 * SP).

AT command: ATSP

Parameter range

NonBeacon firmware: 1 - 0x68B0 (x 10 milliseconds)

Default parameter value

NonBeacon Firmware: 0

Related commands

SM (Sleep Mode), ST (Time before Sleep), DP (Disassociation Cyclic Sleep Period, BE (Beacon Order)

ST (Time before Sleep) command

<Sleep Mode (Low Power)> The ST command is used to set and read the period of inactivity (no serial or RF data is sent or received) before activating Sleep Mode.

NonBeacon firmware

Set/Read time period of inactivity (no serial or RF data is sent or received) before activating sleep mode. ST parameter is only valid with cyclic sleep settings (SM = 4 - 5).

Coordinator and end device ST values must be equal.

AT command: ATST

Parameter range

NonBeacon firmware: 1 - 0xFFFF (x 1 millisecond)

Default parameter value

NonBeacon firmware: 0x1388 (5000 decimal)

Related commands

SM (Sleep Mode), ST (Time before Sleep)

T0 - T7 ((D0-D7) Output Timeout) command

<I/O Settings {I/O Line Passing}> The T0, T1, T2, T3, T4, T5, T6 and T7 commands are used to set/read output timeout values for the lines that correspond with the D0 - D7 parameters. When output is set (due to I/O line passing) to a non- default level, a timer is started which when expired, will set the output to its default level. The timer is reset when a valid I/O packet is received. The Tn parameter

defines the permissible amount of time to stay in a non-default (active) state. If Tn = 0, output timeout is disabled (output levels are held indefinitely).

AT command: ATT0

Parameter range

0 - 0xFF (x 100 milliseconds)

Default parameter value

0xFF

Minimum firmware version required

v1.xA0

VL (Firmware Version - Verbose)

<Diagnostics> The VL command is used to read detailed version information about the RF modem. The information includes:

- Application build date
- MAC, PHY and bootloader versions
- Build dates

AT command: ATVL

Parameter range

0 - 0xFF (x 100 milliseconds)

Default parameter value

0x28 (40 decimal)

Minimum firmware version required

v1.x80

VR (Firmware Version) command

<Diagnostics> The VR command is used to read which firmware version is stored in the modem.

XBee version numbers will have four significant digits. The reported number will show three or four numbers and is stated in hexadecimal notation. A version can be reported as "ABC" or "ABCD." Digits ABC are the main release number and D is the revision number from the main release. "D" is not required and if it is not present, a zero is assumed for D. "B" is a variant designator.

The following variants exist:

- 0 = Non-Beacon Enabled 802.15.4 Code
- 1 = Beacon Enabled 802.15.4 Code

AT command: ATVR

Parameter range

0 - 0xFFFF (read only)

WR (Write) command

<(Special)> The WR command is used to write configurable parameters to the RF modem's non-volatile memory. Parameter values remain in the modem's memory until overwritten by subsequent use of the WR command.

If changes are made without writing them to non-volatile memory, the modem reverts back to previously saved parameters the next time the modem is powered-on.

Note Once the WR command is sent to the modem, no additional characters should be sent until after the "OK/r" response is received.

AT command: ATWR

API operation

By default, XBee-PRO RF Modems act as a serial line replacement (transparent operation) - all UART data received through the DI pin is queued up for RF transmission. When the modem receives an RF packet, the data is sent out the DO pin with no additional information.

Inherent to transparent operation are the following behaviors:

- If modem parameter registers are to be set or queried, a special operation is required for transitioning the modem into command mode.
- In point-to-multipoint systems, the application must send extra information so that the receiving modem(s) can distinguish between data coming from different remotes.

As an alternative to the default transparent operation, API (application programming interface) operations are available. API operation requires that communication with the modem be done through a structured interface (data is communicated in frames in a defined order). The API specifies how commands, command responses and modem status messages are sent and received from the modem using a UART data frame.

API frame specifications

Two API modes are supported and both can be enabled using the AP (API Enable) command. Use the following AP parameter values to configure the modem to operate in a particular mode:

- AP = 0 (default): Transparent operation (UART serial line replacement) API modes are disabled.
- AP = 1: API Operation
- AP = 2: API Operation (with escaped characters)

Any data received prior to the start delimiter is silently discarded. If the frame is not received correctly or if the checksum fails, the data is silently discarded.

API Operation (AP parameter = 1)

When this API mode is enabled (AP = 1), the UART data frame structure is defined as follows:

UART Data frame structure

Start Delimiter (Byte 1)	Length (Bytes 2-3)		Frame Data (Bytes 4-n)	Checksum (Byte n + 1)
0x7E	MSB	LSB	API-specific Structure	1 Byte
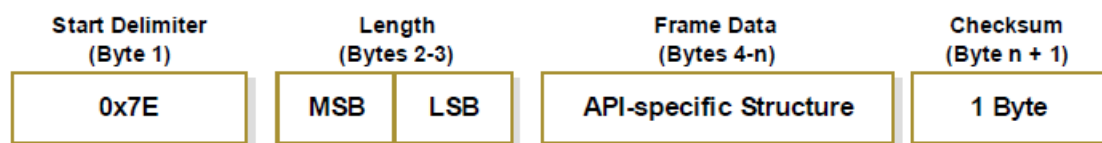
MSB = Most Significant Byte, LSB = Least Significant Byte

API Operation - with Escape Characters (AP parameter = 2)

When this API mode is enabled (AP = 2), the UART data frame structure is defined as follows:

UART Data Frame Structure -with escape control characters
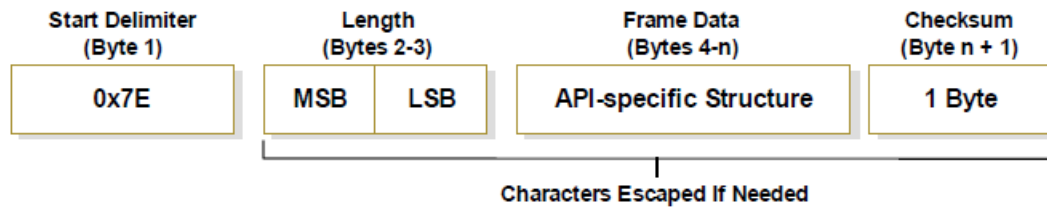
MSB = Most Significant Byte, LSB = Least Significant Byte

Escape characters: When sending or receiving a UART data frame, specific data values must be escaped (flagged) so they do not interfere with the UART or UART data frame operation. To escape an interfering data byte, insert 0x7D and follow it with the byte to be escaped XOR'd with 0x20.

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 above 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.

Checksum

To test data integrity, a checksum is calculated and verified on non-escaped data.

To calculate: Not including frame delimiters and length, add all bytes keeping only the lowest 8 bits of the result and subtract from 0xFF.

To verify: Add all bytes (include checksum, but not the delimiter and length). If the checksum is correct, the sum will equal 0xFF.

API types

Frame data of the UART data frame forms an API-specific structure as follows:

UART data frame and API specific structure
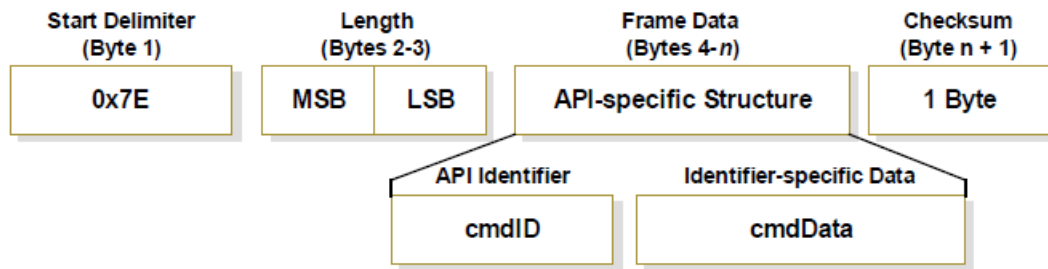
The cmdID frame (API-identifier) indicates which API messages will be contained in the cmdData frame (identifier-specific data). Refer to the sections that follow for more information regarding the supported API types. Note that multi-byte values are sent big endian.

Modem status

API identifier: 0x8A

RF modem status messages are sent from the modem in response to specific conditions.

Modem status frames
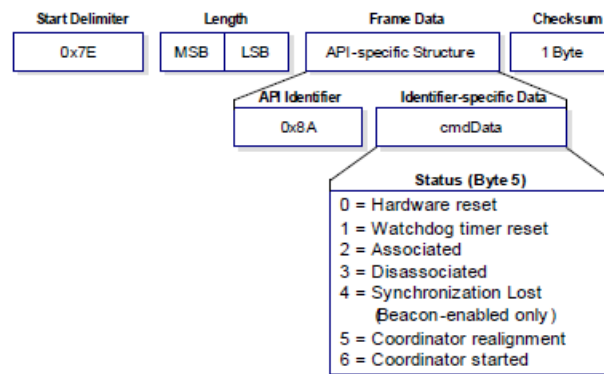
AT command

API Identifier Value: 0x08

The "AT command" API type allows for modem parameters to be queried or set. When using this command ID, new parameter values are applied immediately. This includes any register set with the "AT command - queue parameter value" (0x09) API type.

AT command frames

Example: API frames when reading the DL parameter value of the modem.

Byte 1	Bytes 2-3	Byte 4	Byte 5	Bytes 6-7	Byte 8
0x7E	0x00 0x04	0x08	0x52 (R)	0x44 (D) 0x4C (L)	0x15
Start Delimiter	Length*	API Identifier	Frame ID**	AT Command	Checksum
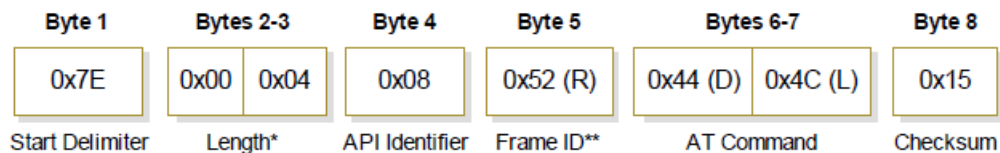
* Length (Bytes) = API identifier + frame ID + AT command

** "R" value was arbitrarily selected.

Example: API frames when modifying the DL parameter value of the modem.

Byte 1	Bytes 2-3	Byte 4	Byte 5	Bytes 6-7	Bytes 8-11	Byte 12
0x7E	0x00 0x08	0x08	0x4D (M)	0x44 (D) 0x4C (L)	0x00000FFF	0x0C
Start Delimiter	Length*	API Identifier	Frame ID**	AT Command	Parameter Value	Checksum
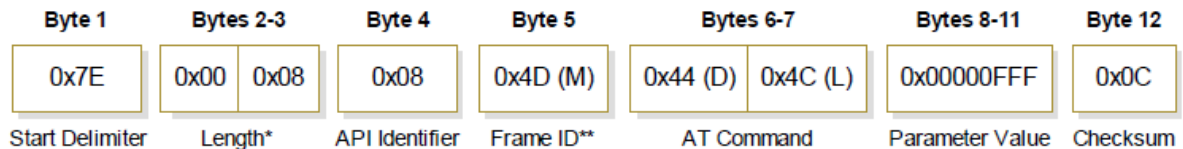
* Length (Bytes) - API identifier + frame ID + AT command + parameter value

** "M" value was arbitrarily selected.

AT command - queue parameter value

API identifier value: 0x09

This API type allows modem parameters to be queried or set. In contrast to the "AT Command" API type, new parameter values are queued and not applied until either the "AT Command" (0x08) API type or the AC (Apply Changes) command is issued. Register queries (reading parameter values) are returned immediately.

AT command frames

(Note that frames are identical to the "AT Command" API type except for the API identifier.)

Start Delimiter	Length		Frame Data	Checksum
0x7E	MSB	LSB	API-specific Structure	1 Byte

API Identifier	Identifier-specific Data
0x09	cmdData

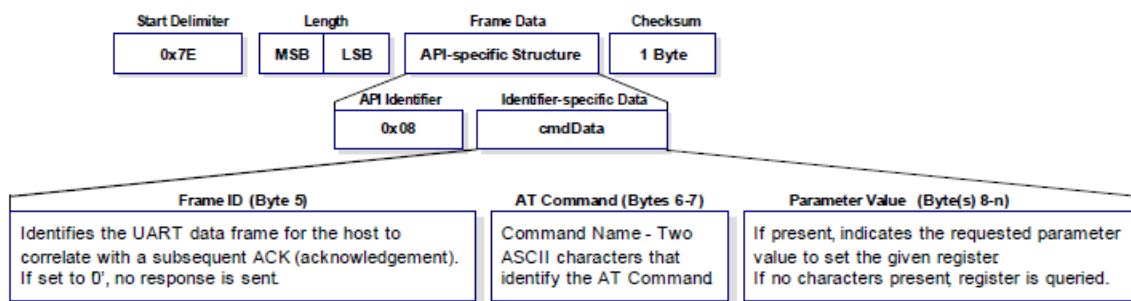| Frame ID (Byte 5)	AT Command (Bytes 6-7)	Parameter Value (Byte(s) 8-n)
Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to '0', no response is requested.	Command Name - Two ASCII characters that identify the AT Command.	If present, indicates the requested parameter value to set the given register. If no characters present, register is queried.

AT command response

API Identifier Value: 0x88

Response to previous command.

In response to an AT Command message, the modem will send an AT Command Response message. Some commands will send back multiple frames (for example, the ND (Node Discover) and AS (Active Scan) commands). These commands will end by sending a frame with a status of ATCMD_OK and no cmdData.

AT command response frames

Start Delimiter	Length		Frame Data	Checksum
0x7E	MSB	LSB	API-specific Structure	1 Byte

API Identifier	Identifier-specific Data
0x88	cmdData

Frame ID (Byte 5)	AT Command (Bytes 6-7)	Status (Byte 8)	Value (Byte(s) 9-n)
Identifies the UART data frame being reported. Note: If Frame ID= 0 in AT Command Mode, no AT Command Response will be given.	Command Name - Two ASCII characters that identify the AT Command	0 = OK 1 = ERROR 2 = Invalid Command 3 = Invalid Parameter	The HEX (non-ASCII) value of the requested register

TX (transmit) request: 64-bit address

API Identifier Value: 0x00

A TX Request message will cause the modem to send RF Data as an RF Packet.

TX packet (64 -bit address) frames

Start Delimiter	Length		Frame Data	Checksum
0x7E	MSB	LSB	API-specific Structure	1 Byte

API Identifier	Identifier-specific Data
0x00	cmdData

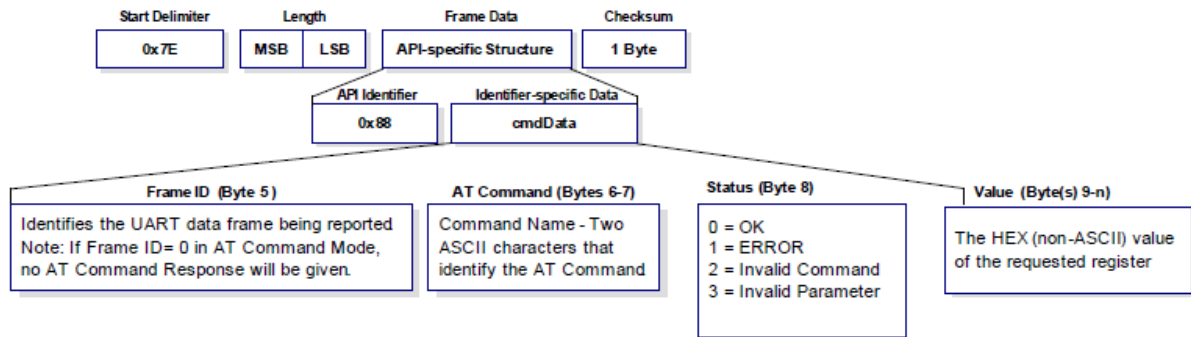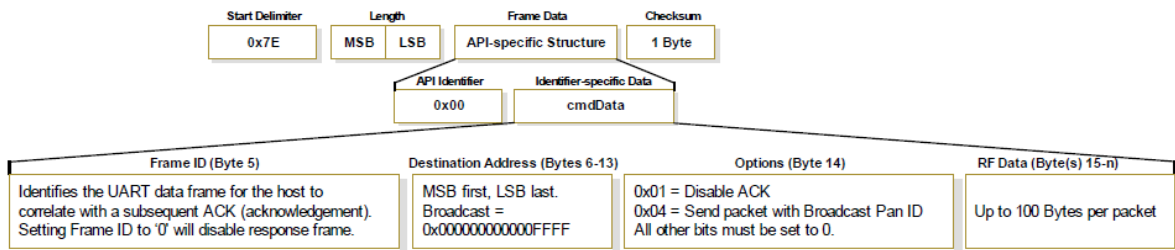| Frame ID (Byte 5)	Destination Address (Bytes 6-13)	Options (Byte 14)	RF Data (Byte(s) 15-n)
Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). Setting Frame ID to '0' will disable response frame.	MSB first, LSB last. Broadcast = 0x000000000000FFFF	0x01 = Disable ACK 0x04 = Send packet with Broadcast Pan ID All other bits must be set to 0.	Up to 100 Bytes per packet

TX (transmit) request: 16-bit address

API Identifier Value: 0x01

A TX Request message will cause the modem to send RF Data as an RF Packet.

TX packet (16-bit address) frames

Start Delimiter	Length		Frame Data	Checksum
0x7E	MSB	LSB	API-specific Structure	1 Byte

API Identifier	Identifier-specific Data
0x01	cmdData

Frame ID (Byte 5)	Destination Address (Bytes 6-7)	Options (Byte 8)	RF Data (Byte(s) 9-n)
Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). Setting Frame ID to '0' will disable response frame.	MSB first, LSB last. Broadcast = 0xFFFF	0x01 = Disable ACK 0x04 = Send packet with Broadcast Pan ID All other bits must be set to 0.	Up to 100 Bytes per packet

TX (transmit) status

API Identifier Value: 0x89

When a TX Request is completed, the modem sends a TX Status message. This message will indicate if the packet was transmitted successfully or if there was a failure.

TX status frames

Notes

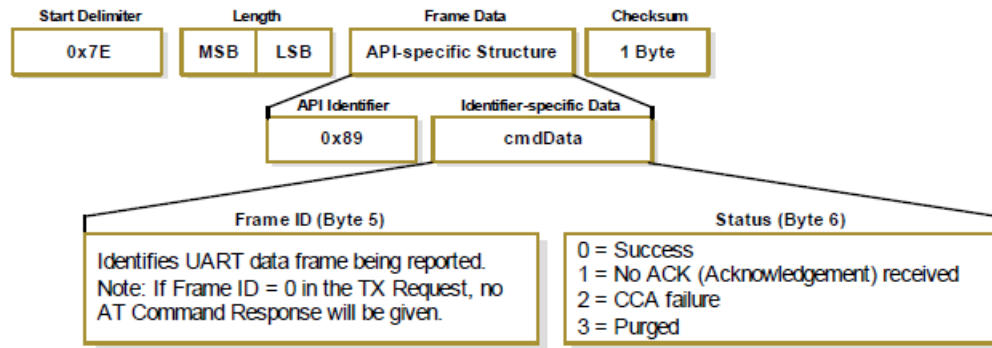- "STATUS = 1" occurs when all retries are expired and no ACK is received.
- If transmitter broadcasts (destination address = 0x000000000000FFFF), only "STATUS" = 0 or 2 will be returned.
- "STATUS = 3" occurs when Coordinator times out of an indirect transmission.
  Timeout is defined as (2.5 x SP (Cyclic Sleep Period) parameter value).

RX (receive) packet: 64-bit address

API Identifier Value: 0x80

When the modem receives an RF packet, it is sent out the UART using this message type.

RX packet (64-bit address) frames
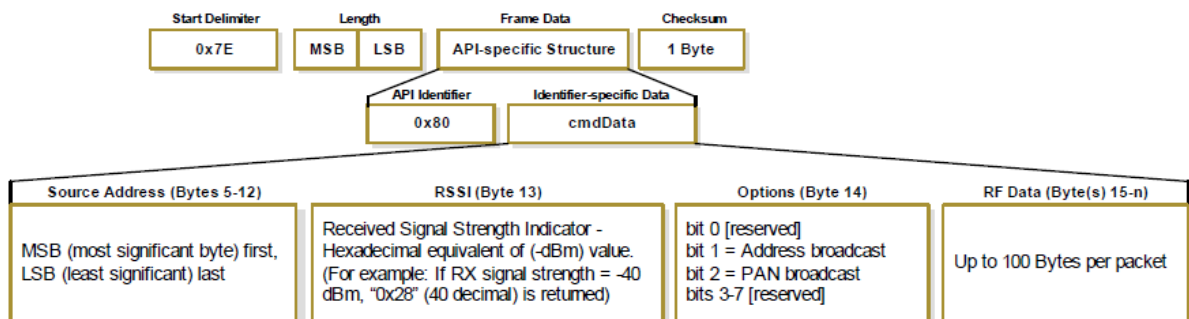
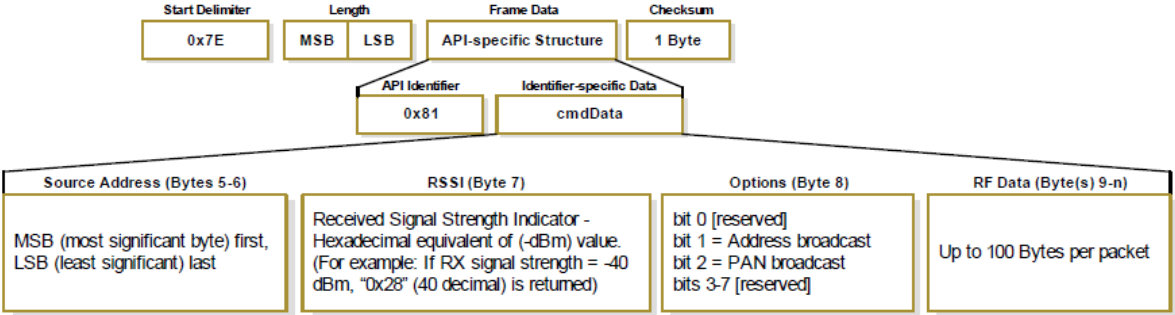RX (receive=) packet: 16-bit address

API Identifier Value: 0x81

When the modem receives an RF packet, it is sent out the UART using this message type.

RX (receive) packet: 16-bit address

API Identifier Value: 0x81

When the modem receives an RF packet, it is sent out the UART using this message type.

RX packet (16-bit) address frames

Start Delimiter	Length		Frame Data	Checksum
0x7E	MSB	LSB	API-specific Structure	1 Byte

API Identifier	Identifier-specific Data
0x81	cmdData

Source Address (Bytes 5-6)	RSSI (Byte 7)	Options (Byte 8)	RF Data (Byte(s) 9-n)
MSB (most significant byte) first, LSB (least significant) last	Received Signal Strength Indicator - Hexadecimal equivalent of (-dBm) value. (For example: If RX signal strength = -40 dBm, "0x28" (40 decimal) is returned)	bit 0 [reserved] bit 1 = Address broadcast bit 2 = PAN broadcast bits 3-7 [reserved]	Up to 100 Bytes per packet

Regulatory information

United States (FCC)

XBee-PRO RF modems comply with Part 15 of the FCC rules and regulations. Compliance with the labeling requirements, FCC notices and antenna usage guidelines is required.

To fulfill FCC certification requirements, the OEM must comply with the following regulations:

- The system integrator must ensure that the text on the external label provided with this device is placed on the outside of the final product.

- XBee-PRO RF Modems may only be used with antennas that have been tested and approved for use with this modem (refer to the antenna tables in this section).

OEM labeling requirements

WARNING! The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product enclosure that displays the contents shown in the figure below.

Required FCC label for OEM products containing the XBee-PRO RF modem

Contains FCC ID: OUR-XBEE/OUR-XBEEPRO[1]

The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (i.) this device may not cause harmful interference and (ii.) this device must accept any interference received, including interference that may cause undesired operation.

FCC notices

IMPORTANT: The XBee-PRO PKG-R RS-232 RF Modem has been certified by the FCC for use with other products without any further certification (as per FCC section 2.1091). Modifications not expressly approved by Digi could void the user's authority to operate the equipment.

IMPORTANT: OEMs must test final product to comply with unintentional radiators (FCC section 15.107 and 15.109) before declaring compliance of their final product to Part 15 of the FCC rules.

IMPORTANT: The RF modem has been certified for remote and base radio applications. If the module will be used for portable applications, please take note of the following instructions:

- For XBee modules where the antenna gain is less than 13.8 dBi, no additional SAR testing is required. The 20 cm separation distance is not required for antenna gain less than 13.8 dBi.

- For XBee modules where the antenna gain is greater than 13.8 dBi and for all XBee-PRO modules, the device must undergo SAR testing.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures: Re-orient or relocate the receiving antenna,

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[1]FCC ID for the XBee is "OUR-XBEE." The FCC ID for the XBee-PRO is "OUR-XBEEPRO."

Increase the separation between the equipment and receiver, Connect equipment and receiver to outlets on different circuits, or Consult the dealer or an experienced radio/TV technician for help.

- Re-orient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect equipment and receiver to outlets on different circuits.
- Consult the dealer or an experienced radio/TV technician for help.

RF exposure statement

If you are an integrating the XBee into another product, you must include the following Caution statement in product manuals to alert users of FCC RF exposure compliance:

CAUTION! To satisfy FCC RF exposure requirements for mobile transmitting devices, a separation distance of 20 cm or more should be maintained between the antenna of this device and persons during device operation. To ensure compliance, operations at closer than this distance is not recommended. The antenna used for this transmitter must not be co-located in conjunction with any other antenna or transmitter.

FCC-approved antennas (2.4 ghz)

The XBee-PRO RF modem can be installed utilizing antennas and cables constructed with standard connectors (Type-N, SMA, TNC, etc.) if the installation is performed professionally and according to FCC guidelines. For installations not performed by a professional, non-standard connectors (RPSMA, RPTNC, etc.) must be used.

The modems are FCC approved for fixed base station and mobile applications on channels 0x0C - 0x17. If the antenna is mounted at least 20cm (8 in.) from nearby persons, the application is considered a mobile application.

Antennas not listed in the table must be tested to comply with FCC Section 15.203 (unique antenna connectors) and Section 15.247 (emissions).

XBee-PRO RF Modems: XBee-PRO RF modems have been tested and approved for use with the antennas listed in the tables below. Cable-loss is required when using antennas listed in the second table.

The antennas in the tables below have been approved for use with this module. Digi does not carry all of these antenna variants. Contact Digi Sales for available antennas.

Antennas approved for use with the XBee-PRO RF modems (cable-loss is not required.)

Part number	Type (description)	Gain	Application*	Min. separation
A24-HSM-450	Dipole (half-wave articulated RPSMA - 4.5")	2.1 dBi	Fixed/mobile	20 cm
A24-HABSM	Dipole (articulated RPSMA)	2.1 dBi	Fixed	20 cm

Part number	Type (description)	Gain	Application*	Min. separation
A24-HABUF-P5I	Dipole (half-wave articulated bulkhead mount U.FL. w/ 5" pigtail)	2.1 dBi	Fixed	20 cm
A24-QI	Monopole (integrated whip)	1.5 dBi	Fixed	20 cm

Antennas approved for use with the XBee-PRO RF modems (cable-loss is required)

Part number	Type (description)	Gain	Application*	Min. separation	Required cable-loss
A24-C1	Surface mount	-1.5 dBi	Fixed/mobile	20 cm	-
A24-Y4NF	Yagi (4-element)	6.0 dBi	Fixed	2 m	8.1 dB
A24-Y6NF	Yagi (6-element)	8.8 dBi	Fixed	2 m	10.9 dB
A24-Y7NF	Yagi (7-element)	9.0 dBi	Fixed	2 m	11.1 dB
A24-Y9NF	Yagi (9-element)	10.0 dBi	Fixed	2 m	12.1 dB
A24-Y10NF	Yagi (10-element)	11.0 dBi	Fixed	2 m	13.1 dB
A24-Y12NF	Yagi (12-element)	12.0 dBi	Fixed	2 m	14.1 dB
A24-Y13NF	Yagi (13-element)	12.0 dBi	Fixed	2 m	14.1 dB
A24-Y15NF	Yagi (15-element)	12.5 dBi	Fixed	2 m	14.6 dB
A24-Y16NF	Yagi (16-element)	13.5 dBi	Fixed	2 m	15.6 dB
A24-Y16RM	Yagi (16-element, RPSMA connector)	13.5 dBi	Fixed	2 m	15.6 dB
A24-Y18NF	Yagi (18-element)	15.0 dBi	Fixed	2 m	17.1 dB
A24-F2NF	Omni-directional (fiberglass base station)	2.1 dBi	Fixed/mobile	20 cm	4.2 dB
A24-F3NF	Omni-directional (fiberglass base station)	3.0 dBi	Fixed/mobile	20 cm	5.1 dB

Part number	Type (description)	Gain	Application*	Min. separation	Required cable-loss
A24-F5NF	Omni-directional (fiberglass base station)	5.0 dBi	Fixed/mobile	20 cm	7.1 dB
A24-F8NF	Omni-directional (fiberglass base station)	8.0 dBi	Fixed	2 m	10.1 dB
A24-F9NF	Omni-directional (fiberglass base station)	9.5 dBi	Fixed	2 m	11.6 dB
A24-F10NF	Omni-directional (fiberglass base station)	10.0 dBi	Fixed	2 m	12.1 dB
A24-F12NF	Omni-directional (fiberglass base station)	12.0 dBi	Fixed	2 m	14.1 dB
A24-F15NF	Omni-directional (fiberglass base station)	15.0 dBi	Fixed	2 m	17.1 dB
A24-W7NF	Omni-directional (base station)	7.2 dBi	Fixed	2 m	9.3 dB
A24-M7NF	Omni-directional (mag-mount base station)	7.2 dBi	Fixed	2 m	9.3 dB
A24-P8SF	Flat panel	8.5 dBi	Fixed	2 m	8.6 dB
A24-P8NF	Flat panel	8.5 dBi	Fixed	2 m	8.6 dB
A24-P13NF	Flat panel	13.0 dBi	Fixed	2 m	13.1 dB
A24-P14NF	Flat panel	14.0 dBi	Fixed	2 m	14.1 dB
A24-P15NF	Flat panel	15.0 dBi	Fixed	2 m	15.1 dB
A24-P16NF	Flat panel	16.0 dBi	Fixed	2 m	16.1 dB
A24-P19NF	Flat panel	19.0 dBi	Fixed	2 m	19.1 dB

* If using the RF modem in a portable application (For example -If the modem is used in a handheld device and the antenna is less than 20cm from the human body when the device is operation): The integrator is responsible for passing additional SAR (Specific Absorption Rate) testing based on FCC rules 2.1091 and FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, OET Bulletin and Supplement C. The testing results will be submitted to the FCC for approval prior to selling the integrated unit. The required SAR testing measures emissions from the modem and how they affect the person.

Europe

The RF modem is certified for use in several European countries; for a complete list, go to
www.digi.com.

If the XBP24-PKI-001-R radio modem is incorporated into a product, the manufacturer must ensure
compliance of the final product with articles 3.1a and 3.1b of the RE Directive (Radio Equipment
Directive). A Declaration of Conformity must be issued for each of these standards and kept on file as
described in the RE Directive (Radio Equipment Directive).

Furthermore, the manufacturer must maintain a copy of the RF modem user guide documentation
and ensure the final product does not exceed the specified power ratings, antenna specifications,
and/or installation requirements as specified in the user manual.

## Power output and operating frequencies

For the XBee device:

- The maximum RF power for the XBP24-PKI-001-R radio modem is 11.15 dBm EIRP when the
  radio is set to PL0, using the command ATPL0.
- The operating channels of the XBP24-PKI-001-R are one of the following frequencies:
  2410, 2415, 2420, 2425, 2430, 2435, 2440, 2445, 2450, 2455, 2460, 2465

OEM labeling requirements

The "CE" marking must be affixed to a visible location on the OEM product.

CE labeling requirements
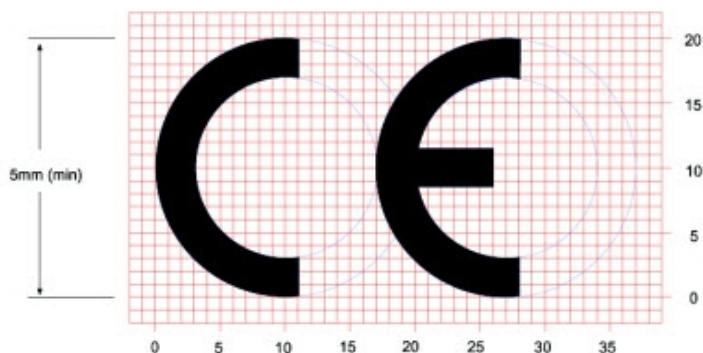
The CE mark shall consist of the initials "CE" taking the following form:

- If the CE marking is reduced or enlarged, the proportions given in the above graduated draw-
  ing must be respected.
- The CE marking must have a height of at least 5mm except where this is not possible on
  account of the nature of the apparatus.
- The CE marking must be affixed visibly, legibly, and indelibly.

Restrictions

The power output of the XBee-PRO RF Modules must not exceed 10 dBm. The power level is set using
the PL command.

The antenna for European installations must be limited to a dipole with maximum gain of 2.1 dBi.

Declarations of conformity

Digi has issued Declarations of Conformity for the XBee-PRO PKG-R RS-232 RF Modem concerning emissions, EMC, and safety. For more information, see www.digi.com/resources/certifications.
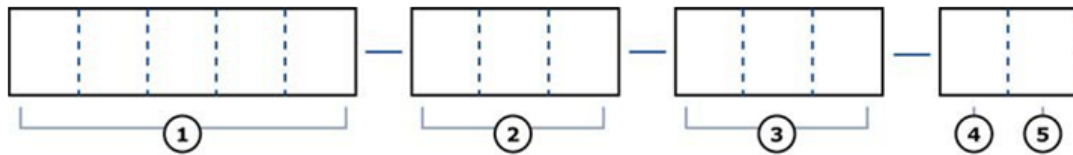
Important note

Digi customers assume full responsibility for learning and meeting the required guidelines for each country in their distribution market. Refer to the radio regulatory agency in the desired countries of operation for more information.

Additional information

Ordering Information

Divisions of the XBee-PRO RF modem part numbers

① Product Family
XBP24 = XBee-PRO 2.4 GHz

② Temperature Rating
PKC = Commercial (0 to 70° C)
PKI = Industrial (-40 to 85° C)
PKD = Class I, Division 2

③ Protocol
001 = 802.15.4
002 = ZigBee

④ Interface
R = RS-232
U = USB

⑤ Accessories Package
A = Accessories package (specific to Interface) included
(blank) means the accessories package is not included

For example:

XBP24-PKI-001-R = XBee-PRO RF Modem (2.4 GHz), Industrial temperature rating, IEEE.

802.15.4 standard, RS-232 Interface with accessories.