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9XTend™ OEM RF Module

Product Manual v2.x4x
For OEM RF Module Part Numbers that begin with: XT09-R..., XT09-M...

1 Watt Transmit Power, 256-bit AES Encryption

MaxStream®
355 South 520 West, Suite 180
Lindon, UT 84042
Phone: (801) 765-9885
Fax: (801) 765-9895

rf-xperts@maxstream.net
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M100115
2007.01.04

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E-mail: rf-xperts@maxstream.net

Live Chat: www.maxstream.net

Contents

1. 9XTend OEM RF Module

The 9XTend OEM RF Module was engineered to provide OEMs an easy-to-use RF solution that provides reliable delivery of critical data between remote devices. The module transfers a standard asynchronous serial data stream, operates within the ISM 900 MHz frequency band and sustains up to 115.2 Kbps data throughput.

1.1. Key Features

Long Range Data Integrity

1 Watt Power Output (variable 1mW - 1W)

Range (@9,600 bps throughput data rate):

- Indoor/Urban: **up to 3000'** (900 m)
- Outdoor RF line-of-sight: **up to 14 miles** (22 km) w/dipole antenna
- Outdoor RF line-of-sight: **up to 40 miles** (64 km) w/high-gain antenna

Range (@115,200 bps throughput data rate):

- Indoor/Urban: **up to 1500'** (450 m)
- Outdoor RF line-of-sight: **up to 7 miles** (11 km) w/dipole antenna
- Outdoor RF line-of-sight: **up to 20 miles** (32 km) w/high-gain antenna

Continuous RF data stream up to **115,200 bps**

Receiver Sensitivity: **-110 dBm** (@ 9600 baud), –**100 dBm** (@ 115200 baud)

Advanced Networking & Security

True Peer-to-Peer (no Master device required), Point-to-Point, Point-to-Multipoint & Multidrop

Retries and Acknowledgements

FHSS (Frequency Hopping Spread Spectrum)

10 hopping channels, each with over 65,000 unique network addresses available

256-bit AES Encryption
(AES algorithm is FIPS-197 certified)

Low Power

2.8 - 5.5 V Supply Voltage

Pin, Serial Port and Cyclic software sleep modes supported

Shutdown pin enables hardware sleep mode that draws only 5 µA (typical)

Easy-to-Use

No configuration necessary for out-of box RF communications

Free X-CTU Software
(Testing and configuration software)

RF Modules easily configured using standard AT & binary commands

Transparent Operation
(Wireless links replace serial wires)

API Operation
(Frame-based communications)

Portable
(small form-factor easily designed into a wide range of data systems)

Software-selectable I/O interfacing rates

Multiple data formats supported
(parity, start and stop bits, etc.)

XII™ Interference Immunity

No Master/Slave setup dependencies

Free & Unlimited Technical Support

1.1.1. Worldwide Acceptance

FCC Approved (USA) Refer to Appendix A [p54] for FCC Requirements.
Systems that include XTend RF Modules inherit MaxStream's Certifications.

ISM (Industrial, Scientific & Medical) license-free 902-928 MHz frequency band

Manufactured under **ISO 9001:2000** registered standards

ESD (Electrostatic Discharge) immunity - ESD-hardened and IEC1000-4-2 (Level 4) tested

9XTend OEM RF Modules are optimized for use in the **US**, **Canada**, **Australia and Israel** (contact MaxStream for complete list of agency approvals).

1.2. Specifications

Table 1-01. 9XTend-PKG-R OEM RF Module

9XTend 900 MHz OEM RF Module Specifications			
Performance		@9600 bps Throughput Data Rate	@115200 bps Throughput Data Rate
Transmit Power Output (software selectable using PL command)		1mW - 1 Watt	1mW - 1 Watt
Indoor/Urban Range		Up to 3000' (900 m)	Up to 1500' (450 m)
Outdoor RF line-of-sight Range		Up to 14 miles (22 km) w/ dipole antenna Up to 40 miles (64 km) w/ high-gain antenna	Up to 7 miles (11 km) w/ dipole antenna Up to 20 miles (32 km) w/ high-gain antenna
Interface Data Rate (software selectable using BD command)		1200 – 230400 bps	1200 – 230400 bps
Throughput Data Rate (software selectable using BR command)		9,600 bps	115,200 bps
RF Data Rate		10,000 bps	125,000 bps
Receiver Sensitivity		-110 dBm	-100 dBm
Power Requirements			
Receive Current		80 mA	
Shutdown Mode Power Down		5 μA typical	
Pin Sleep Power Down		147 μA	
Idle Currents	16 sec cyclic sleep (SM=8)	0.3 - 0.8 mA	
	8 sec cyclic sleep (SM=7)	0.4 - 1.4 mA	
	4 sec cyclic sleep (SM=6)	0.6 - 2.6 mA	
	2 sec cyclic sleep (SM=5)	0.9 - 4.8 mA	
	1 sec cyclic sleep (SM=4)	1.6 - 8.7 mA	
Networking & Security			
Frequency		902-928 MHz	
Spread Spectrum		FHSS (Frequency Hopping Spread Spectrum)	
Modulation		FSK (Frequency Shift Keying)	
Supported Network Topologies		Peer-to-Peer ("Master/Slave" relationship not required), Point-to-Point, Point-to-Multipoint	
Channel Capacity		10 hop sequences share 50 frequencies	
Encryption		256-bit AES Encryption – Refer to the KY Command [p29] to implement	
Physical Properties			
RF Module Board Size		1.44" x 2.38" x 0.20" (3.65 cm x 6.05 cm x 0.51 cm)	
Weight		0.64 oz. (18 g)	
Connector		20-pin	
Operating Temperature		-40 to 85º C (industrial)	
Antenna			
Connector Options		RPSMA (Reverse-polarity SMA) or MMCX	
Impedance		50 ohms unbalanced	
Certifications (partial list)			
FCC Part 15.247		OUR-9XTEND	
Industry Canada (IC)		4214A-9XTEND	

Table 1-02. XTend OEM RF Module Specifications - Relative to user-selected TX Power Output

Power Requirements (Supply voltage and TX currents relative to each TX Power Output option)					
Transmit Power Output	**1 mW**	**10 mW**	**100 mW**	**500 mW ***	**1 W ***
Supply Voltage	2.8 - 5.5 VDC			3.0 - 5.5 VDC	4.75 - 5.5 VDC
Transmit Current (5 V) typical	110 mA	140 mA	270 mA	500 mA	730 mA
Transmit Current (3.3 V) typical	90 mA	110 mA	260 mA	600 mA	**

* If the supply voltage for a given power setting is lower than the minimum supply voltage requirement (as shown in Table 1-02), the TX Power Output will decrease to the highest power level setting given the current supply voltage.

** 1W Power Output is not supported when using a 3.3 supply voltage.

1.3. Pin Signals

Figure 1-01. XTend OEM RF Module Pin Numbers

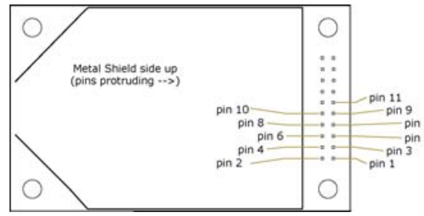


Table 1-03. Pin Signal Descriptions
(Low-asserted signals distinguished with a horizontal line over signal name.)

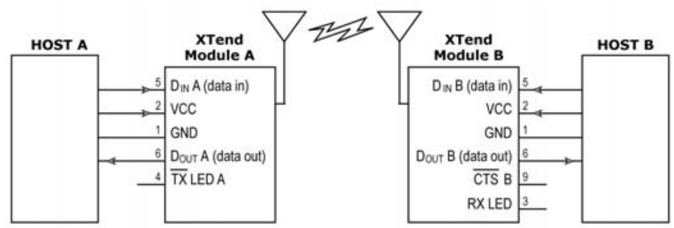
Pin Number	Mnemonic	I/O	High Impedance during Shutdown	Must Connect	Function
1	GND	-	-	yes	**Ground**
2	VCC	I	-	yes	**Power:** 2.8 - 5.5 VDC
3	GPO2 / RX LED	O	yes	-	**General Purpose Output 2:** <Default (CD=2)> Pin is driven low. Refer to the CD Command [p24] for other configuration options.
					RX LED: Pin is driven high during RF data reception; otherwise, the pin is driven low. Refer to the CD Command [p24] to enable.
4	$\overline{\text{TX}}$_PWR	O	yes	-	**Transmit_Power:** Pin pulses low during RF transmission; otherwise, the pin is driven high to indicate power is on and the module is not in Sleep or Shutdown Mode.
5	DI	I	yes	yes	**Data In:** Serial data entering the module (from the UART host). Refer to the Serial Communications [p9] section for more information.
6	DO	O	yes	-	**Data Out:** Serial Data exiting the module (to the UART host). Refer to the Serial Communications [p9] section for more information.
7	$\overline{\text{SHDN}}$	I	no	yes	**Shutdown:** Pin is driven high during operation and low during Shutdown. Shutdown enables the lowest power mode (~5 µA) available to the module. Refer to the Shutdown Mode [p14] section for more information.
8	GPI2 / SLEEP	I	yes	-	**General Purpose Input 2:** reserved for future use
					SLEEP: By default, SLEEP is not used. To configure this pin to enable Sleep Modes, refer to the Sleep Mode [p15], SM Command [p37] & PW Command [p32] sections.
9	GPO1 / $\overline{\text{CTS}}$ / RS-485 TX_EN	O	yes	-	**General Purpose Output 1:** reserved for future use
					$\overline{\text{CTS}}$ (Clear-to-Send): <Default (CS=0)> When pin is driven low, the UART host is permitted to send serial data to the module. Refer to the Serial Communications [p9] & CS Command [p25] sections for more information.
					RS-485 Transmit Enable: To configure this pin to enable RS-485 half and full-duplex communications. Refer to the Serial Communications [p9] & CS Command [p25] sections.
10	GPI1 / $\overline{\text{RTS}}$ / CMD	I	yes	-	**General Purpose Input 1:** reserved for future use
					$\overline{\text{RTS}}$ (Request-to-Send): By default, is not used. To configure this pin to regulate the flow of serial data exiting the module, refer to the Serial Communications [p9] & RT Command [p36] sections.
					CMD (Command): By default, CMD is not used. To configure this pin to enable binary command programming, refer to the Binary Commands [p18] & RT Command [p36] sections.
11	$\overline{\text{CONFIG}}$ / RSSI	I*	no	-	**Configuration:** Pin can be used as a backup method for entering Command Mode during power-up. Refer to the Command Mode [p17] section for more information.
		O*	no	-	**Receive Signal Strength Indicator:** By default, pin is used as an RSSI PWM output after at the conclusion of the power-up sequence. Refer to the RP Command [p35] for more information.
12-20	reserved / do not connect				

* RF module has 10K Ω internal pull-up resistor

Note: When integrating the module with a Host PC board, all lines not used should be left disconnected (floating).

1.4. Electrical Characteristic

Figure 1-02. System Block Diagram
Basic RF Link between Hosts



The data flow sequence is initiated when the first byte of data is received in the DI Buffer of the transmitting module (XTend RF Module A). As long as XTend RF Module A is not already receiving RF data, data in the DI Buffer is packetized then transmitted over-the-air to XTend RF Module B.

1.4.1. Timing Specifications

Figure 1-03. Timing Specifications ('A' and 'B' refer to Figure 1-02)

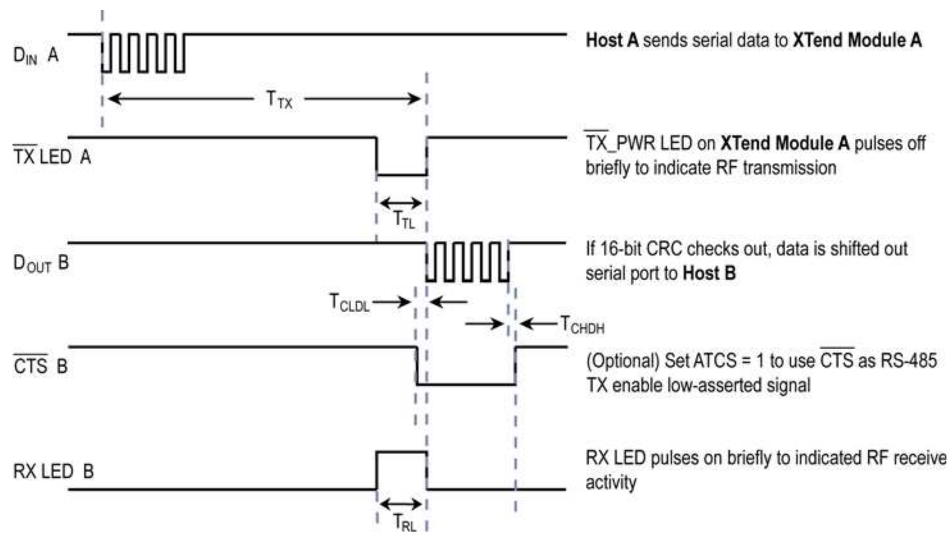


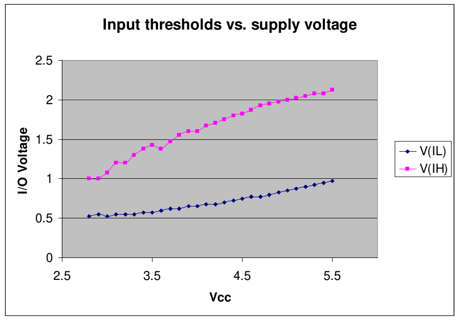
Table 1-04. AC Characteristics (Symbols correspond with Figure 1-02 and Figure 1-03, ATSY Parameter = 0)

Symbol	Description	Sleep Mode	115200 Baud Rate	9600 Baud Rate
T_{TX}	Latency from the time data is transmitted until it is received.	SM = 0 (No sleep)	9.4 msec	94 msec
		SM = 8	16 sec	16 sec
		SM = 7	8 sec	8 sec
		SM = 6	4 sec	4 sec
		SM = 5	2 sec	2 sec
		SM = 4	1 sec	1 sec
T_{TL}	Time that $\overline{TX}$_PWR pin (pin 4) is driven low	--	2.45 msec	29.6 msec
T_{RL}	Time that RX LED (pin 3) is driven high	--	2.26 msec	27.2 msec
T_{CLDL}	Time starting when $\overline{CTS}$ goes low until the first bit appears on DOUT	--	44 µsec	75 µsec
T_{CHDH}	Time after last bit of data until $\overline{CTS}$ goes high	--	7 µsec	7 µsec

Table 1-05. DC Characteristics (Vcc = 2.8 - 5.5 VDC)

Symbol	Parameter	Condition
V_{OL}	Output Low Voltage	V_{OL} = 0.33V (IO = 6 mA)
V_{OH}	Output High Voltage	$V_{OH} = V_{SUPPLY}$ - 0.7V (-IO = 6 mA)

Figure 1-04. Input Thresholds vs. Supply Voltage



1.5. Mechanical Drawings

Figure 1-05. Mechanical drawings of the XTend OEM RF Module (w/RPSMA Connector)

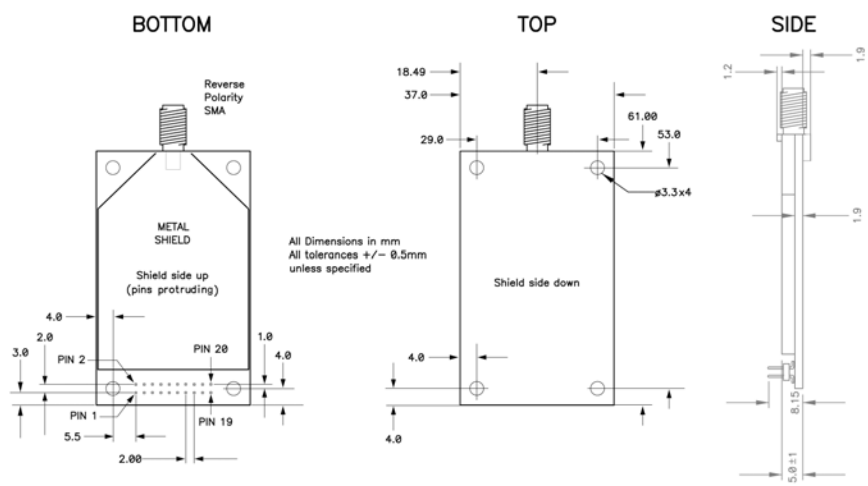
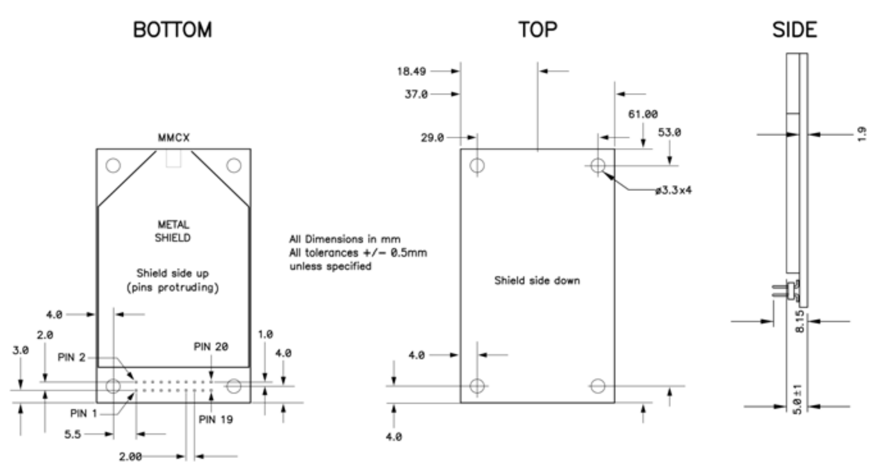


Figure 1-06. Mechanical drawings of the XTend OEM RF Module (w/MMCX Connector)



2. RF Module Operation

WARNING: When operating at 1 Watt power output, observe a minimum separation distance of 2' (0.6m) between modules. Transmitting in close proximity of other modules can damage module front ends.

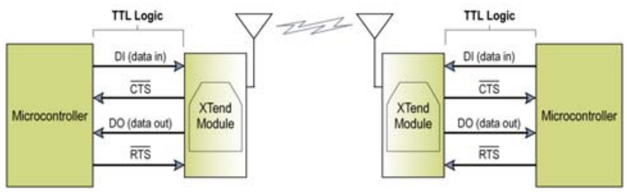
2.1. Serial Communications

The XTend OEM RF Modules interface to a host device through a TTL-level asynchronous serial port. Through its serial port, the module can communicate with any UART voltage compatible device or through a level translator to any serial device (For example: RS-232/485/422 or USB interface board).

2.1.1. UART Data Flow

Devices that have a UART interface can connect directly to the pins of the RF module as shown in the figure below.

Figure 2-01. System Data Flow Diagram in a UART-interfaced environment
(Low-asserted signals distinguished with horizontal line over signal name.)

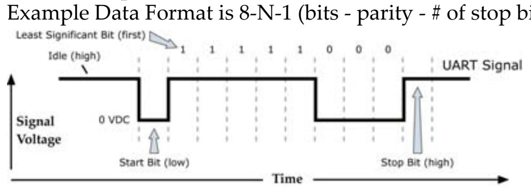


Serial Data

Data enters the module UART through the pin 5 as an asynchronous serial signal. The signal should idle high when no data is being transmitted.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following figure illustrates the serial bit pattern of data passing through the module.

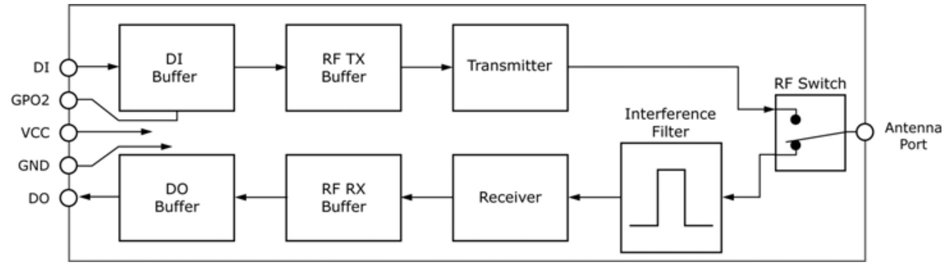
Figure 2-02. UART data packet 0x1F (decimal number "31") as transmitted through the RF module
Example Data Format is 8-N-1 (bits - parity - # of stop bits)



The module UART performs tasks, such as timing and parity checking, that are needed for data communications. Serial communications depend on the two UARTs to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits).

2.1.2. Flow Control

Figure 2-03. Internal Data Flow Diagram (The five most commonly-used pin signals shown)



DI (Data In) Buffer and Flow Control

When serial data enters the module through the DI pin (pin 5), the data is stored in the DI Buffer until it can be processed.

When the RB and RO parameter thresholds are satisfied (refer to 'Transmit Mode' section for more information), the module attempts to initialize an RF connection. If the module is already receiving RF data, the serial data is stored in the module's DI Buffer. The DI buffer stores at least 2.1 KB. 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 RF module).

How to eliminate the need for flow control:

1. Send messages that are smaller than the DI buffer size. The size of the DI buffer varies according to the packet size (PK parameter) and the parity setting (NB parameter) used.
2. Interface at a lower baud rate (BD parameter) than the RF data rate (BR parameter).

Two cases in which the DI Buffer may become full and possibly overflow:

1. If the serial interface data rate is set higher than the RF data rate of the module, the module will receive data from the host faster than it can transmit the data over-the-air.
2. If the module is receiving a continuous stream of RF data or if the module is monitoring data on a network, any serial data that arrives on the DI pin (pin 5) is placed in the DI Buffer. The data in the DI buffer will be transmitted over-the-air when the module no longer detects RF data in the network.

Hardware Flow Control ($\overline{\text{CTS}}$). When the DI buffer is 17 bytes away from being full; by default, the module de-asserts $\overline{\text{CTS}}$ (high) to signal to the host device to stop sending data [refer to FT (Flow Control Threshold) and CS (GPO1 Configuration) Commands]. $\overline{\text{CTS}}$ is re-asserted after the DI Buffer has 34 bytes of memory available.

Software Flow Control (XON). XON/XOFF software flow control can be enabled using the FL (Software Flow Control) Command. This option only works with ASCII data.

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. The DO buffer stores at least 2.1 KB.

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 module, the module will receive data from the transmitting module faster than it can send the data to the host.
2. If the host does not allow the module to transmit data out from the DO buffer because of being held off by hardware or software flow control.

Hardware Flow Control ($\overline{\text{RTS}}$). If $\overline{\text{RTS}}$ is enabled for flow control (RT Parameter = 2), data will not be sent out the DO Buffer as long as $\overline{\text{RTS}}$ (pin 10) is de-asserted.

Software Flow Control (XOFF). XON/XOFF software flow control can be enabled using the FL (Software Flow Control) Command. This option only works with ASCII data.

2.1.3. Transparent Operation

By default, XTend RF Modules operate in Transparent Mode. The modules 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.

When the RO (Packetization Timeout) parameter threshold is satisfied, the module attempts to initialize an RF transmission. If the module cannot immediately transmit (for instance, if it is already receiving RF data), the serial data continues to be stored in the DI Buffer. Data is packetized and sent at any RO timeout or when the maximum packet size is received.

The module operates as described above unless the Command Mode Sequence is detected. The Command Mode Sequence consists of three copies of the command sequence character [CC parameter] surrounded by the before and after guard times [BT & AT parameters].

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 module).

2.1.4. API Operation

API (Application Programming Interface) Operation is an alternative to the default Transparent Operation. The API is frame-based and extends the level to which a host application can interact with the networking capabilities of the module. When in API mode, all data entering and leaving the RF module is contained in frames that define operations or events within the module.

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

- 16-bit address

Receive Data Frames (sent out the DO (Data Out) pin) include:

- Showing a received RF packet (16 bits only)
- Response to a TX (Transmit) packet
- Showing events such as hardware reset, watchdog reset, asynchronous events, etc.

The module will send data frames to the application containing status packets; as well as source, RSSI and payload information from received data packets.

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

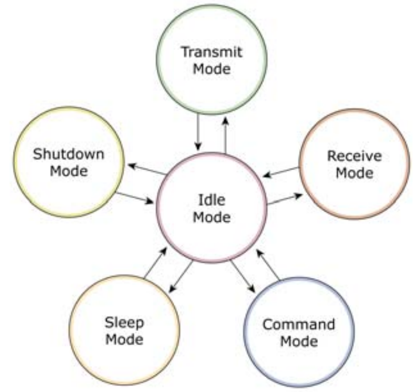
-> Change destination addresses without having to enter command mode
-> Receive success/failure status of each RF packet
-> Identify the source address of each received packet

To implement API operations, refer to 'API Operation' sections [p40].

2.2. Modes of Operation

XTend RF Modules operate in six modes.

Figure 2-04. XTend RF Module Modes of Operation
(RF modules can only be in one mode at a time)



2.2.1. Idle Mode

When not receiving or transmitting data, the RF module is in Idle Mode. The module 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
- Shutdown Mode: Shutdown condition is met
- Sleep Mode: Sleep Mode condition is met
- Command Mode: Command Mode Sequence is issued

The module automatically transitions back to Idle Mode after responding to these conditions.

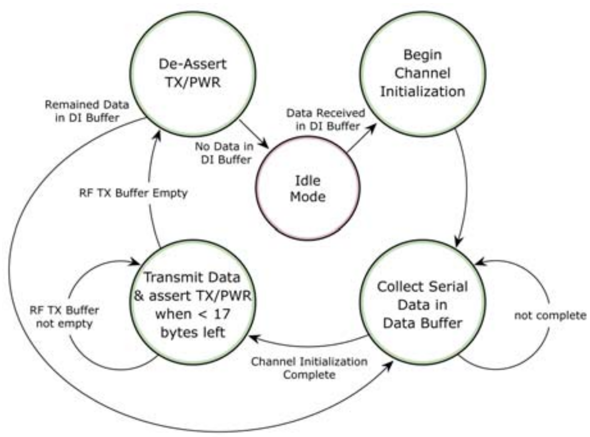
2.2.2. Transmit Mode

When the first byte of serial data is received from the UART in the DI buffer, the module attempts to shift to Transmit Mode and initiate an RF connection with other modules. After transmission is complete, the module returns to Idle Mode.

RF transmission begins after either of the following criteria is met:

1. RB bytes have been received by the UART and are pending for RF transmission.
   [Refer to the RB (Packetization Threshold) Command]
2. At least one character has been received by the UART and is pending for RF transmission; and RO character times of silence been observed on the UART.
   [Refer to the RO (Packetization Timeout) Command]

Figure 2-05. Transmit Mode Data Flow



The character timeout trigger can be disabled by setting RO to zero. In this case, transmission will not begin until RB bytes have been received and are pending for RF transmission. The RB parameter may be set to any value between 1 and the RF packet size [refer to PK (Max RF Packet Size) parameter], inclusive. Note that transition to Transmit Mode cannot take place during RF reception; the RF reception must complete before the radio can transition into Transmit Mode.

If RB or RO conditions are met, the module initializes a communications channel. Serial data in the DI buffer is grouped into RF packets (up to 2048 bytes in each packet, refer to PK Command), converted to RF data and is transmitted over-the-air until the DI buffer is empty.

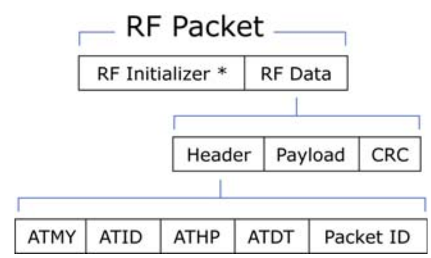
Channel initialization is the process of sending an RF initializer that synchronizes receiving modules with the transmitting module. During channel initialization, incoming serial data accumulates in the DI buffer.

RF data, which includes the payload data, follows the RF initializer. The payload includes up to the maximum packet size (PK Command) bytes. As the TX module nears the end of the transmission, it inspects the DI buffer to see if more data exists to be transmitted. This could be the case if more than PK bytes were originally pending in the DI buffer or if more bytes arrived from the UART after the transmission began. If more data is pending, the transmitting module assembles a subsequent packet for transmission.

Refer to the 'RF Communication Modes' section to view state diagrams that illustrate channel initialization and the sequence of events that follow.

RF Packet

Figure 2-06. RF Packet Components



* When streaming multiple RF packets, the RF Initializer is only sent in front of the first packet.

RF Initializer

An RF initializer is sent each time a new connection sequence begins. The RF initializer contains channel information that notifies receiving modules of information such as the hopping pattern used by the transmitting module. The first transmission always sends an RF initializer.

An RF initializer can be of various lengths depending on the amount of time determined to be required to prepare a receiving module. For example, a wake-up initializer is a type of RF initializer used to wake remote modules from Sleep Mode (Refer to the FH, LH, HT and SM Commands for more information). The length of the wake-up initializer should be longer than the length of time remote modules are in cyclic sleep.

Header

The header contains network addressing information that filters incoming RF data. The receiving module checks for matching a Hopping Channel, VID and Destination Address. Data that does not pass through all three network filter layers is discarded.

Refer to the 'Addressing' section of the "RF Communication Modes" chapter for more information.

CRC (Cyclic Redundancy Check)

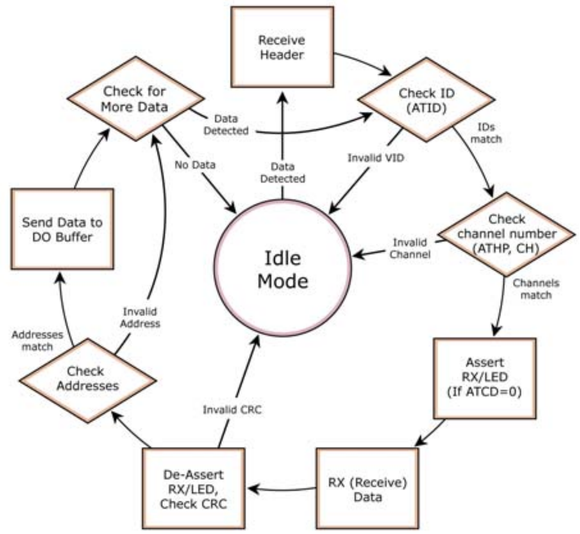
To verify data integrity and provide built-in error checking, a 16-bit CRC (Cyclic Redundancy Check) is computed for the transmitted data and attached to the end of each RF packet. On the receiving end, the receiving module computes the CRC on all incoming RF data. Received data that has an invalid CRC is discarded [refer to the 'Receive Mode' section].

2.2.3. Receive Mode

If a module detects RF data while operating in Idle Mode, the module transitions to Receive Mode to start receiving RF packets. Once a packet is received, the module checks the CRC (cyclic redundancy check) to ensure that the data was transmitted without error. If the CRC data bits on the incoming packet are invalid, the packet is discarded. If the CRC is valid, the packet proceeds to the DO Buffer.

Figure 2-07. Receive Mode Data Flow

* Refer to the 'Address Recognition' section for more information regarding address recognition.



The module returns to Idle Mode when valid RF data is no longer detected or after an error is detected in the received RF data. If serial data is stored in the DI buffer while the module is in Receive Mode, the serial data will be transmitted after the module is finished receiving data and returns to Idle Mode.

2.2.4. Shutdown Mode

Hardware Sleep

For applications where power consumption must be kept to a minimum during idle periods, Shutdown Mode offers the lowest power mode available to the module.

When the SHDN pin (pin 7) is driven low, the module is forced into shutdown mode. Any communication in progress (transmit or receive) will be halted and any buffered data will be lost. For any other mode of operation, SHDN must be driven or pulled high. While in shutdown mode, the module's VCC pin draws 5 µA (typical).

Immediately after the SHDN pin changes state from low to high, the module resets. After reset, there is a delay that must be observed. Delay time is <100ms.

While SHDN pin is driven low, the following pins are set to high impedance by the module: DCD, TX_PWR, RX LED, DO and CTS (See pin signal descriptions, p6). The SHDN line (also used for RSSI indication) is driven low during shutdown.

The following input pins may continue to be driven by external circuitry when in shutdown mode: PIN_PWR_DWN, RTS, DI and SHDN.

Note: Because the DO pin also goes high impedance, if the XTend RF Module is connected to a processor, the UART receive pin could be floating. A weak pull-up should be placed between the module and the microcontroller so that data is not interpreted as being transmitted to the microprocessor.

2.2.5. Sleep Mode

Software Sleep

Sleep Modes enable the module to enter states of low-power consumption when not in use. Three software Sleep Modes are supported:

- Pin Sleep (Host Controlled)
- Serial Port Sleep (Wake on Serial Port activity)
- Cyclic Sleep (Wake on RF activity)

In order to enter Sleep Mode, one of the following conditions must be met (in addition to the module having a non-zero SM parameter value):

1. The module 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.]
2. SLEEP (pin 8) is asserted (only for the 'Pin Sleep' option).

When in Sleep Mode, the module will not transmit or receive data until the module first transitions to Idle Mode. All Sleep Modes are enabled and disabled using SM Command. Transitions into and out of Sleep Modes are triggered by various mechanisms as shown in the table below.

Table 2-01. Summary of Sleep Mode Configurations

Sleep Mode (Setting)	Transition into Sleep Mode	Transition out of Sleep Mode (wake)	Related Commands	Power Consumption
Pin Sleep (SM = 1)	Assert (high) SLEEP pin - A micro controller can shut down and wake modules via the SLEEP pin. Note: The module will complete a transmission or reception before activating Pin Sleep.	De-assert (low) SLEEP pin	(SM)	< 147 µA
Serial Port Sleep (SM = 2)	Automatic transition to Sleep Mode occurs after a user-defined period of inactivity (no transmitting or receiving of data). Period of inactivity is defined by the ST (Time before Sleep) Command.	When a serial byte is received on the DI pin	(SM), ST	< 10 mA
Cyclic Sleep (SM = 4 - 8)	RF module transitions in and out of Sleep Mode in cycles (user-selectable wake-up interval of time is set using the SM command). The cyclic sleep interval of time must be shorter than the interval of time that is defined by the LH (Wake-up Initializer TImer) command. Note: The module can be forced into Idle Mode using the SLEEP pin if the PW (Pin Wake-up) command is issued.		(SM), ST, HT, LH, PW	< 1.6 mA when sleeping (SM=4, 1 sec., @120K baud)

The SM (Sleep Mode) command is central to setting all Sleep Mode configurations. By default, Sleep Modes are disabled (SM = 0) and the module remains in Idle/Receive Mode. When in this state, the module remains constantly ready to respond to serial or RF activity.

Refer to the 'Hardware Sleep' section of the 'Shutdown Mode' section [previous page] to enable the module's lowest power-consuming state (5 µA typical power-down current).

Pin Sleep (SM = 1)

- Pin/Host-controlled
- Typical power-down current: < 147 µA

This mode is voltage level activated. When the SLEEP pin is asserted, the module will finish any transmitting or receiving activity; enter Idle Mode; then enter a state of sleep. When in Pin Sleep Mode, the module will not respond to serial or RF activity.

After enabling Pin Sleep, the SLEEP pin controls whether the module is active or sleeping. When SLEEP is de-asserted, the module is fully operational. When SLEEP is asserted, the module transitions to Sleep Mode and remains in its lowest power-consuming state until the pin is de-asserted. This pin is only active if the module is setup to operate in this mode; otherwise the pin is ignored.

Once in Pin Sleep, CTS (GPO1) is de-asserted (high), indicating that data should not be sent to the module. The PWR pin is also de-asserted (low) when the module is in Pin Sleep Mode.

Note: The module will complete a transmission or reception before activating Pin Sleep.

Serial Port Sleep (SM = 2)

- Wake on serial port activity
- Typical power-down current: < 10 mA

Serial Port Sleep is a Sleep Mode in which the module runs in a low power state until serial data is detected on the DI pin.

The period of time the module sleeps is determined by ST (Time before Sleep) Command. Once a character is received through the DI pin, the module returns to Idle Mode and is fully operational.

Cyclic Sleep (SM = 4-8)

- Typical Power-down Current: < 1.6 mA (when asleep)

Cyclic Sleep Modes allow modules to periodically wake and check for RF data. The module wakes according to the times designated by the Cyclic sleep settings. If the module detects a wake-up initializer during the time it is awake, the module synchronizes with the transmitting module and receives data after the wake-up initializer runs its duration. Otherwise, the module returns to Sleep Mode and continues to cycle in and out of activity until a wake-up initializer is detected.

While the module is in Cyclic Sleep Mode, CTS (GPO1) is de-asserted (high) to indicate that data should not be sent to the module. When the module awakens to listen for data, GPO1 is asserted and any data received on the DI Pin is transmitted. The PWR pin is also de-asserted (low) when the module is in Cyclic Sleep Mode.

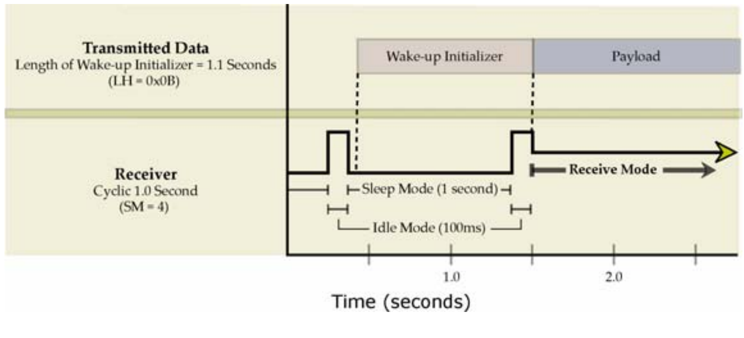
The module remains in Sleep Mode for a user-defined period of time ranging from 0.5 seconds to 16 seconds (SM parameters 4 through 8). After this interval of time, the module returns to Idle Mode and listens for a valid data packet for 100 ms. If the module does not detect valid data (on any frequency), the module returns to Sleep Mode. If valid data is detected, the module transitions into Receive Mode and receives the incoming RF packets. The module then returns to Sleep Mode after a period of inactivity determined by the ST "Time before Sleep" parameter.

The module can also be configured to wake from cyclic sleep when the SLEEP pin is de-asserted. To configure a module to operate in this manner, PW (Pin Wake-up) Command must be issued. Once the SLEEP pin is de-asserted, the module is forced into Idle Mode and can begin transmitting or receiving data. It remains active until data is no longer detected for the period of time specified by the ST Command, at which point it resumes its low-power cyclic state.

Cyclic Scanning. Each RF transmission consists of an RF Initializer and payload. The RF initializer contains initialization information and all receiving modules must wake during the wake-up initializer portion of data transmission in order to be synchronized with the transmitting module and receive the data.

The cyclic interval time defined by the SM (Sleep Mode) command must be shorter than the interval time defined by LH (Wake-up Initializer Timer) command.

Figure 2-08. Correct Configuration (LH > SM):
The length of the wake-up initializer exceeds the time interval of Cyclic Sleep. The receiver is guaranteed to detect the wake-up initializer and receive the accompanying payload data.



2.2.6. Command Mode

To modify or read module parameters, the module must first enter into Command Mode (state in which incoming characters are interpreted as commands). Two command types are supported:

- AT Commands
- Binary Commands

For modified parameter values to persist in the module registry, changes must be saved to non-volatile memory using the WR (Write) command. Otherwise, parameters are restored to previously saved values when the module is powered off and then on again.

AT Command Mode

To Enter AT Command Mode:

1. Send the 3-character command sequence "+++" and observe guard times before and after the command characters. [refer to 'Default AT Command Mode Sequence' below.] The 'Terminal' tab (or other serial communications software) of the X-CTU Software can be used to enter the sequence.

   [OR]

2. Assert (low) the CONFIG pin and turn the power going to the module off and back on (or pulse the SHDN pin).

   [If the module is mounted to a MaxStream RS-232/485 Interface Board, the result can be achieved by pressing the configuration switch down for 2 seconds.]

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

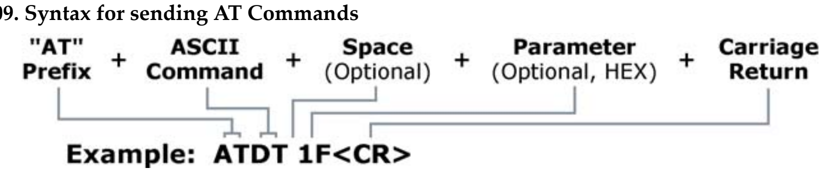
- No characters sent for one second [refer to the BT (Guard Time Before) Command]
- Input three plus characters ("+++") within one second
  [refer to the CC (Command Sequence Character) Command.]
- No characters sent for one second [refer to the AT (Guard Time After) Command.]

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

To Send AT Commands:

Send AT commands and parameters using the syntax shown below.

Figure 2-09. Syntax for sending AT Commands



To read a parameter value stored in the module register, leave the parameter field blank.

The preceding example would change the module's Destination Address to "0x1F". To store the new value to non-volatile (long term) memory, the Write (ATWR) command must subsequently be sent before powering off the module.

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

To Exit AT Command Mode:

1. If no valid AT Commands are received within the time specified by CT (Command Mode Timeout) Command, the module automatically returns to Idle Mode.

   [OR]

2. Send ATCN (Exit Command Mode) Command.

For an example of programming the RF module using AT Commands and descriptions of each configurable parameter, refer to the "RF Module Configuration" chapter [p19].

Binary Command Mode

Sending and receiving parameter values using binary commands is the fastest way to change operating parameters of the module. Binary commands are used most often to sample signal strength [refer to DB (Received Signal Strength) parameter] and/or error counts; or to change module addresses and channels for polling systems when a quick response is necessary. Since the sending and receiving of parameter values takes place through the same serial data path as 'live' data (received RF payload), interference between the two types of data can be a concern.

Common questions about using binary commands:

- What are the implications of asserting CMD while live data is being sent or received?
- After sending serial data, is there a minimum time delay before CMD can be asserted?
- Is a time delay required after CMD is de-asserted before payload data can be sent?
- How does one discern between live data and data received in response to a command?

The CMD pin (pin 10) must be asserted in order to send binary commands to the module. The CMD pin can be asserted to recognize binary commands anytime during the transmission or reception of data. The status of the CMD signal is only checked at the end of the stop bit as the byte is shifted into the serial port. The application does not allow control over when data is received, except by waiting for dead time between bursts of communication.

If the command is sent in the middle of a stream of payload data to be transmitted, the command will essentially be executed in the order it is received. If the module is continuously receiving data, the radio will wait for a break in the received data before executing the command. The $\overline{CTS}$ signal will frame the response coming from the binary command request [refer to figure below].

A minimum time delay of 100 µs (after the stop bit of the command byte has been sent) must be observed before the CMD pin can be de-asserted. The command executes after all parameters associated with the command have been sent. If all parameters are not received within 0.5 seconds, the module returns to Idle Mode.

Note: When parameters are sent, they are two bytes long with the least significant byte sent first. Binary commands that return one parameter byte must be written with two parameter bytes.

Commands can be queried for their current value by sending the command logically ORed (bitwise) with the value 0x80 (hexadecimal) with CMD asserted. When the binary value is sent (with no parameters), the current value of the command parameter is sent back through the DO pin.

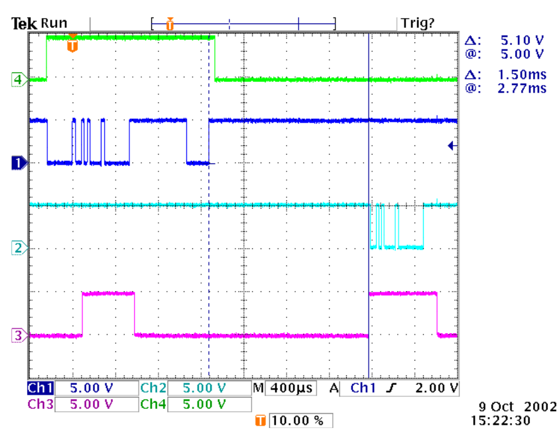
Figure 2-010.Binary Command Write then Read

Signal #4 is CMD

Signal #1 is the DI signal

Signal #2 is the DO signal from the radio

Signal #3 is $\overline{CTS}$



In this graph, a value was written to a register and then read out to verify it. While not in the middle of other received data, note that the $\overline{CTS}$ signal outlines the data response out of the module.

IMPORTANT: In order for the module to recognize a binary command, the RT (GPI1 Configuration) parameter must be set to one. If binary programming is not enabled (RT parameter value is not equal to '1'), the module will not recognize that the CMD pin is asserted and therefore will not recognize the data as binary commands.

Refer to [p19] for a binary programming example (DT command example returns two bytes).

3. RF Module Configuration

3.1. Programming Examples

Refer to the ‘Command Mode’ section [p17] for information regarding entrance into Command Mode, sending AT commands and exiting Command Mode. Refer to the ‘X-CTU’ section [p69] of the ‘Development Guide’ for more information regarding MaxStream’s configuration software.

3.1.1. AT Commands

Note: Do not send commands to the module during flash programming (when parameters are being written to the module registry).

Wait for the "OK" system response that follows the ATWR command before entering the next command or use flow control.

To Send AT Commands (Using the ‘Terminal’ tab of the X-CTU Software)

Example: Utilize the 'Terminal' tab of the X-CTU Software to change the module's DT (Destination Address) parameter and save the new address to non-volatile memory. This example requires the installation of MaxStream’s X-CTU Software and a serial connection to a PC.

Select the ‘Terminal’ tab of the X-CTU Software and enter the following command lines:

Method 1 (One line per command)

Send AT Command	**System Response**
+++	OK <CR> (Enter into Command Mode)
ATDT <Enter>	{current value} <CR> (Read Destination Address)
ATDT1A0D <Enter>	OK <CR> (Modify Destination Address)
ATWR <Enter>	OK <CR> (Write to non-volatile memory)
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)
ATDT <Enter>	{current value} <CR> (Read Destination Address)
ATDT1A0D,WR,CN <Enter>	OK <CR> (Execute commands)

Note: When using X-CTU Software to program a module, PC com port settings must match the baud (interface data rate), parity & stop bits parameter settings of the module. Use the 'Com Port Setup' section of the “PC Settings” tab to configure PC com port settings to match those of the module.

3.1.2. Binary Commands

To Send Binary Commands:

Example: Use binary commands to change the RF module's destination address to 0x1A0D and save the new address to non-volatile memory.

1. RT Command must be set to '1' in AT Command Mode to enable binary programming.
2. Assert CMD (Pin 10 is driven high). (Enter Binary Command Mode)
3. Send Bytes [parameter bytes must be 2 bytes long]:
   - 00 (Send DT (Destination Address) Command)
   - 0D (Least significant byte of parameter bytes)
   - 1A (Most significant byte of parameter bytes)
   - 08 (Send WR (Write) Command)
4. De-assert CMD (pin 10 is driven low). (Exit Binary Command Mode)

Note: $\overline{CTS}$ (pin 9) is high when a command is being executed. Hardware flow control must be disabled as $\overline{CTS}$ will hold off parameter bytes.

3.2. Command Reference Table

Table 3-01. XTend Commands (The RF modules expect numerical values in hexadecimal. Hexadecimal values are designated by a "0x" prefix. Decimal equivalents are designated by a "d" suffix.)

AT Command	Binary Command	AT Command Name	Parameter Range	Command Category	# Bytes Returned	Factory Default
%V	0x3B (59d)	Board Voltage	0x2CCCA - 0x5BFFA [read-only]	Diagnostics	4	--
AM	0x40 (64d)	Auto-set MY	--	Networking & Security	--	--
AP v2.x20*	--	API Enable	0 - 2	Serial Interfacing	1	0
AT	0x05 (5d)	Guard Time After	2 - (ATST-3) [x 100 msec]	Command Mode Options	2	0x0A (10d)
BD	0x15 (21d)	Interface Data Rate	0 - 8 (standard rates) 0x39 - 0x1C9C38 (non-standard rates)	Serial Interfacing	4	3
BR	0x39 (57d)	RF Data Rate	0 - 1	RF Interfacing	1	1
BT	0x04 (4d)	Guard Time Before	0 - 0xFFFF [x 100 msec]	Command Mode Options	2	0x0A (10d)
CC	0x13 (19d)	Command Sequence Character	0x20 - 0x7F	Command Mode Options	1	0x2B ["+"] (43d)
CD	0x28 (40d)	GPO2 Configuration	0 - 4	Serial Interfacing	1	2
CF	--	Number Base	0 - 2	Command Mode Options	1	1
CN	0x09 (9d)	Exit Command Mode	--	Command Mode Options	--	--
CS	0x1F (31d)	GPO1 Configuration	0 - 4	Serial Interfacing	1	0
CT	0x06 (6d)	Command Mode Timeout	2 - 0xFFFF [x 100 ms]	Command Mode Options	2	0xC8 (200d)
DB	0x36 (54d)	Received Signal Strength	0x6E - 0x28 [read-only]	Diagnostics	2	--
DT	0x00 (0d)	Destination Address	0 - 0xFFFF	Networking & Security	2	0
E0	0x0A (10d)	Echo Off	--	Command Mode Options	--	--
E1	0x0B (11d)	Echo On	--	Command Mode Options	--	--
ER	0x0F (15d)	Receive Error Count	0 - 0xFFFF	Diagnostics	2	0
FH	0x0D (13d)	Force Wake-up Initializer	--	Sleep (Low Power)	--	--
FL	0x07 (7d)	Software Flow Control	0 - 1	Serial Interfacing	1	0
FS	0x3E (62d)	Forced Sync Time	0 - 0xFFFF [x 10 msec]	RF Interfacing	2	0
FT	0x24 (36d)	Flow Control Threshold	0 - (DI buffer size - 0x11) [Bytes]	Serial Interfacing	2	DI buffer size minus 0x11
GD	0x10 (16d)	Receive Good Count	0 - 0xFFFF	Diagnostics	2	0
HP	0x11 (17d)	Hopping Channel	0 - 9	Networking & Security	1	0
HT	0x03 (3d)	Time before Wake-up Initializer	0 - 0xFFFF [x 100 msec]	Sleep (Low Power)	2	0xFFFF (65535d)
HV	--	Hardware Version	0 - 0xFFFF [read-only]	Diagnostics	2	--
ID	0x27 (39d)	Modem VID	0x11 - 0x7FFF (user-settable) 0x8000 - 0xFFFF (factory-set, read-only)	Networking & Security	2	0x3332 (13106d)
KY	0x3C (60d)	AES Encryption Key	0 - (Any other 64-digit hex valid key)	Networking & Security	2	0
LH	0x0C (12d)	Wake-up Initializer Timer	0 - 0xFF [x 100 msec]	Sleep (Low Power)	1	1
MD v2.x20*	0x31 (49d)	RF Mode	0 - 6	Networking & Security	1	0
MK	0x12 (18d)	Address Mask	0 - 0xFFFF	Networking & Security	2	0xFFFF (65535d)
MT	0x3D (61d)	Multi-Transmit	0 - 0xFF	Networking & Security	1	0
MY	0x2A (42d)	Source Address	0 - 0xFFFF	Networking & Security	2	0xFFFF (65535d)
NB	0x23 (35d)	Parity	0 - 4	Serial Interfacing	1	0
PB v2.x20*	0x45 (69d)	Polling Begin Address	0 - 0xFFFF	Networking & Security	2	0
PD v2.x20*	0x47 (71d)	Minimum Polling Delay	0 - 0xFFFF (Base: (x 1 ms), Remote: [x 10 ms])	Networking & Security	2	0

Table 3-01. XTend Commands (The RF modules expect numerical values in hexadecimal. Hexadecimal values are designated by a “0x” prefix. Decimal equivalents are designated by a “d” suffix.)

AT Command	Binary Command	AT Command Name	Parameter Range	Command Category	# Bytes Returned	Factory Default
PE v2.x20*	0x46 (70d)	Polling End Address	0 - 0xFFFF	Networking & Security	2	0
PK	0x29 (41d)	Maximum RF Packet Size	1 - 0x800 [Bytes]	RF Interfacing	2	varies
PL	0x3A (58d)	TX Power Level	0 - 4	RF Interfacing	1	4 (1 Watt)
PW	0x1D (29d)	Pin Wake-up	0 - 1	Sleep (Low Power)	1	0
RB	0x20 (32d)	Packetization Threshold	1 - Current value of PK	Serial Interfacing	2	0x800 (2048d)
RC	--	Ambient Power - Single Channel	0 - 0x31 [dBm, read-only]	Diagnostics	1	--
RE	0x0E (14d)	Restore Defaults	--	(Special)	--	--
RM	--	Ambient Power - All Channels	No parameter - 0x7D0	Diagnostics	2	--
RN	0x19 (25d)	Delay Slots	0 - 0xFF [slots]	Networking & Security	1	0
RO	0x21 (33d)	Packetization Timeout	0 - 0xFFFF [x UART character time]	Serial Interfacing	2	3
RP	0x22 (34d)	RSSI PWM Timer	0 - 0xFF [x 100 msec]	Diagnostics	1	0x20 (32d)
RR	0x18 (24d)	Retries	0 - 0xFF	Networking & Security	1	0x0A (10d)
RT	0x16 (22d)	GPI1 Configuration	0 - 2	Serial Interfacing	1	0
SB	0x37 (55d)	Stop Bits	0 - 1	Serial Interfacing	1	0
SH	0x25 (37d)	Serial Number High	0 - 0xFFFF [read-only]	Diagnostics	2	varies
SL	0x26 (38d)	Serial Number Low	0 - 0xFFFF [read-only]	Diagnostics	2	varies
SM	0x01 (1d)	Sleep Mode	0 - 8 (3 is reserved)	Sleep (Low Power)	1	0
ST	0x02 (2d)	Time before Sleep	(ATAT+3) - 0x7FFF [x 100 msec]	Sleep (Low Power)	2	0x64 (100d)
TP	0x38 (56d)	Board Temperature	0 - 0x7F [read-only]	Diagnostics	1	--
TR	0x1B (27d)	Delivery Failure Count	0 - 0xFFFF [read-only]	Diagnostics	2	0
TT	0x1A (26d)	Streaming Limit	0 - 0xFFFF [0 = disabled]	Networking & Security	2	0
TX	0x3F (63d)	Transmit Only	0 - 1	RF Interfacing	1	0
VL	--	Firmware Version - verbose	Returns string	Diagnostics	--	--
VR	0x14 (20d)	Firmware Version	0 - 0xFFFF [read-only]	Diagnostics	2	--
WA	--	Active Warning Numbers	Returns string	Diagnostics	--	--
WN	--	Warning Data	Returns string	Diagnostics	--	--
WR	0x08 (8d)	Write	--	(Special)	--	--
WS	--	Sticky Warning Numbers	Returns string	Diagnostics	--	--

* Firmware version in which command and parameter options were first supported

3.3. Command Descriptions

Commands in this section are listed alphabetically. Command categories are designated between the "< >" symbols that follow each command title. By default, XTend RF Modules expect numerical values in hexadecimal since the default value of the CF (Number Base) Parameter is '1'. Hexadecimal values are designated by the "0x" prefix and decimal values by the "d" suffix.

%V (Board Voltage) Command

<Diagnostics> %V Command is used to read the current voltage of the module circuit board.

Sample Output:

5.02 V (when ATCF = 0)
5051F (when ATCF = 1) *
5.02 (when ATCF = 2)

* When CF = 1 (default), a hex integer is shown that is equal to (voltage * 65536d).

AT Command: AT%V
Binary Command: 0x3B (59 decimal)
Parameter Range (read-only): 0x2CCCA - 0x5BFFA (2.80 - 5.75 decimal)
Number of bytes returned: 4

AM (Auto-set MY) Command

<Networking & Security> AM Command is used to automatically set the MY (Source Address) parameter from the factory-set serial number of the module. The address is formed with bits 29, 28 and 13-0 of the serial number (in that order). The resulting value is displayed as a result of this command.

AT Command: ATAM
Binary Command: 0x40 (64 decimal)

AP (API Enable) Command

<Serial Interfacing> The AP command is used to enable the module to operate using the frame-based API operation.

AT Command: ATAP

Parameter Range: 0 - 2

Parameter	Configuration
0	API Disabled (Transparent Operation)
1	API enabled (w/out escaped characters)
2	API enabled (with escaped characters)

Default Parameter Value:0

Number of Bytes Returned:1

Minimum Firmware Version Required: 2.x20

AT (Guard Time After) Command

<Command Mode Options> AT Command is used to set/read the time-of-silence that follows the command sequence character (CC Command) of the AT Command Mode Sequence (BT + CC + AT). By default, 1 second must elapse before and after the command sequence character.

The times-of-silence surrounding the command sequence character are used to prevent inadvertent entrance into AT Command Mode.

Refer to the 'AT Command Mode' section [p17] for more information regarding the AT Command Mode Sequence.

AT Command: ATAT
Binary Command: 0x05 (5 decimal)
Parameter Range: 2 - (ATST-3), up to 0x7FFC [x 100 milliseconds]
Default Parameter Value: 0x0A (10 decimal)
Number of bytes returned: 2
Related Commands: BT (Guard Time Before), CC (Command Sequence Character)

BD (Interface Data Rate) Command

<Serial Interfacing> The BD command is used to set and read the serial interface data rate (baud rate) used between the RF module and host. This parameter determines the rate at which serial data is sent to the module 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 0-8 are sent to the module, 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.

The range between standard and non-standard baud rates (0x09 - 0x38) is invalid.

Non-standard Interface Data Rates: Any value above 0x38 will be interpreted as an actual baud rate. When a value above 0x38 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 MaxStream's X-CTU Software, non-standard interface data rates can only be set and read using the X-CTU 'Terminal' tab. Non-standard rates are not accessible through the 'Modem Configuration' tab.

AT Command: ATBD

Binary Command: 0x15 (21 decimal)

Parameter Ranges: 0 – 8 (standard rates)
0x39 – 0x1C9C38 (non-standard rates)

Parameter	Configuration (bps)
0	1200
1	2400
2	4800
3	9600
4	19200
5	38400
6	57600
7	115200
8	230400

Default Parameter Value: 3

Non-standard baud rates supported as of firmware v2.x20

Number of bytes returned: 4

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 module'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

BR (RF Data Rate) Command

<RF Interfacing> The BR command is used to set and read the RF data rate (rate that RF data is transmitted over-the-air) of the module.

AT Command: ATBR

Binary Command: 0x39 (57 decimal)

Parameter Range: 0 – 1

Parameter	Baud (bps) Configuration
0	9600
1	115200

Default Parameter Value:1

Number of bytes returned: 1

BT (Guard Time Before) Command

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

Refer to the 'AT Command Mode' section [p17] for more information regarding the AT Command Mode Sequence.

AT Command: ATCC
Binary Command: 0x13 (19 decimal)
Parameter Range: 0x20 – 0x7F
Default Parameter Value: 0x2B (ASCII "+")
Number of bytes returned: 1
Related Commands: AT (Guard Time After), BT (Guard Time Before)

CC (Command Sequence Character) Command

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

Refer to the 'AT Command Mode' section [p17] for more information regarding the AT Command Mode Sequence.

AT Command: ATCC
Binary Command: 0x13 (19 decimal)
Parameter Range: 0x20 – 0x7F
Default Parameter Value: 0x2B (ASCII "+")
Number of bytes returned: 1
Related Commands: AT (Guard Time After), BT (Guard Time Before)

CD (GPO2 Configuration) Command

<Serial Interfacing> CD Command is used to select/read the behavior of the GPO2 line (pin 3).

AT Command: ATCD	
Binary Command: 0x28 (40 decimal)	
Parameter Range: 0 – 8 (standard rates)	
Parameter	Configuration
0	RX LED
1	Default High
2	Default Low
3	(reserved)
4	RX LED (valid address only)
Default Parameter Value: 2	
Number of bytes returned: 1	

CF (Number Base) Command

<Command Mode Options> CF command is used to set/read the command formatting setting.

The following commands are always entered and read in hex, no matter the CF setting:

VR (Firmware Version)
HV (Hardware Version)
KY (AES Encryption Key)

AT Command: ATCF	
Parameter Range: 0 – 2	
Parameter	Configuration
0	Commands utilize default number base; decimal commands may output units
1	All commands forced to unsigned, unit-less hex
2	Commands utilize their default number base; no units are output
Default Parameter Value: 1	
Number of bytes returned: 1	

CN (Exit AT Command Mode) Command

<Command Mode Options> The CN command is used to explicitly exit the module from AT Command Mode.

AT Command: ATCN
Binary Command: 0x09 (9 decimal)

CS (GPO1 Configuration) Command

<Serial Interfacing> CS Command is used to select the behavior of the GP01 pin (pin 9). This output can provide RS-232 flow control, control the TX enable signal (for RS-485 or RS-422 operations).

By default, GP01 provides RS-232 $\overline{\text{CTS}}$ (Clear-to-Send) flow control.

AT Command: ATCS	
Binary Command: 0x1F (31 decimal)	
Parameter Range: 0 – 4	
Parameter	Configuration
0	RS–232 $\overline{\text{CTS}}$ flow control
1	RS–485 TX enable low
2	High
3	RS–485 TX enable high
4	Low
Default Parameter Value: 0	
Number of bytes returned: 1	
Related Commands: RT (GPI1 Configuration), TO (GP01 Timeout)	

CT (Command Mode Timeout) Command

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

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

AT Command: ATCT
Binary Command: 0x06 (6 decimal)
Parameter Range: 2 – 0xFFFF [x 100 milliseconds]
Default Parameter Value: 0xC8 (200d)
Number of bytes returned: 2
Related Command: CN (Exit AT Command Mode)

DB (Received Signal Strength) Command

<Diagnostics> DB Command is used to read the receive signal strength (in decibels relative to milliWatts) of the last received packet. This parameter is useful in determining range characteristics of the RF modules under various conditions.

AT Command: ATDB
Binary Command: 0x36 (54 decimal)
Parameter Range (read–only): 0x6E – 0x28 (–110 to –40 Decimal)
Number of bytes returned: 2

In default mode, this command shows the power level in signed decimal format with the units (dBm). If CF = 1, the magnitude of the value is presented in unsigned hex. If CF = 2, the value is presented in decimal, but without the units.

Sample Output:	-88 dBm	(when ATCF = 0)
	58	(when ATCF = 1)
	-88	(when ATCF = 2)

NOTE: If the DB register is read before the module has received an RF packet, the module will return a value of 0x8000 (which means an RF packet has not yet been received).