MRF450 User Manual

U077.0.2-MRF450

Operation of this module in Periodic Transmit mode requires a license.

FCC Statements

15.19 – Two Part Warning

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference and

(2) This device must accept any interference received, including interference that may cause undesired operation.

15.21 – Unauthorized Modification

NOTICE: The manufacturer is not responsible for any unauthorized modifications to this equipment made by the user. Such modifications could void the user's authority to operate the equipment.

15.27 – Special Accessories

This device is supplied with special accessories that include an RF adapter cable and antenna. These special accessories must be used with the device. It is the responsibility of the user to use the needed special accessories supplied with the equipment.

15.105(b) – Note:

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Industry Canada Statements

RSS-GEN 7.1.2 – Transmitter Antenna / Antenne de L'émetteur

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

This radio transmitter 7955A-MRF450 has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Le présent émetteur radio 7955A-MRF450 a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Approved Antenna List / Liste Antenne Approuvé			
Manufacturer	**Part Number**	**Gain**	**Impedance**
Nearson	L324TR-440	0 dBi	50 Ohm

RSS-GEN 7.1.3 – Notice / Délai

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Table of Contents

Table of Contents i
List of Figures i
List of Tables i
Cervis Inc. Safety Precautions 1
1.0 Introduction 2
1.1 Features 2
1.2 Dimensions (mils)/Locations 3
1.3 Pinout 3
2.0 Installation 4
3.0 Tune-up Procedure 4
4.0 Electrical Characteristics 5
4.1 Power 5
4.2 SPI Mode 5
4.3 UART Mode 5
5.0 RF Characteristics 6
6.0 Operational Modes 7
6.1 Push-To-Transmit Mode 7
6.2 Periodic Transmit Mode 7
7.0 Communication Protocol 8
7.1 SPI 8
7.2 UART 8
7.3 Acknowledgement 9
8.0 Messages 10
8.1 Get / Set Parameter 10
8.2 Transmit 12
8.3 Receive 13
8.4 Error 14

List of Figures

Figure 1. MRF450 Front and Back 2
Figure 2. Dimensions (mils)/Locations 3
Figure 3. State Transitions vs. Current Consumption 5

List of Tables

Table 1. P1, P2, and P3 Pinout 3
Table 2. Recommended Baud Rates and Associated Deviation 6
Table 3. OTA Structure Format 6
Table 4. Packet Format Diagram 8
Table 5. Message IDs and Structures 10
Table 6. Parameter ID Assignment and Data Lengths 10
Table 7. Configurable Parameters 10
Table 8. Transmit ID, Reply 12

Table 9. Receive Message Structure **13**
Table 10. Error Message Structure **14**

Notes and Observations

Cervis Inc. Safety Precautions

- ***Read and follow all instructions.***
- ***Failure to abide by Safety Precautions may result in equipment failure, loss of authority to operate the equipment, and personal injury.***
- ***Use and maintain proper wiring. Follow equipment manufacturer instructions. Improper, loose, and frayed wiring can cause system failure, equipment damage, and intermittent operation.***
- ***Changes or modifications made to equipment not expressly approved by the manufacturer will void the warranty.***
- ***Owner/operators of the equipment must abide by all applicable Federal, State, and Local laws concerning installation and operation of the equipment. Failure to comply could result in penalties and could void user authority to operate the equipment.***
- ***Make sure that the machinery and surrounding area is clear before operating. Do not activate a remote control system until certain that it is safe to do so.***
- ***Turn off the module power before attempting any maintenance. This will prevent accidental operation of the controlled machinery.***
- ***Do not allow liquid to enter the module enclosure. Do not use high pressure equipment to clean the module.***
- ***Operate and store units only within the specified operation and storage temperatures defined in the Specifications of this document.***

1.0 Introduction

The MRF450 radio module is an RF modem. The module consists of a Silicon Labs RF transceiver coupled with a 32-bit Atmel ARM processor. The module is intended to be integrated into Cervis product, providing RF connectivity while hiding the complexity of RF communications and link management.

The radio is designed to operate in the 450 – 470 MHz band with a maximum output power of less than 15 dBm. The radio can operate on any center frequency in the band with a resolution of 1 kHz. The center frequency is fixed for the duration of operation. The radio utilizes 2(G)FSK modulation in a 12.5 kHz channel bandwidth.

1.1 Features

- FCC Part 90.217 Certified
- 12.5 kHz Selectable Channel
- 450–470MHz Operation
- Up to 14dBm Output Power
- 12 kbps Data Rate
- SPI or UART Communications
- Simple Packet-Based Protocol
- Status LEDs

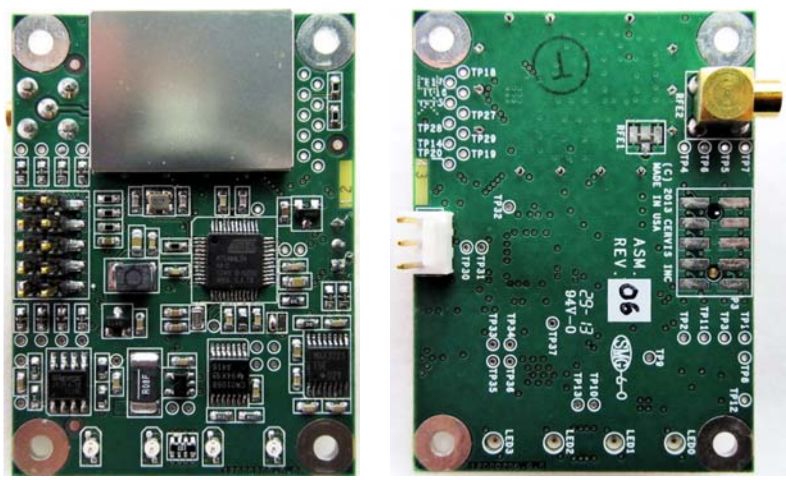

Figure 1. MRF450 Front and Back

1.2 Dimensions (mils)/Locations

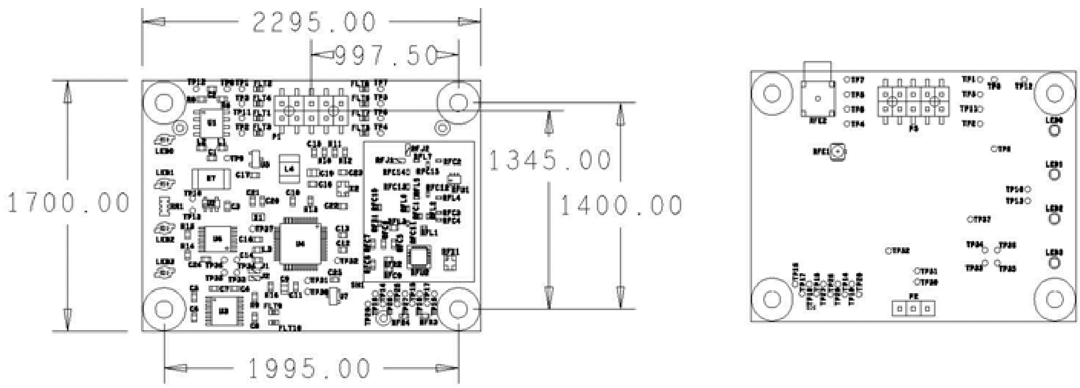

Figure 2. Dimensions (mils)/Locations

1.3 Pinout

Table 1. P1, P2, and P3 Pinout

P1 Pin	Assignment	I/0
P1.1	+VDC	3.3V
P1.2	-VDC	GND
P1.3	Enable	IN, High
P1.4	OC Flag	OUT, Low
P1.5	SPI SCK	IN
P1.6	SPI SDI / UART RX	IN
P1.7	SPI SDO / UART TX	OUT
P1.8	SPI nSS	IN, Low
P1.9	F0	IN/OUT
P1.10	F1 / nRESET	IN/OUT

P3 Pin	Assignment	I/0
P1.1	+VDC	3.3V
P1.2	TMS	IN
P1.3	-VDC	GND
P1.4	TCK	IN
P1.5	-VDC	GND
P1.6	TDO	OUT
P1.7	NC	NC
P1.8	TDI	IN
P1.9	-VDC	GND
P1.10	nRESET	IN, Low

P1 Pin	Assignment	I/0
P1.1	Debug RS232 TX	OUT
P1.2	Debug RS232 RX	IN
P1.3	REF	GND

2.0 Installation

When integrating this module into a host, the user must provide all text in the “FCC Statements” and “Industry Canada Statements” into the host device’s user manual (see Forward Material). The text must not be modified in any way and presented in a conspicuous manner that the end user can be reasonably expected to access.

The module is provided with an RF adapter cable and antenna. The RF adapter cable converts MCX to RP-TNC plug. The connector on the antenna is an RP-TNC jack. Please see section entitled “FCC Statements” for notice concerning these special accessories.

Install the RF adapter cable by plugging the MCX plug into the MCX jack on the module (RFE2). Affix the RP-TNC end of the adapter cable to the housing of the host device utilizing the keyed housing and locking nut. Finally, install the antenna onto the RP-TNC end of the adapter.

3.0 Tune-up Procedure

This module does not require any special tune-up procedure by the user. This module utilizes advanced system-on-chip (SOC) technology. The SOC is tuned by the foundry at time of manufacture and is not subject to change or adjustment. The module contains no adjustable components.

Proper RF operation of the module is verified during the manufacturing process using suitable equipment and methods. The manufacturer has performed a tuning process according to the SOC design guidelines.

4.0 Electrical Characteristics

4.1 Power

The module requires a regulated 3.3 VDC source. The module does not provide under-voltage, over-voltage, or reverse polarity protection so use caution when applying power.

The module transitions between states during normal operation. The integrated PA consumes the largest amount of power when active. Therefore, transitions to the transmit state will cause the largest draw on the host supply. It is recommended to provide a large bulk capacitance with low ESR as close as possible to P1.1 to mitigate host supply drooping during transitions to the transmit state.

Figure 3 illustrates state transitions vs. current consumption.

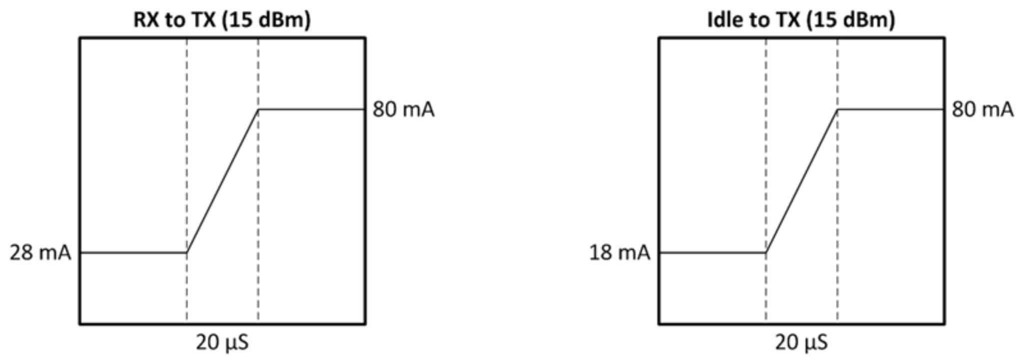

Figure 3. State Transitions vs. Current Consumption

4.2 SPI Mode

In SPI mode, P.5 – P1.8 form a SPI slave interface. P1.5 is the input SPI clock generated by the SPI master (host). The max SCK frequency must be less than 2 MHz. P1.6 is MOSI. P1.7 is MISO. P1.8 is the input slave select and is active low.

The SPI port is configured for standard SPI Bus Protocol Mode 0. In this mode CPOL (clock polarity) is 0 meaning that the clock is at a logic low level when idle. CHPA (clock phase) is 1 meaning that data is latched on the rising edge of the clock and changed on the following edge.

The SPI port requires that nSS be asserted at least one bit-time prior to clocking data. nSS may be released at any time after the last byte has been exchanged. The host must also ensure that at least one bit-time between consecutive bytes of data is observed.

4.3 UART Mode

In UART mode SCK and nSS (P1.5 and P1.8) are unused and configured as inputs with weak pull-ups. In this mode UART RX and UART TX (P1.6 and P1.7) provide an asynchronous serial communications interface. UART RX is configured as an input while UART TX is configured as an output. The interface is RS-232 compatible with the exception that signaling levels are TTL logic levels. The port is always configured with 1 start bit, 8 data bits, 1 stop bit, and no parity. Hardware (RTS and CTS) and software (XON and XOFF) flow control are not utilized. Flow control is handled by the communications protocol discussed later in this document.

The baud rate of the port can be configured. All standard baud rates from 9600 to 115200 are supported with less than 4% error. Non-standard baud rates can also be configured, but, not all requested bauds are possible. Table 2 lists recommended baud rates and associated deviation.

Table 2. Recommended Baud Rates and Associated Deviation

Requested Baud	Generated Baud	% Error
9600	9615	0.16
14400	14493	0.64
19200	19231	0.16
38400	38462	0.16
57600	58824	2.08
115200	111111	3.68
200000	200000	0
250000	250000	0
333333	333333	0
500000	500000	0
1000000	1000000	0
8000000	8000000	0

The following formulae are used to calculate the baud rate:

$$Divisor = \frac{8{,}000{,}000}{DesiredBaud\ x\ 16}$$

Divisor is a 16-bit integer value so be sure to round the result.

$$ActualBaud = \frac{8{,}000{,}000}{Divisor\ x\ 16}$$

Finally, calculate the error percentage. Results greater than 4% typically do not work.

$$Error = 1 - \left(\frac{DesiredBaud}{ActualBaud}\right)$$

5.0 RF Characteristics

The OTA structure is formatted as in Table 3.

Table 3. OTA Structure Format

0	..	4	5	6	7	..	n	n + 1	n + 2
Preamble			Sync		Payload			CRC32	
0xAA	0xAA	0xAA	0x2D	0xD4	CRC over this region				

The module is configured for 12 kbps. This yields 667 µs per byte transmitted. To calculate time of transmission in seconds, add 10 bytes to the payload count and multiply by 0.000667. So, a payload of 4 bytes takes (10 + 4) * 0.000667 = 0.009338s, or 9.3 ms on-the-air.

The additional byte (5 Preamble + 2 Sync + 2 CRC32 = 9) comes from the payload structure. The first byte of the payload is a length indicator used by the module to determine payload length.

6.0 Operational Modes

The module can be configured to operate in one of two modes; Push-To-Transmit mode and Periodic mode. These modes are discussed in this section. Refer to section “8.1 Get / Set Parameter” for instructions on changing the operational mode.

6.1 Push-To-Transmit Mode

Push-To-Transmit is the module’s default mode. Any time power is applied to the module it will begin operation in this mode. This mode is a license-free mode of operation (the operator does not require a license in order to use the module in this mode, following the requirements set forth by the FCC in CFR 47 Part 15.231). The module limits the maximum output power to 68.1 dBuV.

In order to comply with license free operation the interaction between the host and module has restrictions. The host may only issue transmit requests when a manual event occurs on the host, for example when a button is pressed. There is no limit to the number of transmit requests that can be issued while the event is active. However, once the event has passed, for example when the button is released, the host must cease issuing transmit requests within 5 seconds.

Periodic transmit requests are strictly forbidden. This includes, but is not limited to, link maintenance messages, keep-alive messages, and status messages.

6.2 Periodic Transmit Mode

Periodic Transmit mode is intended for licensed operation (CFR 47 Part 90). The module limits the maximum output power to +15 dBm. In this mode there are no restrictions between the host and module, provided the user has configured the module to operate on the frequency channel for which he holds a license.

It is a violation of CFR 47 to operate this module in Periodic Transmit mode without a license.

7.0 Communication Protocol

Communication between the module and host is packetized. Each packet begins with a start-of-packet (SOP) indicator, followed by the length of the packet message, followed by the message, and terminated with a checksum calculated over the message. All multi-byte fields are interpreted in little-endian format; the LSB is stored in the lowest address and the MSB is stored in the highest. A diagram of the packet format follows.

Table 4. Packet Format Diagram

0	1	2	3	..	n	n + 1
SOP	**Message Length**		**Message**			**Chksum**
0x3C	LSB	MSB	Chksum Region			

The checksum is calculated by subtracting the 8-bit sum of the message bytes from 0xFF. In this way, the checksum of a packet can be easily verified by summing the message bytes and checksum. The result of a valid packet is 0xFF.

Handshaking

The synchronization scheme between the module and host varies depending on the communication channel selected. In either scheme the packet structure remains constant.

7.1 SPI

In SPI mode the module is a slave device. As such, it cannot initiate communications. All communication is controlled by the host. The module utilizes a buffer for all packets to the host. F0 (P1.9) is used to communicate the buffer status to the host. When F0 is low, there are no packets available for the host. When F0 is high, at least one packet is available.

The host must check the state of F0 prior to initiating a SPI transfer. If F0 is low the transaction will be handled as a write. No data will be shifted out to the host during the transaction. If F0 is high the transaction will be handled as a read. The module will shift the buffered packet to the host. Data shifted from the host to the module will be ignored. The polarity of this signal may be configured (see Pin Mode parameter).

In order to prevent SPI slave overflows, a second control signal is implemented. F1 is utilized as a CTS (clear to send) signal. The host must check the state of F1 prior to initiating a SPI transfer. If F1 is asserted the SPI slave interface is busy completing a previously requested command and any new request will be silently discarded. As soon as nSS is asserted, F1 is asserted. F1 remains asserted until the requested command completes. The polarity of this signal may be configured (see Pin Mode parameter).

Due to the structured nature of SPI the likelihood that the module and host lose sync is low. No additional facilities are provided in this mode.

7.2 UART

In UART mode, both the host and module can initiate communications. In this mode no special handshaking is required.

In this mode it is potentially possible that the module and host lose sync due to the fact that the SOP byte can occur as valid data. In order to recover from this condition the protocol also provides some simple event timeouts. There is no timeout associated with waiting for the SOP indicator. Once the SOP has been detected an inter-byte timer is started. If the inter-byte timeout expires an error message is sent to the host and the current packet is discarded. A last-byte timer is also maintained. This last-byte timer must elapse before an error message is sent. This ensures that an error message is not sent until the host has completed.

The inter-byte timer is set to 10 byte-times. At 115200 baud this is 868 µs. The last-byte timer is set to 25 byte-times. At 115200 baud this is 2170 µs.

7.3 Acknowledgement

Every packet sent to the module will result in a response packet sent back to the host. In addition, the module will generate a message to the host when an RF packet is received and destined for the host. In UART mode the packet will be sent asynchronously. The host must examine the state of F0 in SPI mode in order to determine if a packet is waiting.

8.0 Messages

The heart of the communication packet structure is the message field. This field carries the specific information of the packet. The first byte of the message field is interpreted as the message ID. The remaining bytes in the message are interpreted based on the message ID. The message IDs and structures follow.

Table 5. Message IDs and Structures

0	..	n
ID	**ID-Dependent**	
Message Field		

8.1 Get / Set Parameter

This group of messages is used to set and read module parameters. The first two bytes identify the specific parameter to be accessed. If data follows the parameter ID, the parameter is set. The module always replies with the current value of the parameter, or an error code. Each parameter can vary in data length. See the table of Parameter ID assignment and data lengths for specific values.

Table 6. Parameter ID Assignment and Data Lengths

Get / Set ID = 0x00, Reply = 0x90.

0	1	2	3	..	n
ID	**Parameter ID**		**Parameter Value**		
0x00			Optional. Set if present		

The following table describes the available configurable parameters.

Table 7. Configurable Parameters

ID	Parameter	Bytes	Default	Description
0x0000	Channel	2	0x0000	Sets the operating center frequency. 450MHz + (Channel * 1000). Values above 20,000 are coerced to 20,000. NOTE: module will NOT transmit until this parameter is set – even if the desired channel is 0.
0x0001	Power	1	0x00	Sets the output RF power. 0 – 255, logarithmic scale. 255 is no greater than module maximum (see ID 0x0050)
0x0002	LED EN	1	0x0F	Bitwise LED enable. A set bit permits LED operation. Bit 0 enables LED0, etc.
0x0003	Baud	4	115200	Sets the baud of the host interface when in UART mode.
0x0004	Pin Mode	1	0x00	Binary-encoded options 1 If clear F0 active low (low when message waiting) 2 If clear F1 active low (high when CTS)
0x0010	My PAN	2	0x0000	Sets the PAN ID of the module.
0x0011	My Address	2	0x0000	Sets the address of the module.
0x0018	DST PAN	2	0x0000	Sets the destination PAN ID for the next transmission.
0x0019	DST Address	2	0x0001	Sets the destination address for the next transmission. 0xFFFF is a broadcast address.
0x0020	Default	1	0x00	0x00 = Idle. Lower power consumption.

ID	Parameter	Bytes	Default	Description
	Mode			0x01 = RX. Fastest response. ~10 mA more than Idle.
0x0030	RX Filter Options	1	0x00	Binary-encoded options. 1 If set, filter DST PAN against My PAN 2 If set, filter DST Address against My Address 4 If set, strip DST PAN from payload 5 If set, strip DST Address from payload 6 If set, strip SRC PAN from payload 7 If set, strip SRC Address from payload If enabled, filter fields must match or the packet is silently discarded. Filtering options are processed prior to stripping options. Enabling filtering on an address field that was not present in the transmitted packet will result in erroneous packet discards – filtering will be performed on the specified byte locations regardless of location contents. Enabling stripping on an address field that was not present in the transmitted packet will result in erroneous payloads – stripping will be performed on the specified byte locations regardless of location contents.
0x0040	TX Options	1	0x01	Binary-encoded options. 1 If set, perform CCA before transmit
0x0041	CCA Threshold	1	0x00	NOT YET IMPLEMENTED. CURRENTLY FIXED AT 0x20. The RSSI value read by the module must be less than this value before a transmit is performed. If the read RSSI value is greater or equal, the module will back off a random length of time (1 – 10 ms) and repeat. See receive section for RSSI conversion formula.
0x0050	Operational Mode	1	0x00	0x00 = Push-To-Transmit mode, unlicensed mode 0x01 = Periodic Transmit mode, licensed mode The mode selected sets the modules maximum RF power output. Push-To-Transmit mode complies with license-free operation. Periodic mode is for licensed use only. Please refer to section “6.0 Operational Modes” for details and restrictions.

8.2 Transmit

This message instructs the module to transmit a packet. The message contains an options field followed by the payload to be sent. The maximum payload is 63 bytes. The maximum payload is further reduced by 2 bytes for each addressing field automatically appended. If all addressing fields are appended by the module (Options = 0xFX) the maximum payload is 63 – (2 * 4) = 55.

Table 8. Transmit ID, Reply

Transmit ID = 0x10, Reply = 0xA0.

0	1	2	..	n
ID	**Options**	**Payload**		
0x10				

The Options field is binary-encoded and defined as in the following table.

Bit	Option	Description
0	Message ACK	If set, send an ACK message to this transmit request.
1	TX Complete ACK	If set, send an ACK message once the packet transmission has completed.
4	DST PAN	If set, append the DST PAN parameter to the front of the payload.
5	DST Address	If set, append the DST Address parameter to the front of the payload.
6	SRC PAN	If set, append the My PAN parameter to the front of the payload.
7	SRC Address	If set, append the My Address parameter to the front of the payload.

8.3 Receive

This message instructs the module to enter receive mode for the specified time in milliseconds. The module will dwell in the receive state until a packet is received or the timeout expires. At this time the module will return to the state specified in the Default Mode parameter. If a transmit command is issued while this command is active it will clear the receive timer and terminate the current receive operation. This message is not necessary when the Default Mode parameter is set to RX.

Table 9. Receive Message Structure

Receive ID = 0x20, Reply = 0xB0.

0	1	2
ID	**Options**	**Time**
0x20		

The options field is binary-encoded and defined as:

Bit	Option	Description
0	Message ACK	If set, send an ACK message to this receive request.
1	Timeout ACK	If set, send an ACK message when the timer expires and no packet was received.

The structure of a received packet varies slightly from the receive request. The structure is illustrated below.

0	1	2	..	n
ID	**RSSI**	**Payload**		
0xB0				

The received packet contains the RSSI value as observed during the RF reception of the packet, along with the packet payload. Based on RX Filter Options, addressing information at the front of the packet may or may not be present.

The RSSI indicator can be converted to dBm with the following linear formula

$$dBm = \frac{RSSI}{2} - Offset$$

Offset should be TBD.

8.4 Error

This message is sent by the module back to the host to indicate unexpected operation.

Table 10. Error Message Structure

Error ID = 0xFF

0	1
ID	**Error**
0xFF	

The Error field is an enumerated type with the following definitions:

Error	Name	Description
0	No Error	No Error
1	No SOP	SOP is missing
2	Length	Length of message exceeds maximum
3	CRC	CRC mismatch
4	Bad ID	Unsupported message ID
5	Bad Parameter	Unsupported parameter address

Visit our Web site at: www.cervisinc.com