Application Programming Interface (API) Specification

PulsON® 400 RCM

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Table of Contents

1 Introduction

The P400 Ranging and Communications Module (RCM) is a single-board ultra wideband (UWB) radio component intended to be integrated into users' electronic devices for enabling high precision distance measurement coupled with wireless data communications. This manual specifies the programmer's interface between the user's Host processor and the RCM. This document provides a reference of the message structures and bit patterns in an Ethernet UDP/IP programming interface. A separate application note, *Using the RCM Serial Interface*, describes the extended header bytes and protocol required to support the 3.3V TTL Serial UART interface.

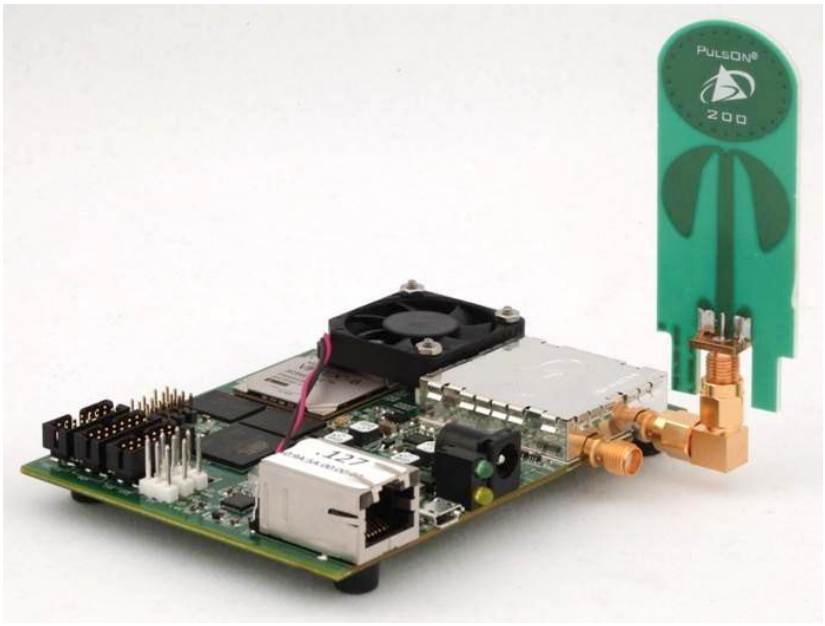


Fig. 1: P400 RCM with attached Broadspec Antenna

We recommend the software developer become familiar with the API through use of the Reconfiguration and Evaluation Tool (RET) application delivered with the Development Kit. This MS Windows PC application provides a graphical representation of the interface data structures and allows the user to quickly become familiar with host behaviors.

The RCM *Quick Start Guide* provides instructions for getting up and running quickly with the RET. The user should reference and build upon the sample applications delivered with the Development Kit.

Usage Notes

This section provides a short overview of key facts relative to RCM behavior and interfaces. Much of this information is covered in the RCM *Quick Start Guide*. Critical points for interfacing via Ethernet are repeated here for convenience.

1. Upon power-up, with or without a host connection, the RCM automatically enters UWB response mode. It will automatically respond to a "range request" packet with its nodeID as range target.
2. Upon successful power-up the amber Power LED and the green Status LED should be lit with a steady glow. Other conditions indicate hardware/firmware failure.
3. The user connects to the RCM from a host PC using either a crossover Ethernet cable (supplied in the Development Kit) or through an Ethernet switch (some laptops have auto-sensing.)
4. As covered in the *Quick Start Guide*, the user must configure his host PC's TCP/IPv4 properties to a static IP address such as 192.168.1.1 with Subnet mask 255.255.255.0. Firewall must be disabled, at least for the RCM addresses of interest.
5. The default UWB Node IDs will correlate with the default IP addresses. For instance, the four RCMs delivered in the Development Kit will have UWB nodeIDs 100, 101, 102, and 103. These RCMs will have default IP addresses of 192.168.1.100, 192.168.1.101, 192.168.1.102, and 192.168.1.103, respectively. This common octet is written on a label attached to the Ethernet socket on the RCM. The RCM nodeID can be changed through this API.
6. The user should verify Ethernet connectivity by inspecting the LEDs on the Ethernet connector and "pinging" the RCM's Ethernet address using a command window (or terminal).
7. The user's code should create a UDP socket targeting port 21210 on the RCM. The RCM will respond to the port that sent the message.
8. Data transferred to/from the RCM is big-endian (network byte order). Code developed on Intel processors must swap bytes (see example code).
9. All RCM devices are slaved to their respective hosts. There is no mechanism built into the RCM to coordinate transmissions other than automatic response to targeted range requests. The hosts are responsible for coordinated transmissions (i.e. Media Access Control). Please contact Time Domain with special requests.
10. The RCM measures distance through a two-way time-of-flight (TW-TOF) radio frequency (RF) ranging technique. If the antennas are altered or extra SMA cable is introduced the range measurement will exhibit a bias based on the longer TOF of the RF pulse.

Sample host interfacing software is available in C and Matlab to help users begin developing their own UWB-enabled applications.

2 The RCM Interface

This is a high-level description of the data passed between a Host processor and the RCM.

RCM modules will power-up in response mode, then wait for both UWB messages arriving from other RCMs as well as commands from the Host.

Figure 2 illustrates a system of 3 RCMs, two with hosts and one without a host. A high-level data flow interface is graphically depicted between one of the hosts and its co-located RCM. (A single host with Ethernet switch could support multiple RCMs wired to it via Ethernet.)

The HOST<->RCM interface consists of six REQUEST messages from host to RCM with their associated CONFIRM messages. In addition, there are three INFO messages that are sent to the host upon receiving UWB packets from other RCMs.

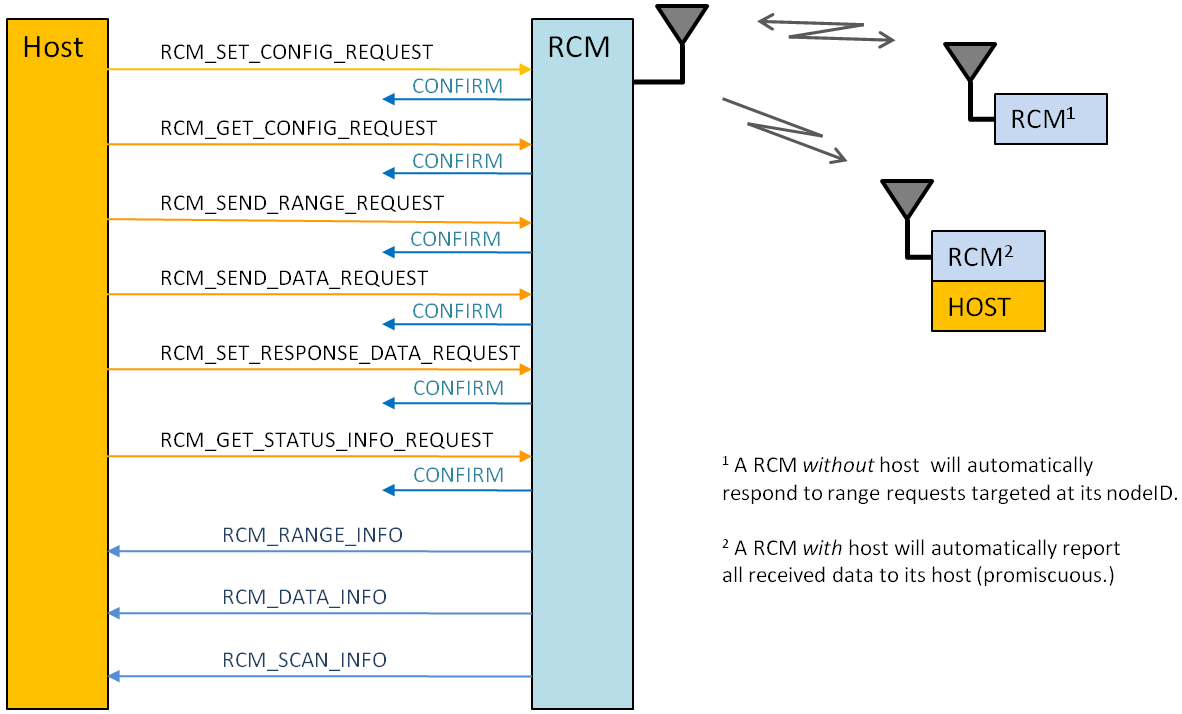


Fig. 2: Message flow - Host to RCM messages and RCM to RCM RF packets

All RCMs, including those without hosts, respond automatically to range request packets that are targeted at them. RCMs with connected hosts will automatically send data and (optionally) scan information to the host in separate UDP packets. The format of these messages is described in this document.

The REQUEST and INFO messages are described in the next subsection. Appendix A contains an illustration of the data flow for a complete range/data conversation. Appendix B contains extra descriptions of many of these parameters.

3 RCM API Messages

3.1 RCM_SET_CONFIG_REQUEST (0x0001)

API: RCM API
Message type: REQUEST (Host)
Corresponding Message type: RCM_SET_CONFIG_CONFIRM (Radio)

Purpose: This message configures the basic parameters in the RCM, thereby defining radio operation.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SET_CONFIG_REQUEST (0x0001)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm and info messages
2	Node ID	UINT32	Node ID of this radio (used for UWB range targeting.) By default this value will be 100 - 10X, matching the last byte of the IP address.
3	Pulse Integration Index	UINT16	Specifies an index which, in general, configures the number of pulses per data symbol. Valid values are [6-10]. The default is 7 meaning 2^7 = 128 pulses per symbol.
4	Antenna Mode	UINT8	Specifies the active antenna for transmission and reception. Valid values are [0=A, 1=B, 2=TXA,RXB, 3=TXB,RXA]. The default value is 0 (use antenna A for both transmissions and receptions.)
5	Code Channel	UINT8	Specifies the active UWB channel. Possible values are [0-6]. The default value is 0.
6	Antenna Delay A	INT32	Specifies the approximate time delay, in picoseconds, of the SMA cable connecting antenna A. The default is that of the default Broadspec antenna connected via 90^{o} SMA elbow.

7	Antenna Delay B	INT32	Specifies the approximate time delay, in picoseconds, of the SMA cable connecting antenna B. The default value (0) is calibrated to the default Broadspec antenna connected via 90^{o} SMA elbow.
8	Flags	UINT16	Bit0 is the “SEND_SCAN” bit. It specifies whether to send SCAN_INFO with each packet reception. [0=don’t send, 1=send]. The default is 0 (don’t send.) Bit1 is the FULL_SCAN bit. Default value is 0 (if sending scans, send SHORT_SCANS.) Bit2 is the “FAN_OFF” bit. It specifies whether to disable power to the fan. [0=on, 1=off]. By default this bit is zero (fan is ON).
9	Transmit Gain	UINT8	Specifies the active UWB transmit power from 0 (lowest) to 63 (highest) where 0 is below the U.S. FCC unlicensed limit which is -13dBm or 50microWatts, and 63 is approximately 0dBm or 1mWatt as measured out of the default Broadspec™ antenna. These power levels assume the delivered Broadspec antenna. NOTE: All RCM devices are delivered configured to comply with FCC unlicensed operation. Other settings besides 0 are for experimental use only and cannot be used for unlicensed commercial products inside the United States.
10	Persist Flag	UINT8	Specifies whether this configuration record will persist through power cycling (write to FLASH memory.) Possible values are 0 (will not persist) or 1 (will persist.)

3.2 RCM_SET_CONFIG_CONFIRM (0x0101)

API: RCM API
Message type: CONFIRM (Radio)
Corresponding Message type: RCM_SET_CONFIG_REQUEST (Host)

Purpose: This message is sent by the RCM to the Host in response to a RCM_SET_CONFIG_REQUEST message previously received by the RCM from the host. Its purpose is to confirm successful operation of the RCM_SET_CONFIG_REQUEST.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SET_CONFIG_CONFIRM (0x0101)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	Status	UINT32	0 = successful, non-zero = error

3.3 RCM_GET_CONFIG_REQUEST (0x0002)

API: RCM API
Message type: REQUEST (Host)
Corresponding Message type: RCM_GET_CONFIG_CONFIRM (Radio)

Purpose: This is a request message sent by the Host to RCM for the current radio configuration.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_GET_CONFIG_REQUEST (0x0002)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets

3.4 RCM_GET_CONFIG_CONFIRM (0x0102)

API: RCM API
Message type: CONFIRM (Radio)
Corresponding Message type: RCM_GET_CONFIG_REQUEST (Host)

Purpose: This message is sent by the RCM in response to a RCM_GET_CONFIG_REQUEST from the host. It provides the current RCM configuration information.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_GET_CONFIG_CONFIRM (0x0102)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm and info messages
2	Node ID	UINT32	Node ID of this radio (used for UWB range targeting.) By default this value will be 100 - 10X, matching the last byte of the IP address.
3	Pulse Integration Index	UINT16	Specifies an index which, in general, configures the number of pulses per data symbol. Valid values are [6-10]. The default is 7 meaning 2^7 = 128 pulses per symbol.
4	Antenna Mode	UINT8	Specifies the active antenna for transmission and reception. Valid values are [0=A, 1=B, 2=TXA,RXB, 3=TXB,RXA]. The default value is 0 (use antenna A for both transmissions and receptions.)
5	Code Channel	UINT8	Specifies the active UWB channel. Possible values are [0-6]. The default value is 0.
6	Antenna Delay A	INT32	Specifies the approximate time delay, in picoseconds, of the SMA cable connecting antenna A. The default is that of the default Broadspec antenna connected via 90^{o} SMA elbow.
7	Antenna Delay B	INT32	Specifies the approximate time delay, in picoseconds, of the SMA cable connecting antenna B. The default is that of the default Broadspec antenna connected via 90^{o} SMA elbow.

8	Flags	UINT16	Bit0 is the “SEND_SCAN” bit. It specifies whether to send SCAN_INFO with each packet reception. [0=don’t send, 1=send]. The default is 0 (don’t send.) Bit1 is the FULL_SCAN bit. Default value is 0 (if sending scans, send SHORT_SCANS.) Bit2 is the “FAN_OFF” bit. It specifies whether to disable power to the fan. [0=on, 1=off]. 0 is the default.
9	Transmit Gain	UINT8	Specifies the active UWB transmit power from 0 (lowest) to 63 (highest) where 0 is below the U.S. FCC unlicensed limit which is -13dBm or 50microWatts, and 63 is approximately 0dBm or 1mWatt as measured out of the default Broadspec™ antenna. These power levels assume the delivered Broadspec antenna. NOTE: All RCM devices are delivered configured to comply with FCC unlicensed operation. Other settings besides 0 are for experimental use only and cannot be used for unlicensed commercial products inside the United States.
10	Unused	UINT8	Reserved
11	Timestamp	UINT32	Milliseconds since RCM power-up. Note this implies a rollover approximately every 50 days.
12	Status	UINT32	0 = successful, non-zero = error

3.5 RCM_SEND_RANGE_REQUEST (0x0003)

API: RCM API
Message type: REQUEST (Host)
Corresponding Message type: RCM_SEND_RANGE_CONFIRM (Radio)

Purpose: This message commands the RCM to send a UWB range request packet (with optional data) to a targeted RCM node. Note the (optional) data sent in this packet is typically received by ALL RCM nodes within range, not just the targeted node. All RCMs that receive this data will promiscuously send this data to their respective host. The targeted node will, however, be the only node that responds with a range response.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SEND_RANGE_REQUEST (0x0003)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	Responder ID	UINT32	Node ID of the range request target.
3	Antenna Mode	UINT8	Specifies the active antenna for transmission and reception. Valid values are [0=A, 1=B, 2=TXA,RXB, 3=TXB,RXA]. The default value is 0 (use antenna A for both transmissions and receptions.)
4	Reserved	UINT8	Reserved
5	Data Size	UINT16	Number of bytes to include in the range request packet. These bytes follow. Maximum = 1024. Note: the RCM transmits 32bit (4byte) words. Any partial words will be zero-filled over the air but these bits will be removed upon reception.
6	Data	N*UINT8	Data to be sent with the range request packet. Max Number of bytes is 1024.

3.6 RCM_SEND_RANGE_CONFIRM (0x0103)

API: RCM API
Message type: CONFIRM (Radio)
Corresponding Message type: RCM_SEND_RANGE_REQUEST (Host)

Purpose: This message is sent by the RCM to the HOST in response to a RCM_SEND_RANGE_REQUEST command. This response confirms the UWB range request packet was successfully sent by the RCM.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SEND_RANGE_CONFIRM (0x0103)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	Status	UINT32	0 = successful, non-zero = error

3.7 RCM_SEND_DATA_REQUEST (0x0004)

API: RCM API
Message type: REQUEST (Host)
Corresponding Message type: RCM_SEND_DATA_CONFIRM (Radio)

Purpose: This message commands the RCM to send a UWB data-only packet (without range request.) All RCMs within range will receive this data and promiscuously send this data to their respective host (if attached.) No automatic acknowledgement is provided for data.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SEND_DATA_REQUEST (0x0004)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	Antenna Mode	UINT8	Specifies the active antenna for transmission and reception. Valid values are [0=A, 1=B, 2=TXA,RXB, 3=TXB,RXA]. The default value is 0 (use antenna A for both transmissions and receptions.)
3	Reserved	UINT8	Not used

4	Data Size	UINT16	Number of bytes to include in the data-only packet. These bytes follow. Maximum = 1024. Note: the RCM transmits 32bit (4byte) words. Any partial words will be zero-filled over the air but these bits will be removed upon reception
5	Data	N*UINT8	Data to be sent with the range request packet. Max Number of bytes is 1024.

3.8 RCM_SEND_DATA_CONFIRM (0x0104)

API: RCM API
Message type: CONFIRM (Radio)
Corresponding Message type: RCM_SEND_DATA_REQUEST (Host)

Purpose: This message is sent from the RCM to the Host in immediate response to a RCM_SEND_DATA_REQUEST command. This response confirms the data-only packet was successfully sent by the RCM.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SEND_RANGE_CONFIRM (0x0104)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	Status	UINT32	0 = successful, non-zero = error

3.9 RCM_SET_RESPONSE_DATA_REQUEST (0x0005)

API: RCM API

Message type: REQUEST (Host)

Corresponding Message type: RCM_SET_RESPONSE_DATA_CONFIRM (Radio)

Purpose: This message allows the Host to set the data buffer in the RCM range response packet. This data will be transmitted by the RCM whenever it sends a range response packet. This data buffer will remain in effect until changed by the host. Upon boot this buffer will be empty.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SET_RESPONSE_DATA_REQUEST (0x0005)	UINT16	Message type

1	Message ID	UINT16	Associates request to confirm packets
2	Reserved	UINT16	Reserved
3	Data Size	UINT16	Number of bytes to include in each range response packet. These actual bytes follow. Maximum = 1024.
4	Data	N*UINT8	Data to be sent with the range request packet. Extra bytes above <Data Size> will be ignored. Note: the RCM transmits 32bit (4byte) words. Any partial words will be zero-filled over the air but these bits will be removed upon reception

3.10 RCM_ SET_RESPONSE_DATA_CONFIRM (0x0105)

API: RCM API
Message type: CONFIRM (Radio)
Corresponding Message type: RCM_SET_RESPONSE_DATA_REQUEST (Host)

Purpose: This message is sent by the RCM to the Host in immediate response to a RCM_SET_RESPONSE_DATA_REQUEST command. This response confirms the buffer was successfully written.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SET_RESPONSE_DATA_CONFIRM (0x0105)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	Status	UINT32	0 = successful, non-zero = error

3.11 RCM_GET_STATUS_INFO_REQUEST (0xF001)

API: RCM API
Message type: REQUEST (Host)
Corresponding Message type: RCM_GET_STATUSINFO_CONFIRM (Radio)

Purpose: This message prompts the RCM to send the Host a data structure describing the hardware and software version numbers as well as other RCM status information.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_GET_STATUSINFO_REQUEST (0xF001)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets

3.12 RCM_GET_ STATUS_INFO_CONFIRM (0xF101)

API: RCM API
Message type: CONFIRM (Radio)
Corresponding Message type: RCM_GET_STATUSINFO_REQUEST (Host)

Purpose: This message is sent by the RCM to the Host in immediate response to a RCM_GET_VERSION_REQUEST command. This response provides a list of the hardware and software version numbers as well as other RCM status information.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_GET_STATUSINFO_CONFIRM (0xF101)	UINT16	Message type
1	Message ID	UINT16	Associates request to confirm packets
2	RCM Version Major	UINT8	RCM embedded major version number
3	RCM Version Minor	UINT8	RCM embedded minor version number
4	RCM Version Build	UINT16	RCM embedded build version number
5	UWB Kernel Major	UINT8	kernel code major version number
6	UWB Kernel Minor	UINT8	kernel code minor version number
7	UWB Kernel Build	UINT16	kernel code build version number
8	FPGA Firmware Version	UINT8	Firmware version number

9	FPGA Firmware Year	UINT8	Firmware year
10	FPGA Firmware Month	UINT8	Firmware month
11	FPGA Firmware Day	UINT8	Firmware day
12	Serial Number	UINT32	Device serial number
13	Board Revision	UINT8	PCB revision – a single ASCII character
14	Power-On BIT Test Result	UINT8	Built-in Test Results, non-zero indicates BIT failure.
15	Reserved	UINT16	Reserved
16	Temperature	INT32	Board temp in 0.25 ^{o}C (divide this number by 4 to produce floating point ^{o}C.).
17	Status	UINT32	Status

3.13 RCM_RANGE_INFO (0x0201)

API: RCM API
Message type: INFO (Radio)
Corresponding Message type: none

Purpose: This message is sent by the local requesting RCM to its Host at the end of a full UWB ranging conversation or timeout. Timeouts, indicated in the status field, can occur if the targeted responder failed to receive, or the requester failed to acquire the response packet.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_RANGE_INFO (0x0201)	UINT16	Message type
1	Message ID	UINT16	Identifier to correlate range requests with info messages
2	Responder ID	UINT32	Node ID of the UWB module that sent the range response.
3	Range Status	UINT8	0 = Success 1 = Timeout waiting on response 2 = LED Failure other = TBD

4	Antenna Mode	UINT8	Specifies the default antenna port for transmissions and receptions during this range conversation. Valid values are 0 = Transmit and Receive on the A port, 1 = Transmit and Receive on the B port, 2 = TX on B, RX on A, 3 = TX on A, RX on B. The default value is 0 (use antenna port A for both transmissions and receptions.)
5	Stopwatch Time	UINT16	Time of range conversation, in milliseconds.
6	Channel Quality	UINT32	A relative measure of the rise time of the direct path pulse.
7	RSSI	UINT32	Relative Signal Strength Indicator – computed as the scan peak SNR.
8	Timestamp	UINT32	Milliseconds from boot to time of range conversation.
9	Range Value	UINT32	Distance between UWB modules in millimeters.
10	Range Error Estimate	INT32	Estimated standard deviation (in mm) of associated range measure.

3.14 RCM_DATA_INFO (0x0202)

API: RCM API
Message type: INFO (Radio)
Corresponding Message type: none

Purpose: This message is sent by the local connected RCM to its Host whenever the RCM receives a UWB message. Note that a promiscuous RCM will “overhear” two packets per range conversation: one is the request packet, and the other the response packet. If these packets contain user data then the promiscuous RCM will send two of RCM_DATA_INFO packets to its host (if attached.) This enables the RCM to support “sideways” data transmission outside the range request/response pair.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_DATA_INFO (0x0202)	UINT16	Message type
1	Message ID	UINT16	Identifier to correlate data packets across radios

2	Source ID	UINT32	Node ID of the UWB module that sent the data.
3	Channel Quality	UINT32	A relative measure of the rise time of the direct path pulse.
4	RSSI	UINT32	Relative Signal Strength Indicator – computed as the scan peak SNR.
5	Timestamp	UINT32	Milliseconds from boot to time of data reception. conversation.
6	Antenna ID	UINT8	Indicates which antenna was used to receive this data (0=A, 1=B)
7	Reserved	UINT8	Reserved
8	Data Size	UINT16	Number of bytes received. These bytes follow.
9	Data	N*UINT8	Data bytes received. Max will be 1024.

3.15 RCM_SCAN_INFO (0x0203)

API: RCM API
Message type: INFO (Radio)
Corresponding Message type: none

Purpose: This message is optionally sent by the RCM to the Host whenever it receives an RF packet. This is debug information only and is not sent by default. The default state is defined by the RCM_SET_CONFIG_REQUEST message.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_SCAN_INFO (0x0203)	UINT16	Message type
1	Message ID	UINT16	Identifier used to correlate transmissions with info messages
2	Source ID	UINT32	Node ID of the transmitting radio
3	Antenna ID	UINT8	Designator of receiving antenna (0=A, 1=B)
4	Reserved	UINT24	Reserved
5	Channel Quality	UINT32	A relative measure of the rise time of the direct path pulse.

6	RSSI	UINT32	Relative Signal Strength Indicator – computed as the scan peak SNR.
7	Timestamp	UINT32	Milliseconds from boot to time of data reception.
8	Leading Edge Offset	UINT32	Offset from first sample where radio found leading edge of pulse.
9	Lockspot Offset	UINT32	Offset from first sample where radio locked on the pulse.
10	Number of Scan Samples	UINT32	The number of data points (UINT32) that follow.
11	Scan Data	INT32	Scan values collected by the radio.

3.16 RCM_FULL_SCAN_INFO (0xF201)

API: RCM API
Message type: INFO (Radio)
Corresponding Message type: none

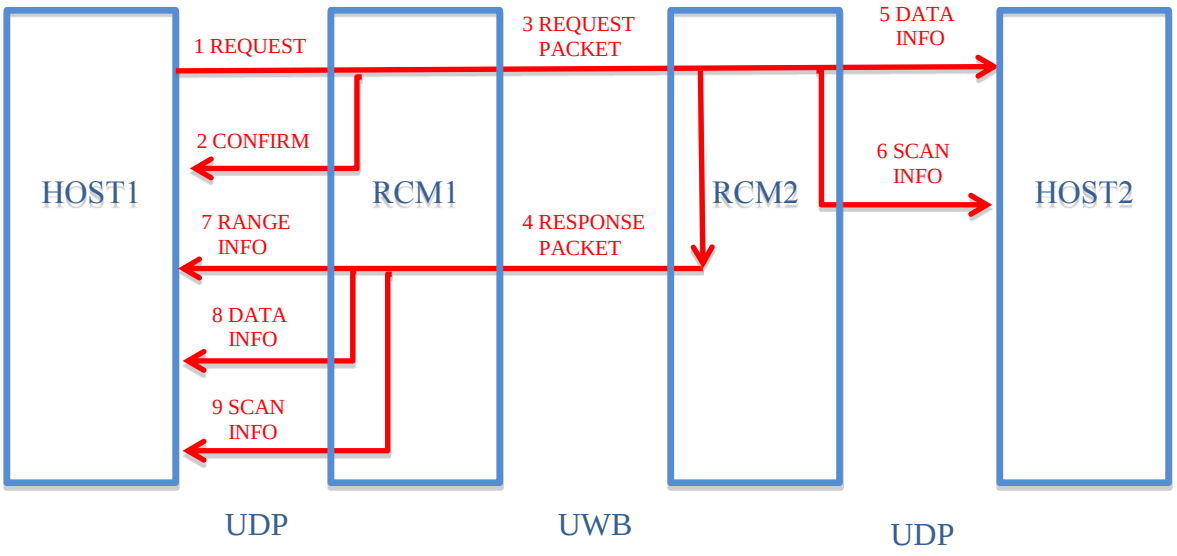
Purpose: This message is optionally sent by the RCM to the Host whenever it receives an RF packet. This is debug information only and is not sent by default. The default state is defined by the RCM_SET_CONFIG_REQUEST message. Due to the number of samples in a full waveform scan, the waveform scan data is split into many RCM_FULL_SCAN_INFO messages.

Packet Definition:

#	Parameter	Type	Definition
0	RCM_FULL_SCAN_INFO (0xF201)	UINT16	Message type
1	Message ID	UINT16	Identifier used to correlate transmissions with info messages
2	Source ID	UINT32	Node ID of the transmitting radio
3	Timestamp	UINT32	Milliseconds from boot to time of data reception.
4	Channel Quality	UINT32	A relative measure of the rise time of the direct path pulse.
5	RSSI	UINT32	Relative Signal Strength Indicator – computed as the scan peak SNR.
6	Leading Edge Offset	UINT32	Offset from first sample where radio found leading edge of pulse.

7	Lock Spot Offset	UINT32	Offset from first sample where radio locked on the pulse.
8	Scan Start	INT32	The start position of the waveform scan relative to the lock spot in picoseconds.
9	Scan Stop	INT32	The stop position of the waveform scan relative to the lock spot in picoseconds.
10	Scan Step	UINT16	The amount of time between each sample in bins. By default this is 32 bins equating to about 61 ps between samples.
11	Reserved	UINT16	Reserved
12	Antenna ID	UINT8	Designator of receiving antenna (0=A, 1=B)
13	Operational Mode	UINT8	Specifies the mode of the radio when this scan was collected. [RCM=0]
14	Number of Samples in this Message	UINT16	The number of samples that follow in this UDP message.
15	Total Number of Scan Samples	UINT32	The total number of samples in the full waveform scan.
16	Message Index	UINT16	The index of this message within the sequence of RCM_FULL_SCAN_INFO messages.
17	Total Number of Messages	UINT16	The total number of RCM_FULL_SCAN_INFO messages in the entire scan.
18	Scan Data	INT32	Scan values collected by the radio.

Appendix A: Anatomy of a Complete Range Conversation



1 REQUEST: HOST1 issues a RCM_SEND_RANGE_REQUEST message to RCM1, which is connected via Ethernet or Serial.

2 CONFIRM: RCM1 responds immediately with a RCM_SEND_RANGE_CONFIRM message.

3 REQUEST PACKET: RCM1 emits a UWB packet in range request form targeted at RCM2.

4 RESPONSE PACKET: RCM2, if targeted by HOST1 as the RESPONDER, immediately responds with a UWB response packet.

5 DATA INFO: Any user data in the request packet is reported to HOST2 (if connected.)

6 SCAN INFO: If configured to send scan info, RCM2 will send SCAN_INFO data to HOST2.

7 RANGE INFO: After receiving a response from RCM2, RCM1 will compute distance and report a RANGE_INFO message to HOST1.

8 DATA INFO: Any RESPONSE_DATA in the response packet will be reported to HOST1.

9 SCAN INFO: If configured to send scan info, RCM1 will report scan data to HOST1.

NOTE1: DATA INFO is reported to ANY host connected to ANY RCM that "overhears" a packet (promiscuous operation.)
NOTE2: SCAN INFO is only sent to the host if the host has pre-configured the RCM to send it.
NOTE3: A single MESSAGE_ID in HOST1's originating REQUEST message will be echoed at all end-points of this information flow. All RANGE, DATA, and SCAN INFO messages, at source, sink, and promiscuous hosts, can be tied together using this single MESSAGEID. Thus MESSAGE_ID becomes an important tool when logging data and post-processing for full system connectivity and range analysis.

Appendix B: Parameter Descriptions

The following sections provide additional UWB or system-level detail for API parameters described in Section 3.

B.1 Message ID

The Message ID parameter is a convenient way for the system integrator to keep track of messages and associated responses.

The user typically specifies a unique Message ID for each REQUEST command sent to one or more local RCMs. The RCM will echo this Message ID in each of its responses. In addition, upon receipt of RANGE_INFO, DATA_INFO, and SCAN_INFO messages the Message ID in each of these messages will uniquely match the RCM_SEND_RANGE_REQUEST message used to generate these INFO packets.

Typical host software for data collection will increment Message ID between each RANGE_REQUEST and use the Message ID to help relate RANGE, DATA, and SCAN info to a particular RANGE_REQUEST, as well as isolate and debug dropped Ethernet/UDP messages.

B.2 Pulse Integration Index (PII)

This value determines the number of pulses used in each radio symbol or scan point. Larger PII values result in a higher signal-to-noise ratio (SNR) with longer distance operation at the expense of slower ranging and data rates. Both RCM nodes must be configured with identical PII values in order to establish communication and ranging.

The user configures the "power of 2" of the pulse integration value. For example, a configured value of PII=7 results in the transmitting node sending 128 pulses per symbol and the receiving node expecting 128 pulses per symbol. If the user needs distance more than speed, he or she can reconfigure PIIs of both transmitter and receiver to 8, providing 2x the SNR in each symbol resulting in approximately 40% more distance in line-of-sight conditions. The ranging conversation time will almost double from 27ms to nearly 47ms.

The entire range of PII values are plotted in **Figure 3**. Each provides a separate maximum distance and range measurement duration. Range measurement duration includes both a request packet and a response packet. The duration assumes that less than 70 user data bytes are sent in each packet. The maximum distance also assumes US Federal Communications Commission (FCC)-compliant power levels and standard Broadspec antennas.

Range measurement duration is the stopwatch time from request packet start to response packet received and does not include overhead due to communication and processing by the user host computer.

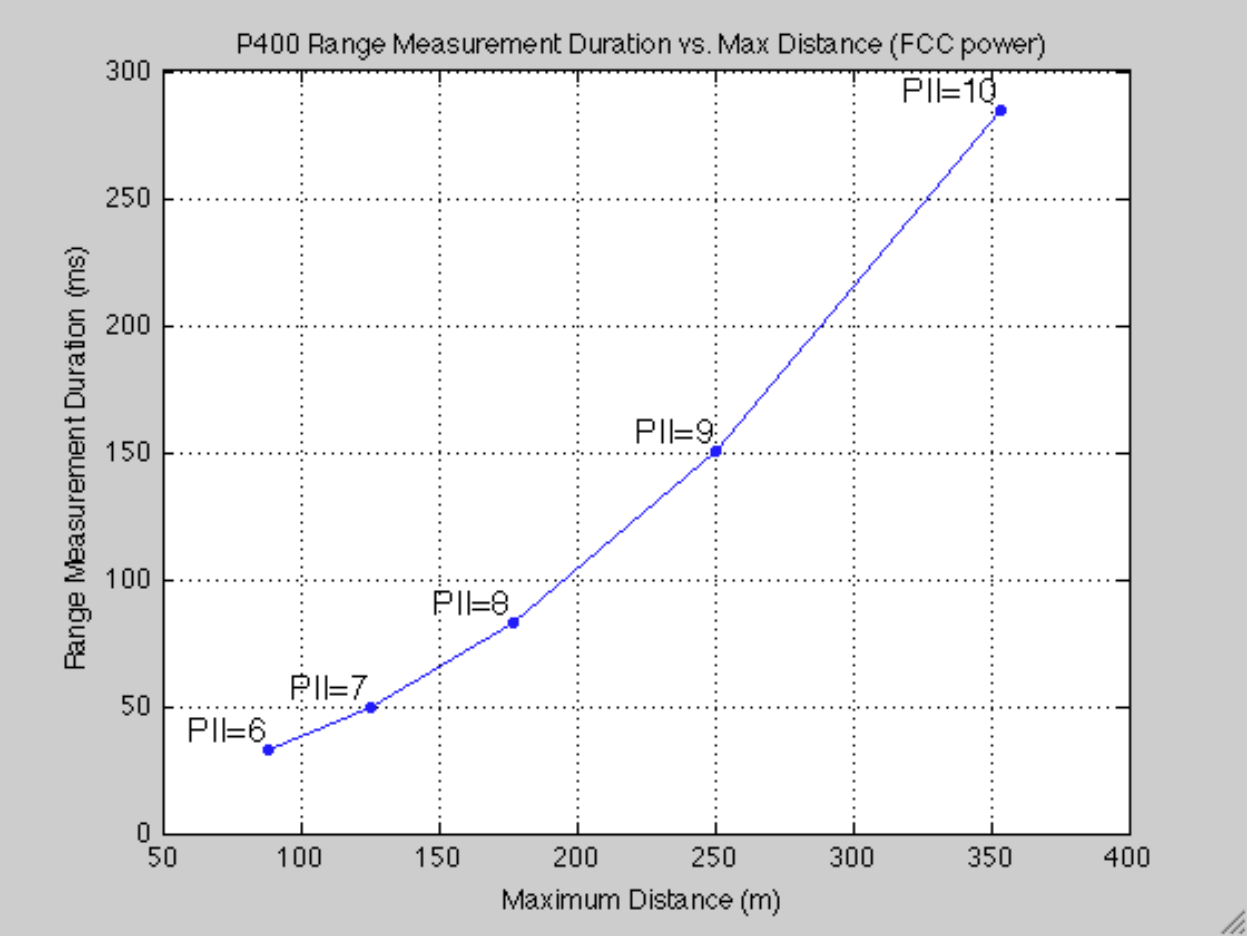


Fig. 3: Estimated maximum distance versus range measurement duration for the P400 RCM

PII	6	7	8	9	10
DataInt	64	128	256	512	1024
*MaxD(m)	88	125	177	250	354
RTime(ms)	33	50	83	150	285
RRate(Hz)	30	20	12	6.7	3.5

Fig. 4: Pulse Integration Index (PII) settings for the P400 RCM

*Point-to-Point Line-of-Sight estimate

B.3 Antenna Mode

The P400 RCM supports two antenna ports. The port nearest the corner of the board is typically designated as the "A" port. By default the RCM uses the A port. The user can define which port is to be used for transmit and which is to be used for receive. It is possible to use the same antenna for both transmission and reception. This definition is specified in the following Host to RCM commands:

- RCM_SET_CONFIG_REQUEST
- RCM_SEND_RANGE_REQUEST
- RCM_SEND_DATA_REQUEST

The following table illustrates the values:

Mode Value	Transmit Port	Receive Port
0	A	A
1	B	B
2	A	B
3	B	A

Fig. 5: Antenna mode configuration settings for the P400 RCM

B.4 Code Channel

Seven separate and independent communications channels have been provided. RCMs only support one channel at a time. RCMs receiving on a particular code channel will not hear those transmitting on a different channel. The channels are designated as channels 0 through 6. The default channel is channel 0. These channels allow the user to implement a code-division multiple access (CDMA) network supporting up to 7 different "cells", or a unique beacon code used for coordination which does not interfere with sub-cells.

The user is responsible for coordinating these code channels. Many more code channels are possible. The user should contact Time Domain for additional or unique code channel enhancements.

B.5 Antenna Delay A & B

The RCMs implement a Two-Way Time-of-Flight (TW-TOF) ranging technique. The result of a ranging conversation is the time it takes a pulse to travel from the pulser circuit of the requester to the sampling circuit of the responder and back. This value is divided by two and multiplied by the speed of light to return distance.

Typically the user wants a distance measurement relative to the antennas of the radios. The RCMs have been calibrated by default to presume a zero Antenna Delay when using the default Broadspec antennas with a simple 90 degree elbow SMA connector.

If the system integrator changes to a new UWB antenna or uses a SMA coaxial cable extension, (for

instance to keep the RCM inside an electronics box with the antenna outside) then the range value reported will increase proportional to this extended TOF. The user can either consistently subtract the extra bias in his software or reconfigure the RCM (using the RCM_SET_CONFIG_REQUEST) to store this bias using these registers.

B.6 Timestamp

Time stamp is the number of milliseconds that have elapsed since the latest RCM power-up. This parameter is not used by the RCM, but is provided to enable the system integrator to establish when the range was collected or data was received.

Note this is an interrupt-driven CMOS timestamp with millisecond accuracy. It is not based on picosecond timing triggers in the RF front end.

B.7 RSSI and Channel Quality

RSSI and channel quality measurements do not require a full range conversation. These metrics accompany any range, data, or scan information whenever the RCM receives a packet.

RSSI, or Relative Signal Strength Indicator, is a standard metric provided by many radios. However in a pulse-based UWB radio this information becomes more valuable because it does not suffer from multipath fading or enhancement. For the RCM RSSI is the maximum absolute value of the Signal to Noise Ratio in the waveform scan.

The channel quality metric is a measure of the rise time of the leading edge pulse found in the scan. Line-of-sight signals have very short rise times. Through-wall or reflected signals lose some of their high frequency content and therefore the rise time will increase.

These metrics are meant to provide two capabilities. First, RSSI can be used as a coarse, receive-only distance measurement. Due to multipath resistance it will be more accurate than a narrowband distance based on signal strength, and channel quality can be used to de-rate non-Line of Sight measurements. Second, channel quality is the fundamental metric used in our TW-TOF range error estimate. When a host overhears a transmission from a distant node he can use this metric to estimate the range error he would get if he sent a range request to that node. This will help optimize the scheduling in ad-hoc tracking networks.

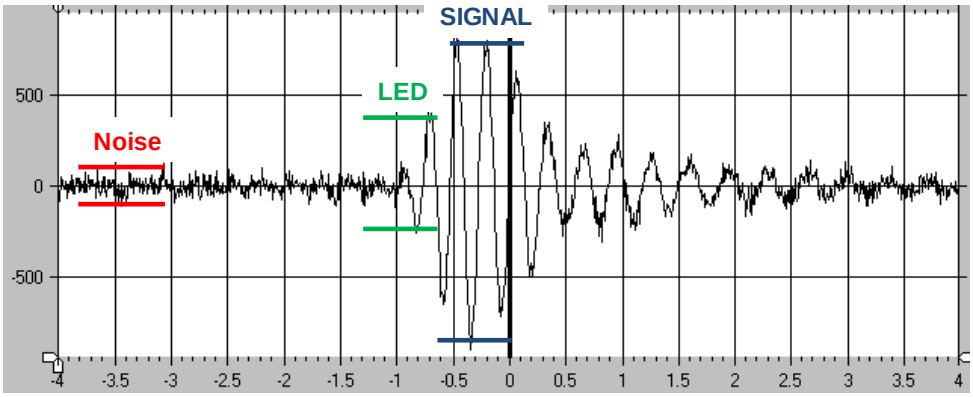


Fig. 6: Illustration of LESNR (scaled ratio of LED to Noise) and Signal (RSSI)

B.8 Range Value

Range value is the distance between the requesting and responding RCMs. More precisely it is a measure of TOF of the most direct path of a RF pulse from pulser to sampler, after subtraction of the antenna delay offsets. In a calibrated system, the range value should have a standard deviation of no more than 10 cm measured from the radiating point of the antennas. This point is shown in the following illustration. Range value is reported in millimeters.

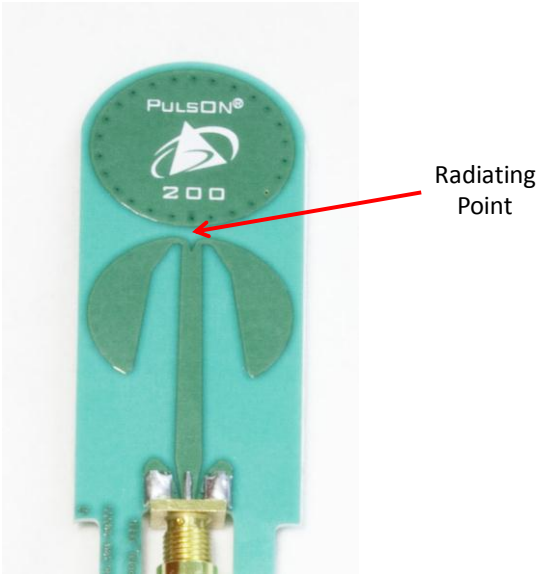


Fig. 7: Broadspec UWB antenna with radiating point indicated

B.9 Leading Edge Offset, Lockspot Offset, Number of Scan Samples & Scan Data

These parameters are all associated with the direct sequential scan of the pulse waveform and subsequent computation of the direct path. In order for the RCM to compute an accurate TOF estimate it must measure the offset from the lockspot, which is often on a multipath reflection, to the most direct pulse. The RCM performs a scan relative to the lockspot, then measures the offset and updates the range estimate.

350 points of the scan data, centered around the leading edge, are provided in SCAN_DATA. The resolution of the scan waveform is 61ps. The leading edge offset is the index in this scan where the system determined the time-of-arrival (TOA) of this pulse. The lockspot offset is the relative index where the radio acquired.

The SCAN_INFO is not required to use the RCM. It is provided to allow the user to investigate (optionally) the channel impulse response around the direct path and make conclusions about the range or channel multipath content.

These parameters are illustrated in the following figure.

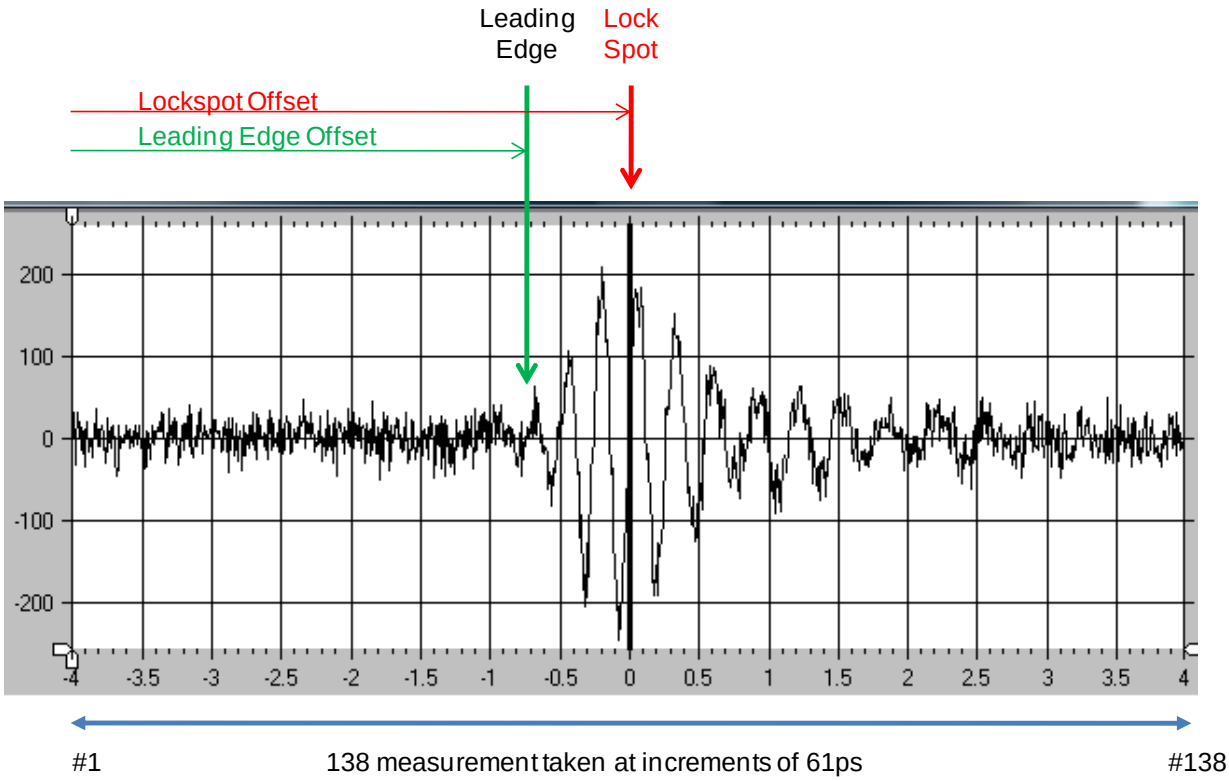


Fig. 8: Waveform scan showing Lockspot, Lockspot Offset, Leading Edge and Leading Edge Offset