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CRESCENDO VHF HALF-DUPLEX

USER MANUAL

STI-GLOBAL GROUP
Offices: ★ Sydney ★ Perth ★ Madrid

Crescendo VHF Half-Duplex

User Manual

DISCLAIMER

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Contents

1. Introduction

Crescendo is a series of data-driven and packet-driven radio modems for high-speed data applications.

This manual is specific to Crescendo VHF Half-Duplex. Some of the relevant features of this model include:

- Full VHF band switching (148-174MHz)
- 5W (+ 37dBm) maximum transmit power
- Wideband (25kHz) or narrowband (12.5kHz) channels, with software selectable frequency raster (6.25kHz, 12.5kHz or 25kHz)
- Raw air rate 19.2Kbit/s (25kHz channels) or 9.6Kbit/s (12.5kHz channels)
- Half-duplex data-driven or packet-driven operation with Automatic Repeat Request (ARQ)
- Windows GUI for configuration and diagnostics (Cruise Control)
- Internal configuration menu with diagnostic and statistical information
- LED front panel user interface
- Two RS-232 serial ports (main and auxiliary)
- Operating voltage 9 to 16VDC
- Type Approvals:
- AS-4295
- ETSI (planned)
- FCC (planned)
- Industry Canada (planned)

2. Installation

2.1 General considerations

There are a number of guidelines to observe when installing a Crescendo.

Antenna selection is vital to a good RF link. Different antennas are required depending on the application. Please contact your antenna manufacturer or RF Innovations for correct antenna selection.

Antenna placement has a significant impact on RF link performance. In general, higher antenna placement results in a better communication link. A vantage point should be chosen to clear the propagation ellipsoid. An unobstructed, line-of-sight link will always perform better than a cluttered or obstructed link. See sections 2.3 below for safety considerations.

Obstructions, such as walls and poles, will distort the antenna radiation pattern and VSWR, resulting in less efficient transmission and reception.

Antennas in close proximity are potential sources of mutual interference. A transmitter can cause overload of a nearby receiver, if due precautions are not taken in antenna location. Moreover, transmitters in close proximity may cause intermodulation. Slight adjustments in antenna placement may help solving interference problems.

All items of radio equipment, such as antennas, are sources of RF radiation. They should thus be placed away from electrical equipment, such as computers, telephones or answering machines.

Serial cable runs between radio modem and attached terminal equipment (eg RTU or PC) should be kept as small as possible. A maximum cable capacitance of 2,400pF is recommended for transfer rates up to 19.2Kbit/s. If a non-shielded, 30pF / foot cable is used, the maximum length should be limited to 80 feet (approximately 24m). For higher interface speeds, the length of the serial cable should be shortened.

Long serial cables should also be avoided in areas with frequent lightning activity or static electricity build-up. Nearby lightning strikes or high levels of static electricity may lead to interface failure.

RF Innovations supply a range of external interface converters for applications requiring long cable runs.

2.2 External antennas

Long antenna feed lines cause RF loss, both in transmission and reception levels, and degrade link performance. When long cable runs are required use a suitable low-loss cable.

As an example, RG58 (tinned-copper braid) will exhibit a loss of 7.1dB/30m at 148-174MHz, whereas RG58 CellFoil will exhibit 3dB less (4.2dB/30m).

Antennas should not be located within close reach of people, due to radiation hazard. Exposure guidelines should be followed at all times.

Use extreme caution when installing antennas and follow all instructions provided. Because external antennas are subject lightning strikes, RF Innovations recommends protecting all antennas against lighting strike by using lightning surge arrestors.

2.3 Safety and Compliance

2.3.1 Human Exposure to Emissions

To limit human exposure, the following guidelines should be observed:

1. Take reasonable precautions in any installation to maintain a clearance of no less than 1 m (one metre) from the antenna to any person.

2. Do not apply power to the device unless the clearance described in 1 above has been allowed.

The guidelines above apply when transmitting at maximum power, with an antenna gain of up to 13 dB.

For further information on human RF exposure, contact your local health department. For example, Health Canada's Safety Code 6 provides a comprehensive set of guidelines.

2.3.2 Modifications

Changes or modifications not expressly approved by RF Innovations may void the user's authority to operate the equipment legally, as well as any warranty provided.

3. Configuration

3.1 Overview

The Crescendo provides four user interfaces that allow the radio to be configured and its performance to be monitored:

1. ***Cruise Control management interface:*** All radio configuration and diagnostics parameters can be accessed using the Windows-based Cruise Control Graphical User Interface (GUI).

2. ***Terminal menu interface:*** A menu system is available over either of the Crescendo's serial ports. This menu interface can be accessed through any terminal emulation program, such as RFI InTerm, which can be downloaded from http://www.rfinnovations.com.au.

3. ***AT command interface:*** The AT command interface can be used to configure the Crescendo through ASCII Hayes attention commands. This can be used to read / adjust the Crescendo configuration and read performance parameters.

4. ***Front panel interface:*** The front panel interface consists of six dual colour (red / green) LEDs and a push button. This panel can display the radio status, RSSI, configured transmit power, temperature, and serial port status.

3.2 Cruise Control

The following sections briefly outline how to use Cruise Control with the Crescendo. For more information, see the Cruise Control Manual. Figure 1 below is a typical screenshot of the Cruise Control Configuration Tool.

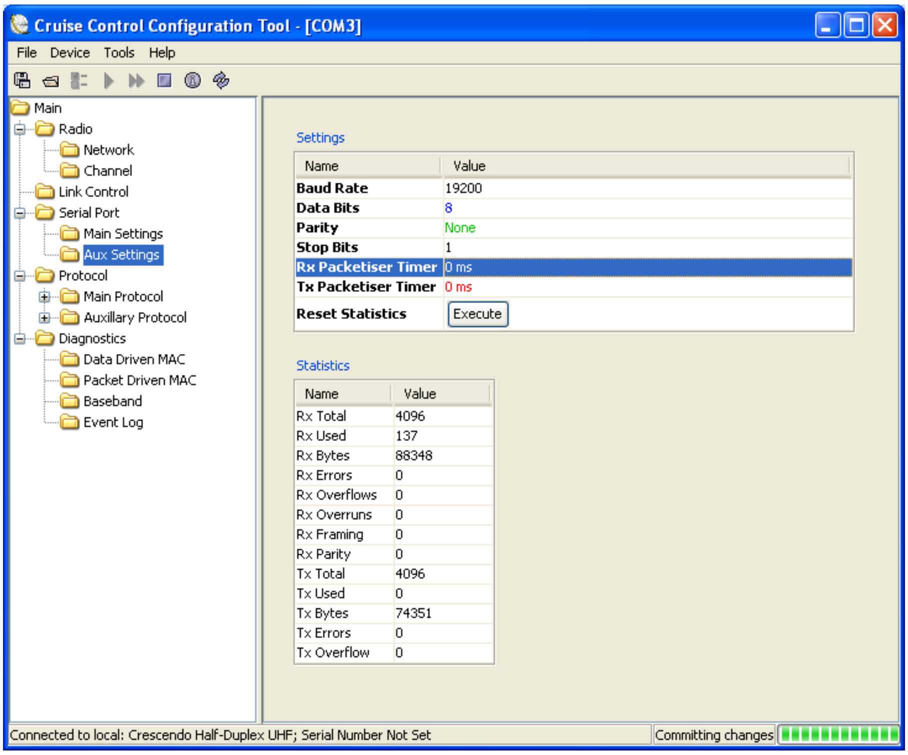

Figure 1: Cruise Control Configuration Tool

3.2.1 Installation

The requirements for using the Cruise Control application are:

- Pentium III+ Windows based machine.
- At least 1 available serial port.

The Cruise Control application is provided on a CD, and runs with a self-installer.

3.2.2 Connecting to a Local Device

In order to connect to a local device, attach the Crescendo to the PC running Cruise Control via a serial port. Configure Cruise Control with the appropriate serial port settings (19200 8N1 by default), and ensure that the Crescendo is configured with Hayes AT command interface[1] on the connected port.

[1] For a port to accept AT commands it must first be in local command mode. See section 6.5.3 on page 73 for information on enabling and disabling local command mode.

Use the `Device -> Connect to Local Device` menu item to connect to the local device. Once all the settings have been downloaded from the device, the available configuration groups are displayed in a tree on the left. The items that can be configured in each group are displayed in tables on the right.

The names of editable items are displayed in black. Read only items have their names in grey.

Changes made to the configuration or protocol mode of the serial port which Cruise Control is using do not take effect immediately. They take effect when the `disconnect` button in Cruise Control is pressed, or the radio is reset.

It is possible to remotely connect to a device over the air by using `Device -> Connect to Remote Device` and entering the remote address of the device. For best results when using a remote connection:

- Do not connect to a remote device through store-and-forward repeaters.
- Do not connect to a remote device while a live system is running.

3.2.3 Saving and Loading Configurations

The current configuration of a device can be saved by selecting:

- `File -> Save As...`: This saves the configuration of the connected device to a selected file. The configuration can later be re-applied to a device by using the `File -> Upload` option or viewed using `Tools -> View Saved Configuration`.

It is recommended that only local devices have their configuration loaded from file. Performing this operation on a remote device updates only those items that can be edited remotely.

3.3 Terminal Menu Interface

The terminal menu provides access to all configuration parameters in the radio. There are two methods to access the terminal menu:

- Execute the `AT?` command at the Hayes AT command interface. See section 3.4 on page 12 for information on executing AT commands. The terminal menu will not be started when it is open on another port, or a Hayes dial-up connection is established. In either case the `BUSY` response is returned.
- Select mode 6 on the front panel interface. See section 3.5 on page 13 for information on selecting front panel modes. This will always result in the menu being opened on the auxiliary port, at 19200 8N1.

Changes made to the configuration or protocol mode of the serial port which the terminal menu is using do not take effect immediately. They take effect when the radio is reset.

A full terminal menu reference can be found in Appendix B on page 59.

3.4 Hayes AT Command Interface

The Crescendo radio supports Hayes ATtention commands. These are used to query radio configuration and performance parameters, set radio configuration, and establish communication links between radios over the air.

For a port to accept AT commands it must be first in local command mode. See section 6.5.3 on page 36 for information on enabling and disabling local command mode.

The format for the query and configuration AT command is:

```
ATxxx<[I1, I2, … In]><=value><TERM>
```

Where:

- `AT` is the attention code. All AT commands must be prefixed with `AT`. This is case insensitive, so `At`, `aT`, or `at` can also be used.
- `xxx` is the actual command. The list of valid AT commands is given in 0 on page 62.
- `<[I1, I2, … In]>` is an optional section that allows the specification of an index. Indexes are used to access one of an array of similar items. For example, the Crescendo radio has two serial ports which can both have different configurations. The command `ATS52[0]=1004` set the point-to-point destination on the main port, while the command `ATS52[1]=1004` will set the point-to-point destination on the auxiliary port.
- `<=value>` is an optional section that is used to set the value of a configuration parameter. If this section is omitted, then the value of the configuration parameter will be displayed.
- `<TERM>` is the terminator for the AT command. A terminator can consist of a carriage return (ASCII value 13_D) or a carriage return followed by a line feed (ASCII value 10_D).

For each AT command that is issued a response is generated. The list of responses to AT commands is shown in Table 1.

Response Code	Response Number	Description
OK	0	Returned whenever a command is entered that is executed correctly.
CONNECT	1	Returned whenever a connection is established with a remote unit.
RING	2	Returned whenever this unit is dialled by a remote unit.
NO CARRIER	3	Returned whenever a connection fails to be established, or is dropped while it is operating.
ERROR	4	Returned whenever a command is invalid or could not be executed.
BUSY	7	Returned whenever an attempt is made to dial a remote unit and that unit already has a connection established, or an attempt is made to enable the menu via `AT?` but the menu system is already enabled on the other serial port.
NO ANSWER	8	Returned whenever an attempt is made to dial a remote unit, and that unit fails to answer.

Table 1: AT command response codes

3.5 Front Panel Interface

The front panel interface allows for real-time monitoring of radio parameters without external equipment. The front panel can also be used to enable the menu on the Crescendo's auxiliary port regardless of the current serial port configuration.

There are six front panel modes. To select a front panel mode, press the front panel button. The current panel mode is shown by lighting a single red LED. To select another front panel mode, continue to hold the button until the LED scrolls down to the appropriate mode, then release. The list of modes is shown in Table 2.

LED	Mode	Function
1	Radio Status	Section 3.5.3 on page 14 describes the functionality of the LEDs when in radio status mode.
2	RSSI	Displays the current RSSI as a bar graph. Table 3 shows the level for each bar item.
3	Transmit Power	Displays the configured transmit power as a bar graph. Table 3 shows the level for each bar item.
4	Temperature	Displays the internal temperature as a bar graph. Table 3 shows the level for each bar item.
5	Serial Port	Shows the main serial port status. The meaning of each individual LED is shown in Table 4.
6	Configuration	Enables the terminal menu on the auxiliary port at 19200 8N1. The LED display is the same as mode 1.

Table 2: Front panel modes

3.5.1 RSSI, Tx Power, Temperature Status (Mode 2, 3, 4)

When in mode 2, 3, or 4 the front panel is used as a bar graph, with the lowest value indicated by all LEDs off, and the highest by all LEDs on. The bar grows by lighting LED 6 up to LED 1 green. If the top LED is red, then it indicates that the current value is half way between the listed value and the previous value. Table 3 shows the levels for the bar graph display.

LED	RSSI	Transmit Power	Temperature
1	-60 dBm	+37 dBm	+62ºC
2	-70 dBm	+36 dBm	+50ºC
3	-80 dBm	+30 dBm	+38ºC
4	-90 dBm	+27 dBm	+26ºC
5	-100 dBm	+20 dBm	+14 ºC
6	-110 dBm	+0 dBm	+2 ºC
All Off	-120 dBm	Not Used	-10 ºC

Table 3: Front panel RSSI, transmit power, and temperature modes

3.5.2 Main Serial Port Status (Mode 5)

LED	Description
(1) DCD	Green when the DCD output is low, red when it is high.
(2) DTR	Green when the DTR input is low, red when it is high.
(3) Tx Serial Data	Flashes green when serial data is transmitted from the Crescendo on either serial port.
(4) Rx Serial Data	Flashes green when serial data is received by the Crescendo on either serial port. Flashes red when a receive error occurs on either serial port. See section 4.4 on page 19 for serial statistics.
(5) RTS	Green when the RTS input is low, red when it is high.
(6) CTS	Green when the CTS output is low, red when it is high.

Table 4: Mode 5 LED functions

3.5.3 Radio Status LEDs (Mode 1)

LED	Description
(1) Tx RF Data	Flashes green when RF data is transmitted. Flashes red when an RF user or Tx Sync packet is discarded due to retries being exhausted.
(2) Rx RF Data	Flashes green when RF data is received. Flashes red when a received RF packet is discarded.
(3) Tx Serial Data	Flashes green when serial data is transmitted from the Crescendo on either serial port. Flashes red with Rx RF Data when a RF packet is discarded due to a Tx Serial buffer overrun.
(4) Rx Serial Data	Flashes green when serial data is received on either serial port. Flashes red when a receive error occurs on either serial port. See section 4.4 on page 19 for serial statistics.
(5) Online	Solid green if packets addressed to the unit has been received. The duration the LED stays green is set by the Online Timeout. Solid green when a connection is established with a remote radio. Flashes red when a point-to-point link goes from the connected to not connected state.
(6) Power / Fault	Flashes green when the radio is operating normally. Flashes red when a fault has occurred. Faults are displayed in Cruise

	Control under `Main -> Diagnostics -> Faults`. Faults that are detected by the radio are: • Point-to-point destination address equal to source address • Reserve section of a datagram packet not equal to `0x0000`. • The last time the radio reset was due to a watchdog reset. When a fault occurs, it is latched for 15 minutes. If after 15 minutes the alarm has not re-occurred it is cleared. The fault can be cleared manually by re-powering the radio.

Table 5: Mode 1 LED functions

4. Serial Port Operation

4.1 Overview

The Crescendo radio has two DCE RS-232 serial ports with DB9 connectors. The serial port pin outs can be found in Appendix A.3 on page 56.

The main port supports:

- TX, RX, and GND.
- RTS and DTR inputs.
- CTS and DCD outputs.

While the auxiliary port supports:

- TX, RX, and GND.

Both serial ports support over the air data transfer. In general, due to the presence of control lines, the main port should be used as the main data port. The auxiliary port should be used for performance monitoring and configuration.

Both main and auxiliary serial ports have internal byte buffers on transmit and receive interfaces. This configuration is shown in Figure 2.

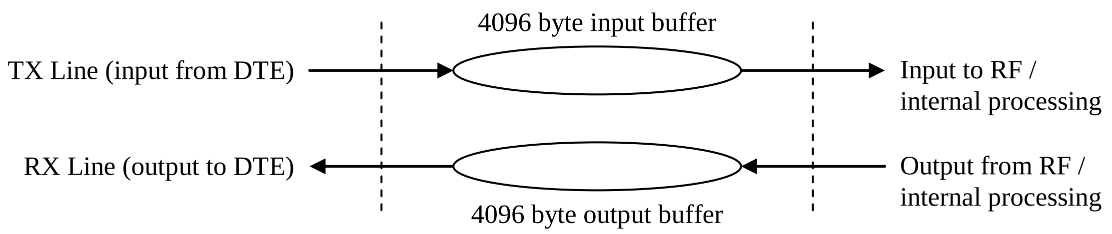

Figure 2: Buffering scheme on the Crescendo

This serial port buffering scheme has a number of ramifications on the Crescendo operation:

- No preamble is required to account for radio turn-on time.
- If the data cannot be sent, it will be buffered until the transmitter is ready.
- If the data terminal equipment (DTE) is not ready for data, the Crescendo can buffer the data until the DTE is ready.
- If the buffer is full, additional data received will be discarded until space has become available.

4.2 Configuration

`Main -> Serial Port -> Settings`

Both main and auxiliary serial ports support the following configuration options:

- Baud rate: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600 or 115200.
- Data bits: 7 or 8
- Parity: None, odd, or even
- Stop bits: 1 or 2

4.3 Advanced Features

4.3.1 Control Lines

`Main -> Serial Port`

The main serial port has four control lines:

- Ready to Send (RTS)
- Clear to Send (CTS)
- Data Terminal Ready (DTR)
- Data Carrier Detect (DCD)

The main serial port supports hardware flow control using the RTS and CTS control lines. When hardware flow control is enabled:

- The radio will only transmit data to the DTE when the RTS line is high.
- The radio will raise the CTS line when its input buffer is less than three quarters full, and drop the CTS line when its input buffer is at least three quarters full.

NOTE: When hardware flow control is enabled, the CTS line configuration is ignored.

In addition to hardware flow control, the CTS and DCD lines can be configured to behave in one of the following ways:

- ***Always High:*** The control line is always held high.
- ***Always Low:*** The control line is always held low.
- ***Mirrors DTR:*** The control line mirrors the state of the DTR input.
- ***Mirrors RTS:*** The control line mirrors the state of the RTS input.
- ***Follows Rx Carrier:*** The control line goes high when a valid carrier is detected and goes low when the carrier stops.
- ***Follows Tx Enable:*** The control line goes high when the transmitter is enabled and goes low when the transmission is finished. This includes acknowledgements and retries when the radio is operating in packet driven mode.
- ***Follows Online:*** The control line goes high if a packet addressed to the unit has been received. The duration the control line stays high is set by the Online Timeout. The Online Timeout can be configured between 100 and 65535ms. The control line also stays high while a connection is established with a remote radio.

DTR is used to control Hayes dial-up connections (see section 6.5.5 on page 37)

4.3.2 Packetiser Timers

`Main -> Serial Port -> Settings`

Many protocols delimit packets of data by silence on the communications line for a set period of time. A common example of such a protocol is Modbus.

Due to the framed structure over the air when the radio is in packet driven mode, packetiser timers should be used to support protocols and increase the efficiency of data transmission. Packetiser timers can be set between 0 and 10000ms.

The RX packetiser timer is used to detect the end of each packet. The Crescendo will only begin transmitting data once the end of the packet has been detected. The suggested RX packetiser timer values for each serial baud rate when using the radio in packet driven mode is given in Table 6.

For protocols such as ModBus, DNP3, and TDE, the RX packetiser timer should be set greater than maximum delay between characters in the same packet. Table 6 can also be used as a guide.

Baud	RX Timer
300	>= 35ms
600	>= 18ms
1200	>= 10ms
2400	>= 6ms
4800	>= 4ms
9600	>= 3ms
19200	>= 2ms
38400	>= 2ms
57600	>= 2ms
115200	>= 2ms

Table 6: Packetisation timers for different baud rates

If the packet size is greater than the RX serial buffer size (4096 bytes), then RX packetiser timers should not be used as the internal buffers will overflow, and bytes will be lost. Tx packetiser timers should be used instead, and set to the suggested value given in Table 7.

When using the data driven protocol, it is recommended to use TX packetiser timers and data timeout, rather than the RX packetiser timers, to maintain a low end-to-end latency.

- Set the data timeout to the maximum delay between characters in the same packet. Suggested values are given in Table 6. See section 6.2 for more information on the data timeout setting.
- Set the TX packetiser timer to the maximum delay between RF blocks.

Suggested TX packetiser timer values are given in Table 7.

Channel Width	TX Timer
12.5 kHz	>= 25ms
25 kHz	>= 13ms

Table 7: TX packetisation timers for different channel widths

Using packetiser timers will increase the latency induced by the radio system, as no part of the packet can be transmitted until it has been fully received.

4.4 Statistics

`Main -> Serial Port -> Settings`

Statistics are maintained for each serial port and these can be used to analyse and debug problems.

Name	Number	Description
Rx Total	0	The size of the input buffer.
Rx Used	1	The number of bytes currently stored in the input buffer.
Rx Bytes	2	The total number of bytes that have been received.
Rx Errors	3	The total number of errors that have occurred during data reception. This is the sum of Rx Overflows, Rx Overruns, Rx Framing, and Rx Parity errors.
Rx Overflows	4	The total number of overflow errors that have occurred. An overflow error occurs whenever data is received, but the internal buffer is already full.
Rx Overruns	5	The total number of overrun errors that have occurred. An overrun error occurs whenever the internal processor is overloaded and cannot handle the incoming data.
Rx Framing	6	The total number of framing errors that have occurred. Framing errors usually occur due to mismatched serial port baud rates between the DTE and DCE.
Rx Parity	7	The total number of parity errors that have been detected.
Tx Total	8	The size of the output buffer.
Tx Used	9	The number of bytes currently stored in the output buffer.
Tx Bytes	10	The total number of bytes that have been transmitted.
Tx Errors	11	The total number of errors that have occurred while transmitting. This is equal to the Tx Overflows count.
Tx Overflows	12	The total number of overflows that have occurred. An overflow occurs when the radio attempts to insert data into the transmit buffer internally, and the buffer is full.

Table 8: Serial port statistics

These statistics can be used to isolate a number of potential problems in a Crescendo system.

- A large number of Rx framing errors indicates that the radio serial port configuration (baud, data bits, parity, and stop bits) does not match the serial port configuration of the DTE.
- A large number of Rx overflow errors indicate that the DTE is supplying data faster than it can be transferred over the air.
- A large number of Tx overflow errors indicate that data is arriving over the air faster than the DTE can retrieve it from the radio.

5. Radio Operation

This section describes the two modes of Crescendo operation: data and packet-driven. These modes underlie the different protocols supported, described in section 6.

Regardless of the mode used serial characters are assembled in small blocks for the purpose of Forward Error Correction (FEC). These blocks are then subject to error coding / interleaving, and protected by a CRC. This operation is transparent to the user, with the advantage of added robustness in multipath fading and noisy environments.

5.1 Data-Driven Mode

In data-driven mode many of the features that are available in the Crescendo are not utilised in order to provide a serial transfer with minimum delay. In particular data driven mode does not utilise:

- Unit addressing / repeaters
- Retries / routing
- Complex network structures / network address

Data driven mode provides a low latency broadcast network where any data presented on the main port of a unit is immediately transmitted over the air, received by all units in range, and transmitted out their main ports.

Data-driven mode is used when the data driven protocol (see section 6.2) is selected on the main port. For all other protocols the packet-driven mode is used.

5.2 Packet-Driven Mode

Packet-driven operation is based upon Automatic Repeat Requests (ARQ) with retries and exponential back-off.

A transmission consists of a packet transmitted from source to destination, followed by an acknowledgement from destination to source. Acknowledgements are done on an end-to-end basis, so intermediate repeaters simply pass the packet and acknowledgement on. This is shown in Figure 3.

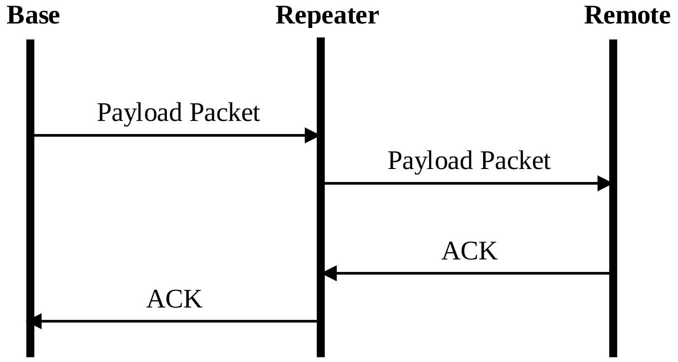

Figure 3: Packet driven with ARQ operation

If a payload packet or ACK is lost, resulting in the base radio not receiving the ACK, the source radio retransmits the payload packet. This continues until the number of retries for the packet has been exhausted.

5.2.1 Data Path

Internally, the Crescendo stores a set of payload frames that are waiting to be transmitted, and a set of payload frames that have been received but not yet processed. Combining this with the serial port interface described in section 4 on page 16, an overall picture of the data path in the Crescendo radio can be obtained, shown in Figure 4.

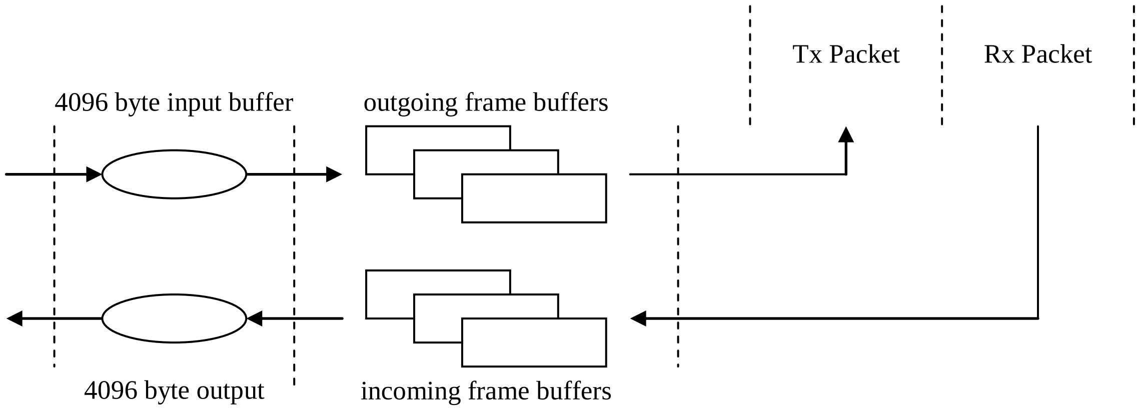

Figure 4: Overall data path in the Crescendo radio modem

Due to the framed structure over the air, and the data path shown above, the Crescendo cannot be regarded as a direct wire replacement. It will induce additional latency in the communications link, as well as potentially causing changes in the timing between bytes.

In addition, when the link is bad due to interference or low signal level, bytes can be lost when the number of retries are exhausted.

LATENCY

The Crescendo will introduce latency into the system. This latency is caused by the following factors:

- ***Serialisation delays:*** Serialisation delay is the time taken for the incoming RS-232 bit stream to be converted back into bytes. The serialisation delay for each serial port can be calculated in milliseconds using Equation 1.

$$t_{serial} = 1000\frac{bits}{baud}$$

Equation 1: Latency induced by serialisation delay

- Where *bits* is the number of bits in a byte (including start, stop and parity bits), and *baud* is the baud rate of the serial port.
- Thus, for 9600 baud, 8N1 the serialisation delay is around 1ms per serial port.
- ***Switching delay:*** When the Crescendo is presented with data to send over the air, it switches from receive to transmit mode and performs synchronisation tasks to prepare for the transmission of the data. The time taken to do this is the switching delay.

- ***Link quality:*** The quality of a link can have a substantial impact on the latency induced by the radio. The Crescendo will retry packets that become corrupted due to RF interference, configurable between 0 and 20 retries. The more retries that are required to successfully transmit a packet, the greater the latency induced. This is only applicable to packet driven mode.
- ***Multiple protocols:*** When multiple protocols are used (including management with Cruise Control), latency will be increased as extra protocol data is inserted into the data stream.
- ***Repeaters:*** The addition of repeaters in a network will increase latency due to payload packets and acknowledgements being transmitted multiple times before reaching their destination.

For systems that require low latency, the Crescendo has a data driven protocol which reduces many of the delays mention above.

5.3 Radio Parameters

5.3.1 Addressing

`Main -> Radio`

Each radio in a Crescendo network has a unique 16-bit address. The address space is divided into sections as shown in Table 9.

Address Range	Usage
0	**Reserved.**
1 – 61439	**Singlecast addresses.** Each radio in a network must have a unique singlecast address.
61440 – 65534	**Reserved.** These addresses are reserved for use in future Crescendo releases.
65535	**Broadcast address.** This address is used when data transmitted is to be processed by all radios. This address can only be used in the datagram packet header

Table 9: Crescendo address space

The singlecast radio address is used for routing traffic between units and determining the end points in a communications link.

Only one singlecast address can be assigned to each radio, and each radio in a particular network must have a unique address.

5.3.2 Transmit Power

`Main -> Radio`

The transmit power of the Crescendo can be configured to transmit at fixed levels into a 50Ω load:

- 0dBm (1mW)
- +20dBm (100mW)
- +27dBm (500mW)
- +30dBm (1W)
- +36dBm (4W)
- +37dBm (5W)
-

A maximum power setting can be configured by the distributor to limit the allowable power for a given combination of radio and antenna.

5.3.3 RSSI Trip

`Main -> Radio`

The RSSI trip setting is the lowest RF signal level for which the radio modem will attempt to acquire data.

An RSSI trip can be thought of as a “receiver unsquelch”.

RSSI Trip is configurable between -120 and -40dBm.

5.3.4 Channel Selection

`Main -> Radio -> Channel`

Crescendo has six radio channels that can be configured by the distributor. Each channel comprises a pair of uplink / downlink (or transmit / receive) frequencies.

The channel frequencies can be set anywhere within the radio switching bandwidth (148 – 174 MHz). The supported channel frequency rasters are 6.25kHz, 12.5kHz and 25kHz.

The channel to be used can be set by adjusting the current channel setting.

5.3.5 Retries

`Main -> Radio -> Network`

The maximum number of retries per packet can be configured between 0 and 20. When a low number of retries is selected, the link may become unreliable in the presence of interference or collisions. When a high number of retries is selected, the link will be more reliable. However, additional retries will induce substantial latency in the presence of interference.

Two parameters are used to set the number of retries to use:

- ***Singlecast retries:*** The number of retries to use on data that is destined for a single receiving radio. This is applied to any transmission using the point-to-point or Hayes dialup protocols.
- If the remote unit is non-existent, due to a misconfigured destination address, the remote being out of range, or the remote unit being faulty, the data will be retransmitted a number of times equal to the singlecast retries setting. This can dramatically reduce the throughput of a radio network.

- ***Broadcast retransmissions:*** The number of retries to use on data that is destined for multiple radios. This is applied to any transmission when using the point-to-multipoint protocol, or to any packet addressed to the broadcast address when using the datagram protocol.

When a unit is broadcasting data, the transmission cannot be acknowledged, as collisions would occur between the acknowledgements. Instead, a broadcasting unit will transmit all data a fixed number of times equal to the broadcast retransmissions parameter, and receiving units will discard any duplicate data received.

Two parameters determine how long the Crescendo will wait for an acknowledgement after transmission before retrying. These parameters are:

- ***Repeaters in Network***: The maximum number of repeaters through which a packet must go before reaching its destination. Note that this may be less than the total number of repeaters in the network. This parameter should be set the same for all units in the network. The repeaters in network setting can be configured between 0 and 65535.
- ***Max Packet Size:*** This is the maximum number of bytes of payload a packet will have. This parameter should be set the same for all units in the network. The max packet size can be configured between 0 and 4096 bytes.

5.4 Network Architecture

5.4.1 Network Topology

The Crescendo has few restrictions on network topology, as there are no time division synchronisation requirements. An example of a tree network topology is given below to help illustrate network concepts.

TREE NETWORK

A Crescendo network consists of a set of sub-networks (subnets). Each subnet has a single base or repeater and any number of remotes.

1. ***Base subnet:*** The root node of the tree, containing a unit not configured as a store-and-forward repeater.
2. ***Repeater subnet:*** A branch node of the tree, containing a unit configured as a store-and-forward repeater.

These two types of subnet are shown in Figure 5.

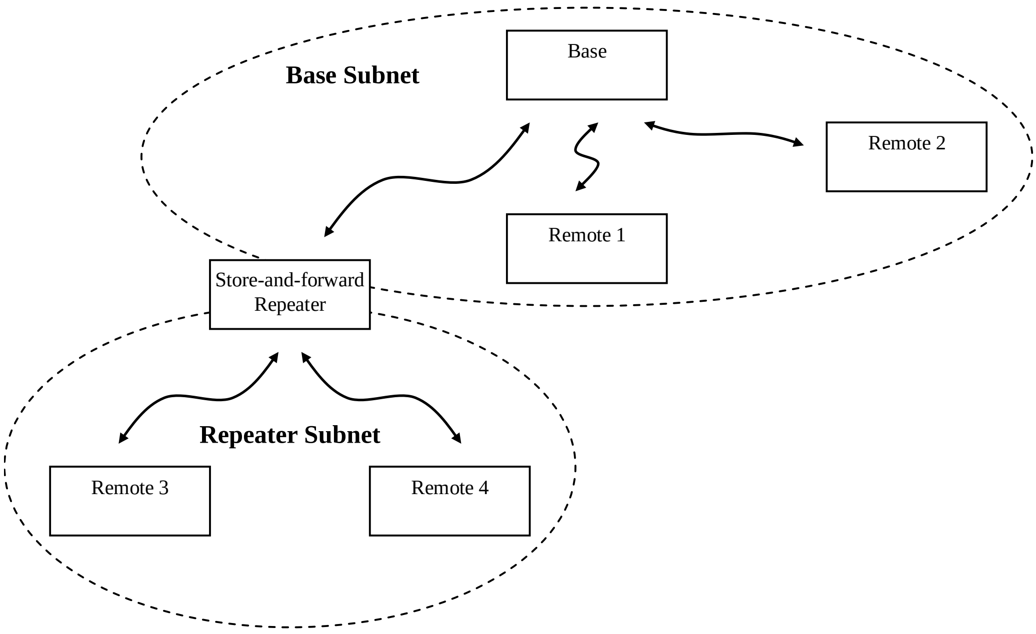

Figure 5: Crescendo tree network topology

When allocating radio addresses, a recommended convention is to reserve the first two decimal digits as the subnet number, and the last three digits for individual radios residing within the subnet. For example, consider the scenario shown in Figure 5, and the address allocation given in Table 10.

Subnet	Subnet Address	Radio	Radio Address
Base subnet	1	Base	1000
		Remote 1	1001
		Remote 2	1002
Repeater subnet	27	Store-and-forward Repeater	27000
		Remote 3	27001
		Remote 4	27002

Table 10: Addressing for a tree network topology

Following this convention can reduce the complexity of implementing routing tables.

A subnet should not be confused with co-located networks (see section 5.4.2). All units on the base and repeater subnets should have the same network address. For more on store-and-forward repeaters see section 5.4.3 on page 28.

5.4.2 Network Address

`Main -> Radio -> Network`

The network address is a high level address used to differentiate between co-located networks. For a unit to send to or receive from another unit, their network addresses must match. A co-located network should not be confused with a base or repeater subnet (see section 5.4.1)

Figure 6 shows an example of two co-located networks. In this example all units that are a part of network A should have the same network address, and all units in network B should share a different network address.

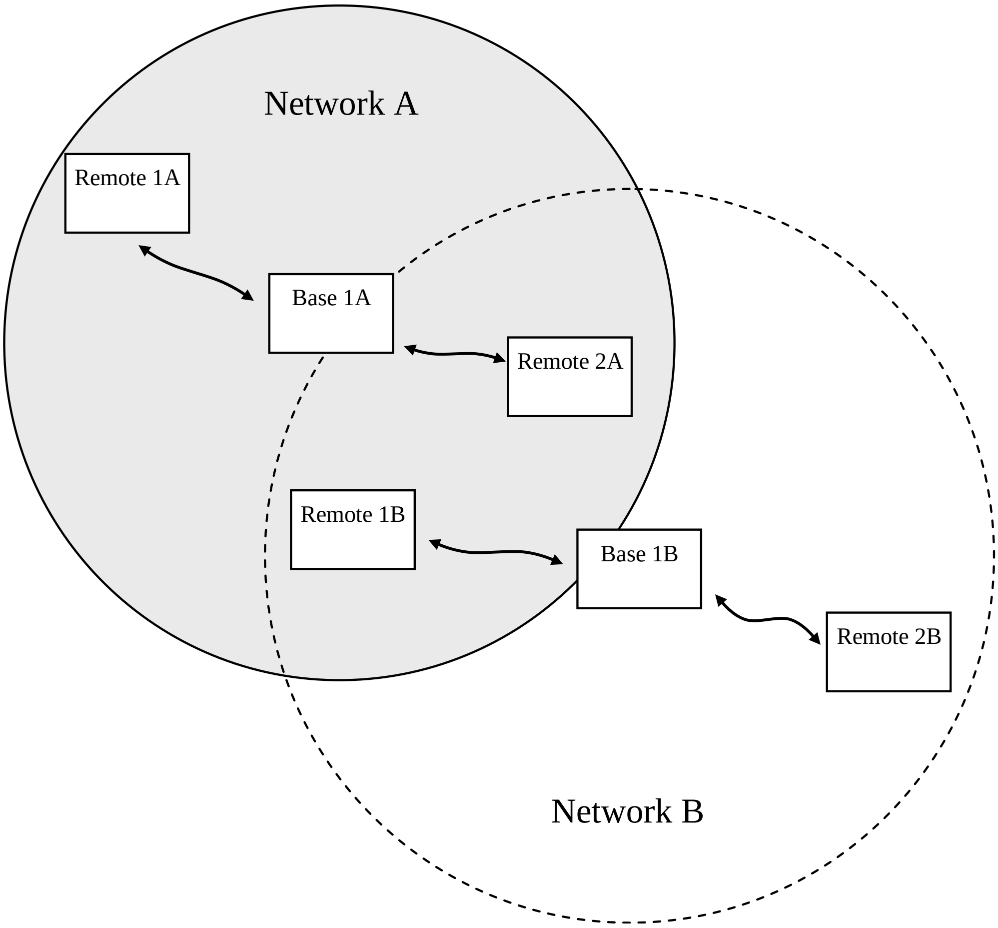

Figure 6: Co-located networks

When co-locating Crescendo networks it is important to observe the following:

- If the co-located networks operate on different Tx and Rx frequencies, RF interference will not occur. This is the ideal situation.
- If the co-located networks share Tx or Rx frequencies, the networks must have different network addresses. If they do not, units on one network could masquerade as units on the other network, causing random errors including data loss and reception of erroneous messages.
- Even with a different network address, the networks can cause interference with each other. This could cause retries, resulting in increased latency, and possible data loss if retry counts are exhausted.

5.4.3 Store-and-forward Repeater

A Crescendo unit may be configured to operate as a store-and-forward repeater (see Appendix B.1). A store-and-forward repeater can be used to extend the range of a network. It behaves as a combination of base and remote unit in the following manner:

- If a packet is received over the air which is addressed to the repeater, the packet data will be transmitted out the serial port.
- If a packet is received over the air which is not addressed to the repeater, but with a next hop address equal to the repeater's address, the packet will be submitted for retransmission.
- If a packet is received over the air which is addressed to the broadcast address, the packet will be submitted for retransmission, and the packet data will be transmitted out the serial port.

When setting up a network with store-and-forward repeaters, it may be necessary to adjust the following parameters on units in the network:

- Repeaters in Network.
- Wait for Carrier.
- Routing Tables

Routing traffic to take advantage of store-and-forward repeaters is covered in section 5.5 on page 28.

5.5 Routing

Routing of data operates differently depending on the protocol mode that is selected (protocol modes are covered in section 6 on page 33):

- ***Data Driven Protocol:*** When operating in data driven protocol, all data received on the main serial port of a unit is transmitted out the main serial port of all other units in the network. The routing table has no impact on data driven operation.
- ***Point-to-Multipoint Protocol:*** When operating in point-to-multipoint protocol, all data inserted on the serial port of the base is output on the same serial port of each repeater and remote within the network. The routing table has no impact on point-to-multipoint operation.
- ***Point-to-Point, Hayes Dial-up, and Datagram Protocols:*** When operating in any of these protocol modes the routing of data is governed by the network structure and routing table.

5.5.1 Network Structure

`Main -> Radio -> Network`

A typical Crescendo network has a base and store-and-forward repeaters forming a backbone, with a set of remotes hanging off the base and each repeater. In order for a packet to reach its destination, routing tables need to be configured on the units.

5.5.2 Routing Table

Main -> Radio -> Network -> Routing Table

Complete control can be maintained over the routing of data through a Crescendo network by configuring the routing table. The routing table consists of 16 entries on each unit which specify rules to apply for data with destination addresses within a particular range.

- The destination of point-to-point data is simply the point-to-point destination address (see section 6.3 on page 34).
- The destination of Hayes dial-up data is the address that was used when dialling (see section 6.5 on page 35).
- The destination of a Datagram packet is set in the Datagram header (see section 6.6 on page 38).

An example routing table is shown in Figure 7.

```
 *** Routing Table Menu ***


    |First Addr         |Last Addr          |Hop Addr           |
    |-------------------|-------------------|-------------------|
(0) |               2000|               2999|               2000|
(1) |               3000|               4999|               3000|
(2) |                  0|                  0|                  0|
(3) |                  0|                  0|                  0|
(4) |                  0|                  0|                  0|
(5) |                  0|                  0|                  0|
(6) |                  0|                  0|                  0|
(7) |                  0|                  0|                  0|
(8) |                  0|                  0|                  0|
(9) |                  0|                  0|                  0|
(A) |                  0|                  0|                  0|
(B) |                  0|                  0|                  0|
(C) |                  0|                  0|                  0|
(D) |                  0|                  0|                  0|
(E) |                  0|                  0|                  0|
(F) |                  0|                  0|                  0|
(ESC) - Previous Menu

Enter Selection:
```

Figure 7: Example routing table

In this example, the rules applied are:

1. Any packet with destination address between 2000 and 2999 is transmitted to radio 2000 for further routing.
2. Any packet with destination address between 3000 and 4999 is transmitted to radio 3000 for further routing.
3. Any packet with a destination address that is not covered by the routing table is transmitted directly to that radio.

Examples of routing tables used in real systems with store-and-forward repeaters are given in section 7.

5.6 Diagnostics

5.6.1 Data Quality

`Main -> Link Control`

The Crescendo continually measures the 'quality' of the received signal by comparing the received waveform against an internally generated 'ideal' baseband signal. The result is a value from 0-255 that is indicative of the quality of the data. In general, a data quality of greater than 100 is good, and less then 50 is poor. The following data quality values are kept:

- ***Data Quality:*** The most recent data quality measurement.
- ***Lowest Data Quality:*** The lowest data quality measurement since the radio was powered up, or since the baseband statistics were reset (see section 5.6.5).

5.6.2 RSSI

`Main -> Link Control`

The Crescendo provides received signal strength indication (RSSI) with a range from -40dBm to -120dBm. The following RSSI values are kept:

- ***Average Noise:*** The average RSSI level while no valid carrier is present on the receive channel.
- ***Average RSSI:*** The average RSSI level while data is being received.
- ***Bad Trigger:*** The RSSI level for the last bad trigger while receiving.

5.6.3 Monitor RSSI

`Main -> Diagnostics`

The monitor RSSI function reports a weighted RSSI value. It is different from the average RSSI and average noise values provided above in that it reports a value regardless of whether a valid carrier is present. When used with the terminal interface, the monitor RSSI function has a rapid refresh rate, making short transmissions easily detectable.

5.6.4 PRBS Generator

`Main -> Diagnostics`

When the PRBS generator is enabled, the Crescendo continually transmits a PN-9 sequence over the RF interface. This diagnostic feature can be used in conjunction with the Monitor RSSI feature to diagnose possible RF propagation issues in a radio network.

5.6.5 Statistics

`Main -> Diagnostics`

The Crescendo provides three sets of radio performance statistics:

- Baseband statistics relate to the performance of the lowest level of the radio data path, and are described in Table 11.
- Data driven MAC statistics relate to the performance of the radio when using the data driven serial protocol, and are described in Table 12.
- Packet driven MAC statistics relate to the performance of the radio when using a serial protocol other than the data driven protocol, and are described in Table 13.

BASEBAND STATISTICS

Name	Number	Description
Tx Sync	0	The total number of symbol/frame synchronisations sent for the start of a packet transmission.
Tx ReSync	1	The total number symbol/frame resynchronisations.
Rx Sync	2	The total number of symbol/frame synchronisations received for the start of a packet.
Rx ReSync	3	The total number of symbol/frame resynchronisations received.
Bad Triggers	4	The total number of times an RSSI trip was detected and a frame sync pattern match could not be found.
Low Quality	5	The total number of times that a data quality of less than 50 was measured.

Table 11: Baseband statistics

DATA DRIVEN MAC STATISTICS

Name	Number	Description
Tx Bytes	0	The number of bytes that have been transmitted.
Rx Bytes	1	The number of bytes that have been received and processed.
Tx Blocks	3	The total number of blocks sent.
Rx Good Blocks	4	The total number blocks received.
Rx Bad Blocks	5	The total number of blocks received with bad CRCs.
Tx Empty Blocks	6	The total number of blocks sent with no data.
Rx Empty Blocks	7	The total number of blocks received with no data.
Tx Starts	8	The total number of times the transmit mode was enabled for a set of blocks.
Rx Ends	9	The total number of times a complete set of blocks was received.
Rx Overruns	10	The total number of bytes discarded owing to a lack of room in the serial buffer.
Overruns	11	The total number of times a packet received over the air is discarded because the serial side is not ready to receive.
Bad Trigger	12	The total number of times an RSSI trip is detected and a frame sync pattern match cannot be found.

Table 12: Data driven MAC statistics

PACKET DRIVEN MAC STATISTICS

Name	Number	Description
Tx Bytes	0	The number of bytes that have been transmitted.
Rx Bytes	1	The number of bytes that have been received and processed.
Tx Packets	3	The total number of packets that have been transmitted correctly.
Rx Good Packets	4	The total number packets that have been received correctly.
Tx Retries	5	The total number of times that a packet was retransmitted because an ACK was not received, or the destination was the broadcast address.
Tx Discards	6	The total number of packets that have been discarded because the allowed number of singlecast retries was exceeded.
Rx Bad Headers	7	The total number of packets that have been received where the packet header CRC was incorrect.
Rx Bad Packets	8	The total number of packets that have been received where the packet data CRC was incorrect.
Rx Duplicates	9	The total number of packets that have been received and discarded because they are a duplicate of packets that have already been received and processed.
Rx Overflow	10	The number of times a received packet has been discarded due to lack of buffer space.
Overruns	11	The number of times a Tx or Rx packet has been discarded due to a baseband error.
Bad Trigger	12	The number of times receipt of a packet has been stopped due to a bad trigger being detected.

Table 13: Packet driven MAC statistics

6. Protocol Operation

6.1 Overview

Both of the Crescendo's serial ports can be independently configured with different protocol modes. Protocol modes serve two purposes:

- Provide methods for configuring the radio for operation, and for interrogating it in order to determine current operational status.
- Allow the Crescendo radio to determine how data received on its serial ports is to be converted into RF packets.

In addition to the protocol modes, each serial port can be configured with a packetiser timer, to maintain compatibility with protocols which cannot handle the inter-character delays introduced by the Crescendo block allocation scheme. The use of packetiser timers is discussed in section 4.3.2 on page 18.

Section 7 on page 43 provides some example applications using these protocol modes to achieve different data communications requirements.

6.2 Data Driven Protocol

`Main -> Protocol`

The data driven protocol provides a low latency connection between the radios in a network. When data driven protocol is enabled, the packet driven nature of the Crescendo is disabled, changing the radio behaviour to the following:

- Addressing and routing are not used.
- Retries are disabled, but error checking is still utilised.
- All data presented to the main serial port is transmitted immediately over the air, and appears on the main serial port of all units in range which have data driven protocol configured.

There are two configurable parameters which affect the way the data driven protocol operates:

- ***Data Timeout:*** The period, in milliseconds, for which the radio will continue to transmit after all data in the serial buffer has been transmitted. The data timeout can be configured between 0 and 255ms.
- ***Lead-in Count:*** The number of lead-in bytes the Crescendo will discard and not transmit over the air. Using a Lead-in Count and lead-in bytes gives the radio modems time to connect to each other before the data to be transmitted over the air arrives on the serial port. This can reduce end-to end latency. The lead-in count can be configured between 0 and 255 bytes.

The following restrictions apply when using the data driven protocol:

- The data driven protocol can only be configured on the main port.
- While data driven is configured on the main port, Hayes dial-up protocol can be configured on the auxiliary port. The dialling capability of the Hayes dial-up protocol on the auxiliary is disabled.

6.3 Point-to-point Protocol

`Main -> Protocol`

The point-to-point protocol establishes a connection between two end points. Both end points must have the point-to-point protocol selected on the same serial port, and have the point-to-point destination set to the remote radio modem address.

There are two operational modes configurable for the point-to-point protocol:

- ***Connection Based:*** This mode of operation provides a connection oriented link. It will report the state of the connection via the RF link status parameter (either connected or not connected) and the online LED will be solid green. If there is no data being transferred between the end units background polling packets are sent to maintain the connection.
- ***Connectionless:*** This mode provides a packet oriented link. It does not maintain the state of the link through background polling.

When operating in point-to-point mode, the radio will send all data to a fixed destination. Data inserted at one end will appear at the other end. This is the simplest method of creating a wire replacement link.

Point-to-point applications are given in section 7.1 on page 43.

6.4 Point-to-multipoint Protocol

`Main -> Protocol`

In a point-to-multipoint network, data transmitted by a unit is output by all the remotes and intervening store-and-forward repeaters.

When using point-to-multipoint protocol, there are no acknowledgments on transactions. This is because multiple units may be receiving the data, and if they were to all attempt to acknowledge the transmission, they would interfere with each other.

Instead of acknowledgements, a unit will transmit each message a fixed number of times equal to the broadcast retries parameter. For this reason, the number of retransmissions used in a point-to-multipoint network should be configured to maintain a reasonable throughput.

Point-to-multipoint applications are given in section 7.2 on page 46.

6.4.1 Strict and Relaxed Addressing

`Main -> Protocol`

The point-to-point and point-to-multipoint protocols can use strict or relaxed addressing. When strict addressing is used:

- If point-to-multipoint protocol is selected, only data transmitted by a unit that is also in point-to-multipoint protocol will be output on the serial port.
- If point-to-point protocol is selected, only data transmitted by the receiver’s destination will be output on the serial port.
- If relaxed addressing is used, data will be output regardless of the source address or source protocol mode. Data transmitted by a unit in point-to-multipoint mode will be output on units in point-to-point and point-to-multipoint mode. Data transmitted by a unit in point-to-point mode will be output on the destination, regardless of its point-to-point destination address, as long as it is in point-to-point or point-to-multipoint mode.

6.4.2 Local Mode

Both point-to-point and point-to-multipoint protocol modes allow local command mode to be entered using the escape sequence (section 6.5.3 on page 36). Returning to online mode is achieved using the online command (`ATO`). The protocol can also be configured to start in local command mode when power is applied. For data to be transferred between two end units, both units must be online, not in local command mode.

If the radio modem receives RF data while in local mode, it will be stored in the RF buffer until local mode is exited.

6.5 Hayes Dial-up Protocol

`Main -> Protocol -> Hayes Dial-up`

The Hayes dial-up protocol provides a connection mechanism that emulates a PSTN modem's dialling mechanism. This is a more powerful method of operating than using point-to-point or point-to-multipoint networks, as it allows dedicated communication between a base and one of many remotes.

In Hayes Dial-up protocol, the state of the connection will be reported via the RF link status parameter (either connected or not connected). The online LED will be solid green while the connection is up. If there is no data being transferred between the end units, background polling packets are sent to maintain the connection.

Hayes Dial-up applications are given in section 7.3 on page 49.

6.5.1 Dialling

The AT commands may be used to initiate dialling of a remote radio. The `ATD` command is used to establish a connection. The syntax of the `ATD` command is:

```
ATD<address><extension>
```

Where `<address>` is the address of the radio that is being dialled and `<extension>` is the serial port or internal extension port that is being dialled. The available extension numbers are shown in Table 14.

Extension	Name	Description
00	Main Port	Establishes a connection between the current serial port and the main port on the remote unit.
01	Auxiliary Port	Establishes a connection between the current serial port and the auxiliary port on the remote unit.

Table 14: Hayes dial-up extension numbers

If the radio receives a character on the serial port while dialling is in progress, it will immediately terminate the connection attempt and issue a `NO CARRIER` response message.

If a connection is established then the `CONNECT` response message will be returned.

6.5.2 Answering

The Crescendo provides two options for answering dial-up calls:

- ***Auto-answer:*** In auto-answer mode, when a connection request is made the Crescendo will output a configurable number of RING responses on the destination, then automatically connect.
- ***Manual answer:*** When in manual answer mode, the Crescendo will output a RING response on the destination once per second until the ATA command is received, at which point the connection is established. If no ATA command is received after the configured number of RING responses are output, the connection is not established, and the dialler receives the NO ANSWER response. The NO ANSWER message is shown after the wait for carrier timeout.

6.5.3 Escape Sequence

While a protocol port is in the online state, all the data received on the port will be sent to the remote radio. AT commands are not interpreted, and are passed over the air.

To force the radio to return to local command mode, the escape sequence is used. The escape sequence consists of a delay greater than the escape guard time (default is one second), three escape characters (default is '+') typed rapidly, and another delay greater than the escape guard time. As soon as the radio returns to local command mode, it will respond with the message OK.

When a protocol port is in local command mode, the port can be returned to the online state by issuing the ATO command.

The escape sequence can be entered while in point-to-point and point-to-multipoint protocol modes. This allows all AT commands except dial commands to be entered. When returning online, the point-to-point or point-to-multipoint mode is restored.

6.5.4 Hanging Up

The ATH command is used to terminate a connection. After communications have finished, enter the escape sequence (+++). The radio responds with an OK message. Execute the ATH command, and the local radio will respond with NO CARRIER. The remote radio will output NO CARRIER as the communications link is lost.

Hanging up can also be achieved by using DTR modes, described in section 6.5.5.

6.5.5 DTR Modes

In addition to the AT commands that are used to control the dial-up connection, DTR may be configured to provide similar functionality. Only the main port supports DTR, so the setting for DTR mode on the auxiliary port Hayes protocol is not used.

There are four available DTR modes:

- ***Ignore DTR:*** DTR is not used to control the Hayes communications settings.
- ***Hangup on DTR Low:*** If DTR is low then the radio will hang-up the current connection. If DTR is low when a dial attempt is made, then the connection will be severed immediately after being established.
- ***Hangup on DTR Dropped:*** If a falling edge (high to low transition) is detected on the DTR line, the radio will hang-up the current connection.
- ***Local Mode on DTR Low:*** If the radio is online, and DTR is disasserted, the radio modem will return to local command state, but will still remain connected. The only way to return to the online state is to set DTR high, and then issue the `ATO` command. If DTR is low when the `ATO` command is issued, then the radio will immediately return to local mode.

6.5.6 Traceroute

The AT commands may be used to obtain diagnostic information from the radio network. The `ATT` command is used to start a traceroute diagnostic to a destination radio. The syntax of the `ATT` command is:

```
ATT<address>
```

Where `<address>` is the address of the destination radio.

The traceroute diagnostic periodically sends a query to the destination radio and expects a response. The traceroute response will contain the RSSI and data quality of the destination and intervening repeaters. It can be stopped by entering any character to the radio. The traceroute diagnostic will then display the number of requests and responses in the session, and return the port to local command mode.

```
att1003

1000 -> (1003, -84 dBm, 255 QF) -> (1000, -90 dBm, 255 QF)
1000 -> (1003, -84 dBm, 255 QF) -> (1000, -90 dBm, 255 QF)
1000 -> (1003, -84 dBm, 255 QF) -> (1000, -91 dBm, 255 QF)
1000 -> (1003, -84 dBm, 255 QF) -> (1000, -90 dBm, 255 QF)
1000 -> (1003, -84 dBm, 255 QF) -> (1000, -90 dBm, 255 QF)
Tx: 23 Rx: 23 Lost: 0 (0.0%)
```

6.6 Modbus RTU Protocol

Main -> Protocol -> Modbus

When using the Modbus RTU protocol, the Crescendo expects Modbus RTU packets on the serial port in the following format.

Start T1-T2-T3-T4	Address (1 byte)	Function (1 byte)	Data (0…251 bytes)	CRC (2 bytes)

Figure 8: Datagram protocol packet format

The fields of a Modbus packet are:

- ***Start:*** A silent interval of at least 3.5 character times.
- ***Address (8-bit):*** The address of the slave unit in the Modbus transaction.
- ***Function (8-bit):*** The Modbus function indicating the function to perform, or response to a function request.
- ***Data:*** Any additional information required for the action that was specified in the function field.
- ***CRC:*** A 16-bit cyclic redundancy check over the address, function, and data using the polynomial 0xA001.

6.7 Distributed Network Protocol (DNP)

Main -> Protocol -> DNP

The Crescendo supports the Distributed Network Protocol (DNP) as defined by the DNP Users Group (http://www.dnp.org/). The packet structure for a DNP packet expected on the serial port is shown in Figure 9.

Start 0x0564	Len (8)	Ctrl (8)	Destination (16)	Source (16)	CRC (16)	…	Data (0…16)	CRC (16)

Figure 9: DNP packet format

- ***Start (16-bit):*** A fixed start of packet marker, always `0x0564`.
- ***Len (8-bit):*** The length of the packet, including all fields except *Start*, *Length*, and *CRC*.
- ***Ctrl (8-bit):*** Defines the control information for the packet.
- ***Destination (16-bit):*** The 16-bit destination address. This can be any singlecast address, or the broadcast address.
- ***Source (16-bit):*** The 16-bit source address. When sending a packet to a radio, this field does not need to be set.
- ***Data:*** The fixed length header block is followed by optional data blocks of up to 16 bytes.
- ***CRC (16-bit):*** A 16-bit CRC value calculated over the previous fields, excluding the *CRC* fields. The CRC uses the polynomial 0xA6BC.

Main -> Protocol -> Datagram

6.8 Datagram Protocol

When using the datagram protocol, packets are passed to the Crescendo to be transmitted over the air. The packet format is given in Figure 10.

Start 0xC1	Length (16)	Destination (16)	Source (16)	DP (2)	SP (2)	Res. (4)	Data (1…Slot Size)	CRC (32)

Figure 10: Datagram protocol packet format

Note that the number of data bytes in a datagram packet must be no greater than the max packet size configured. The fields of a datagram packet are:

- ***Start (8-bit):*** A fixed start of packet marker, always `0xC1`.
- ***Length (16-bit):*** The length of the packet, including all fields except *Start*, *Length*, and *CRC*.
- ***Destination (16-bit):*** The 16-bit destination address. This can be any singlecast address, or the broadcast address. The destination cannot be the same as the radio's source address.
- ***Source (16-bit):*** The 16-bit source address. When sending a packet to a radio, this field does not need to be set. The source will automatically be set to the radio's local address.
- ***DP (2-bit):*** The destination serial port. This can be either 00 for the main port or 01 for the auxiliary port.
- ***SP (2-bit)***: The source serial port. When sending a packet to a radio, this field does not need to be set. The value will automatically be set to the serial port the packet was inserted on.
- ***Res (4-bit):*** Reserved for future use. This field should be set to all zeros.
- ***Data:*** The data to be transmitted. The amount of data in each datagram must be equal to or less than the slot size.
- ***CRC (32-bit):*** A 32-bit CRC value calculated over the entire packet, excluding the *Start* and *CRC* fields.

There are two options for the CRC field.

1. ***Fixed:*** The value is fixed to `0xEDB88320`.

2. ***CRC:*** The CRC value is calculated using a 32-bit CRC with

- Initial Value: 0xFFFFFFFF
- Polynomial: 0xEDB88320
- Final XOR: 0xFFFFFFFF

When a radio modem receives a datagram packet over the air, the data will be output by the datagram protocol in the same packet format, as described in Figure 10.

An example Datagram packet with a calculated CRC-32 is shown in Figure 11.

Start 0xC1	Length 0x0009	Destination 0x0001	Source 0x0000	DP / SP / Res 0x00	Data 0x54 0x45 0x53 0x54	CRC 0x9496D61C

Figure 11: Example datagram protocol packet

Datagram protocol applications are given in section 7.4.

6.9 RF Link Status

`Main -> Protocol`

The Crescendo provides an RF link status indication for each serial port. The RF link status depends on the protocol mode being used and the current state of that protocol. The meaning of different RF link status values is provided in Table 15 for each protocol mode.

Protocol	State	RF Link Status
Point-to-point	Connection Based	Connected if a path exists between the local and remote device. Not Connected if there is no communications path.
	Connectionless	N/A
Point-to-multipoint		N/A
Hayes dial-up	Connection established	Connected if a path exists between the local and remote device. Not Connected if there is no communications path.
	No connection established	Not Connected
Datagram		N/A

Table 15: RF link status for different protocol modes

Whenever the protocol mode on a serial port is temporarily disabled (such as when the menu is enabled on the port, or when the Cruise Control application has been started), the RF Link Status will be displayed as N/A.

6.10 Protocol to Radio Address Mapping

`Main -> Protocol`

Protocol address mapping can be used in situations where the radio address is not the same as the protocol address, or where there is more than one protocol address for each radio address. A protocol mapping entry has each of the following fields:

- ***First Addr:*** The first protocol address to apply to the protocol mapping.
- ***Last Addr:*** The last protocol address to apply to the protocol mapping.
- ***Radio Addr:*** The radio address to apply to the protocol mapping.
- ***Type:*** A protocol mapping entry can be one of four types:

- ***Unused:*** The protocol mapping entry is not used.
- ***Single:*** For a single entry, the packet is sent to the associated radio address if the protocol address matches the first address. The last address is ignored. This is a "one-to-one" mapping.
- ***Mapped:*** For a mapped entry, the mapping is applied if the protocol address is within the range specified by the first and last addresses. To determine the radio address, the offset from the first address is added to the associated radio address entry. This is a series of "one-to-one" mappings.
- ***Grouped:*** For a grouped entry, the packet is sent to the associated radio address if the protocol address is within the range of the first and last address. This is a "many-to-one" mapping.
-
- An example protocol mapping table is shown in Figure 12.

```
*** Protocol Mapping Menu ***


    |Type                |First Addr          |Last Addr           |Radio Addr          |
    |--------------------|--------------------|--------------------|--------------------|
(0) |Single              |                   1|                   0|                1001|
(1) |Unused              |                   2|                   0|                1002|
(2) |Single              |                   3|                   0|                1003|
(3) |Mapped              |                   4|                  10|                1004|
(4) |Grouped             |                  11|                  20|                1011|
(5) |Unused              |                   0|                   0|                   0|
(6) |Unused              |                   0|                   0|                   0|
(7) |Unused              |                   0|                   0|                   0|
(8) |Unused              |                   0|                   0|                   0|
(9) |Unused              |                   0|                   0|                   0|
(A) |Unused              |                   0|                   0|                   0|
(B) |Unused              |                   0|                   0|                   0|
(C) |Unused              |                   0|                   0|                   0|
(D) |Unused              |                   0|                   0|                   0|
(E) |Unused              |                   0|                   0|                   0|
(F) |Unused              |                   0|                   0|                   0|
(ESC) - Previous Menu

Enter Selection:
```

Figure 12: Example protocol mapping table

For the example in Figure 12 the following mapping would occur:

1. A protocol packet with an address of 1 would be sent to radio address 1001.
2. A protocol packet with an address of 4 would be sent to radio address 1004.
3. A protocol packet with an address of 9 would be sent to radio address 1009.
4. A protocol packet with an address of 10 would be sent to radio address 1010.
5. A protocol packet with an address of 11 would be sent to radio address 1011.
6. A protocol packet with an address of 15 would be sent to radio address 1011.
7. A protocol packet with an address of 2 would be sent to radio address 2. Note the unused entry (1).
8. Any protocol packet with an address that does not have a matching entry will be sent to a radio address that matches the protocol address.

Note that only DNP and Modbus RTU protocol utilise the protocol mapping table and that the mapping is only applied to packets arriving over the serial port.

6.11 Multiple Protocol Modes

The Crescendo is a dual serial port radio modem, and both ports can be independently configured with different protocol modes. Using both ports for data may result in increased latency, owing to greater bandwidth requirements and increased probability of collision.

7. Applications

This section presents typical Crescendo usage scenarios. The aim of these scenarios is to illustrate radio configuration.

7.1 Point-to-point Networks

7.1.1 Basic Point-to-point Network

The simplest point-to-point network consists of two units configured such that the point-to-point destination of one unit is the address of the other. This scenario is shown in Figure 13.

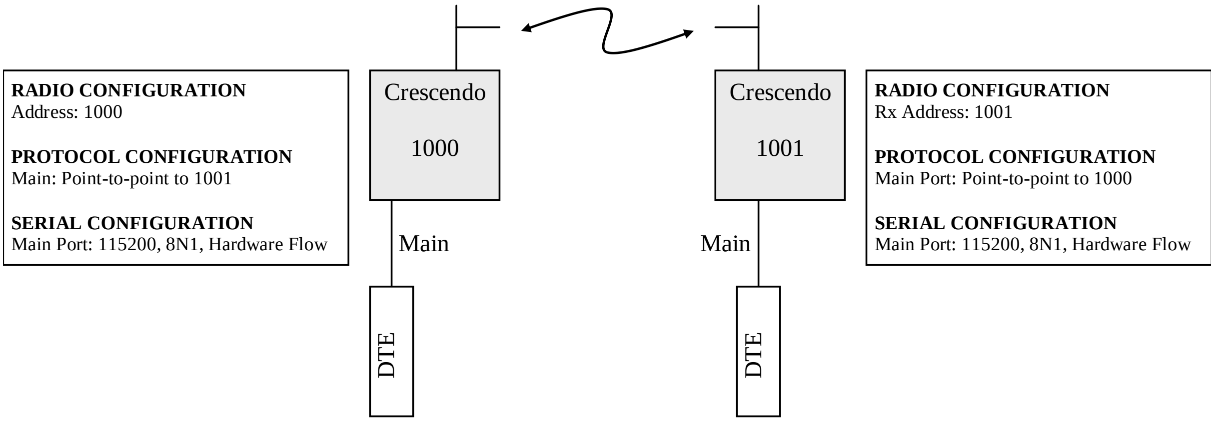

Figure 13: Basic point-to-point network

In this network, data presented on the main port of the unit 1000 will be output on the main port of unit 1001, and vice versa.

Other configuration parameters which may help in fine tuning the system operation are:

- Rx packetiser timers. See page 18 for more information.
- Point-to-point connection mode. See page 34 for more information.

7.1.2 Multiple Port Point-to-point Network

Two point-to-point destinations can be used by configuring the point-to-point protocol on both serial ports of base unit, and then having two remotes each connected to a different port. This scenario is shown in Figure 15.

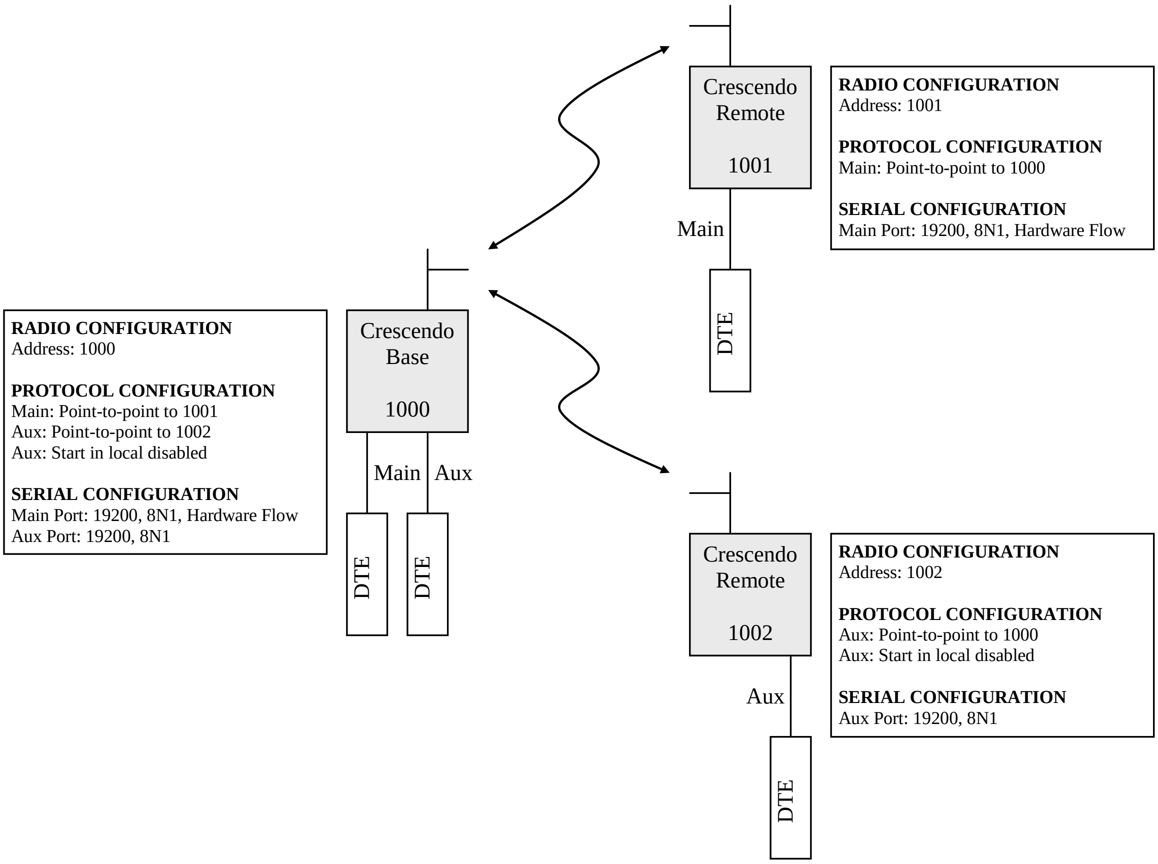

Figure 14: Multiple port point-to-point network

Note that the main port on the base is connected to the main port on radio 1001, while the auxiliary port on the base is connected to the auxiliary port on remote 1002.

Other configuration parameters which may help in fine tuning the system operation are:

- Rx packetiser timers. See page 18 for more information.
- Max packet size.
- Singlecast retries. See page 24 for more information.

7.1.3 Multiple Destination Point-to-point Network

Multiple destinations can be used by configuring any number of remote units and then changing the destination address of the base unit using local command mode. This scenario is shown in Figure 15.

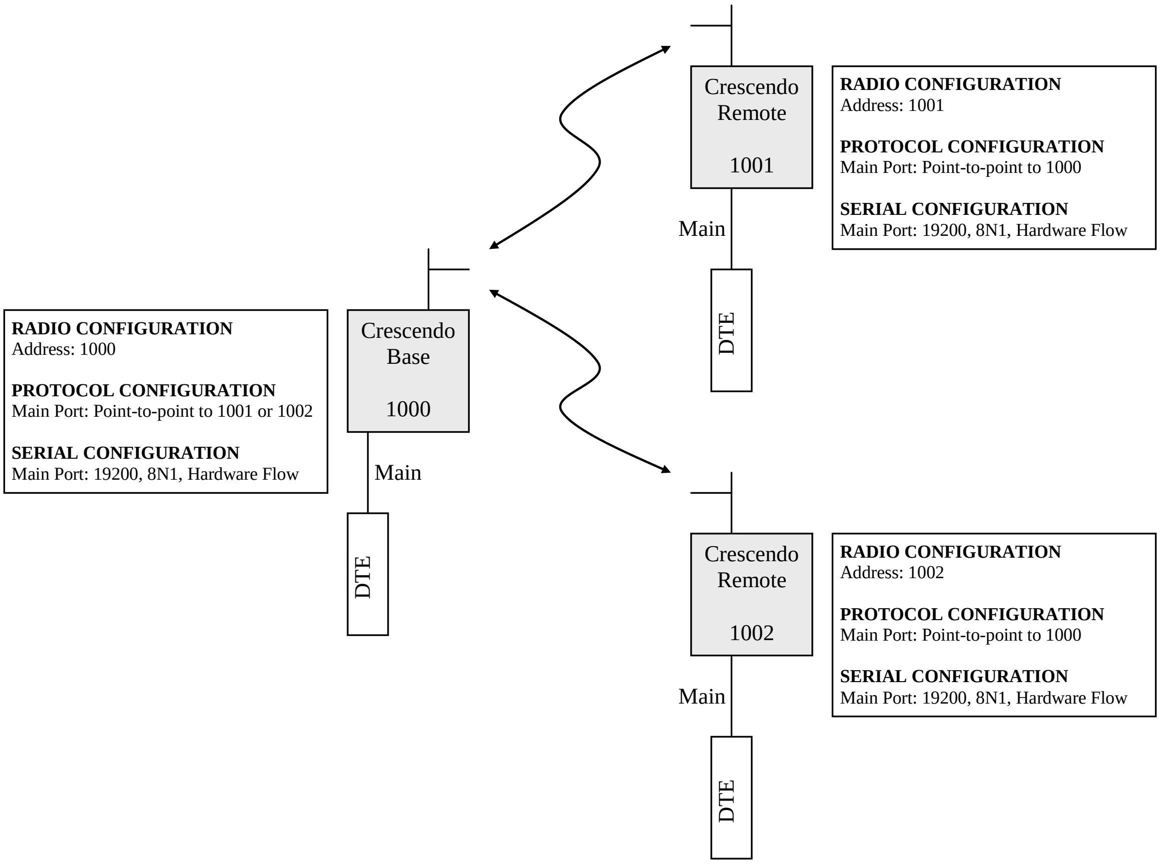

Figure 15: Multiple destination point-to-point network

The point-to-point destination address on the main port of the base unit determines which remote unit the base is connected to. To change the point-to-point destination address on main port, the follow these steps:

- Enable the local command mode on the main port by transmitting the escape sequence (see section 6.5.3 on page 36).
- Use the AT command to change the main port point-to-point destination (`ATS52=1001`).
- Return the port to online state using the online command (`ATO`).

Other configuration parameters which may help in fine tuning the system operation are:

- Rx packetiser timers. See page 18 for more information.
- Max packet size.
- Singlecast retries. See page 24 for more information.
-

7.1.4 Point-to-point Network with Repeater

Repeaters can be used to extend the range of a point-to-point network, as shown in Figure 20.

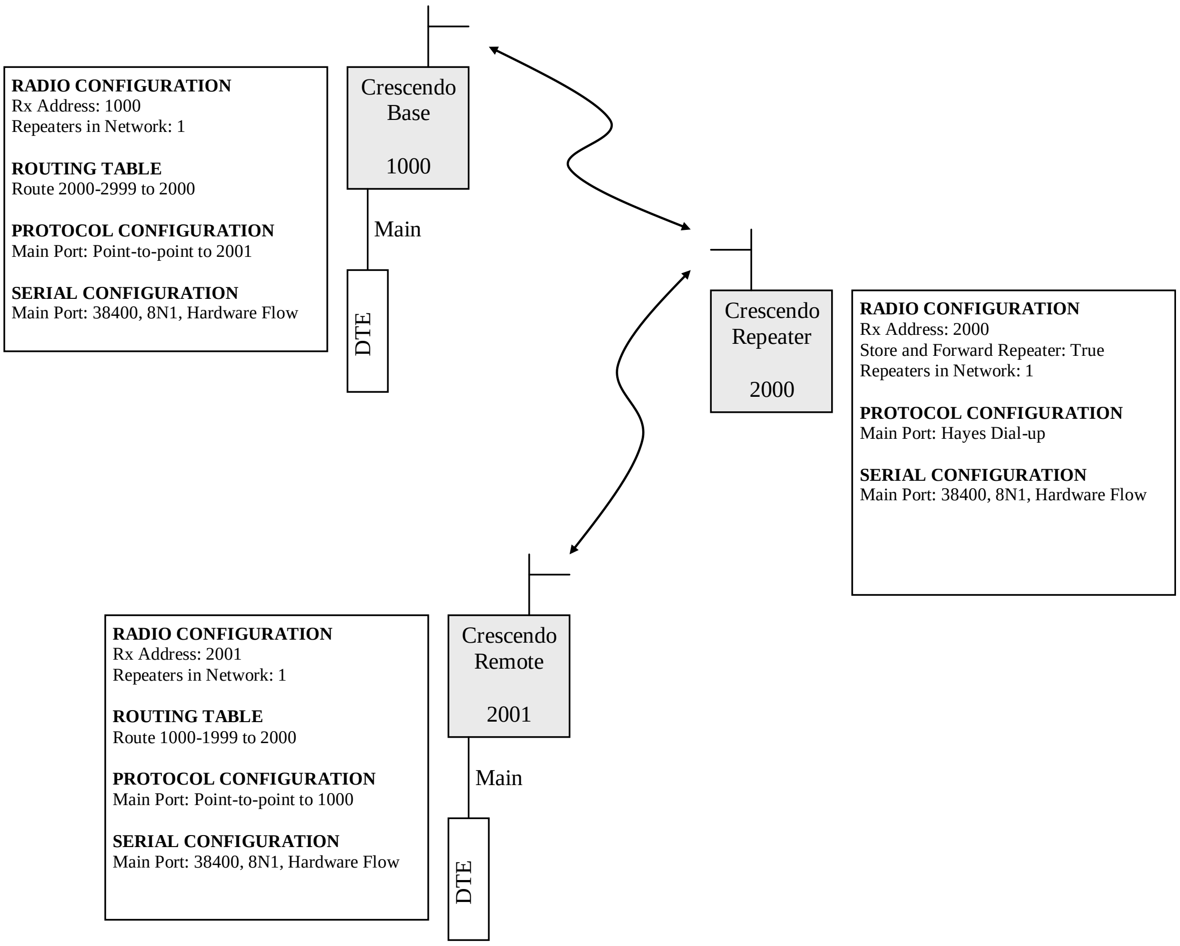

Figure 16: Point-to-point network with repeater

The following should be noted for the point-to-point network with repeaters:

- All units in the network have 'Repeaters in network' set to 1.
- The main port protocol on the repeater is set to Hayes even though the main port is not used. This is so the unit is in packet driven mode rather than data driven mode (see section 5).
- Routing tables need to be set on the base and remote radio modems.

Other configuration parameters which may help in fine tuning the system operation are:

- Rx packetiser timers. See page 18 for more information.
- Max packet size.
- Singlecast retries. See page 24 for more information.

7.2 Point-to-multipoint Networks

7.2.1 Basic Point-to-multipoint Network

A basic point-to-multipoint network is shown in Figure 17.

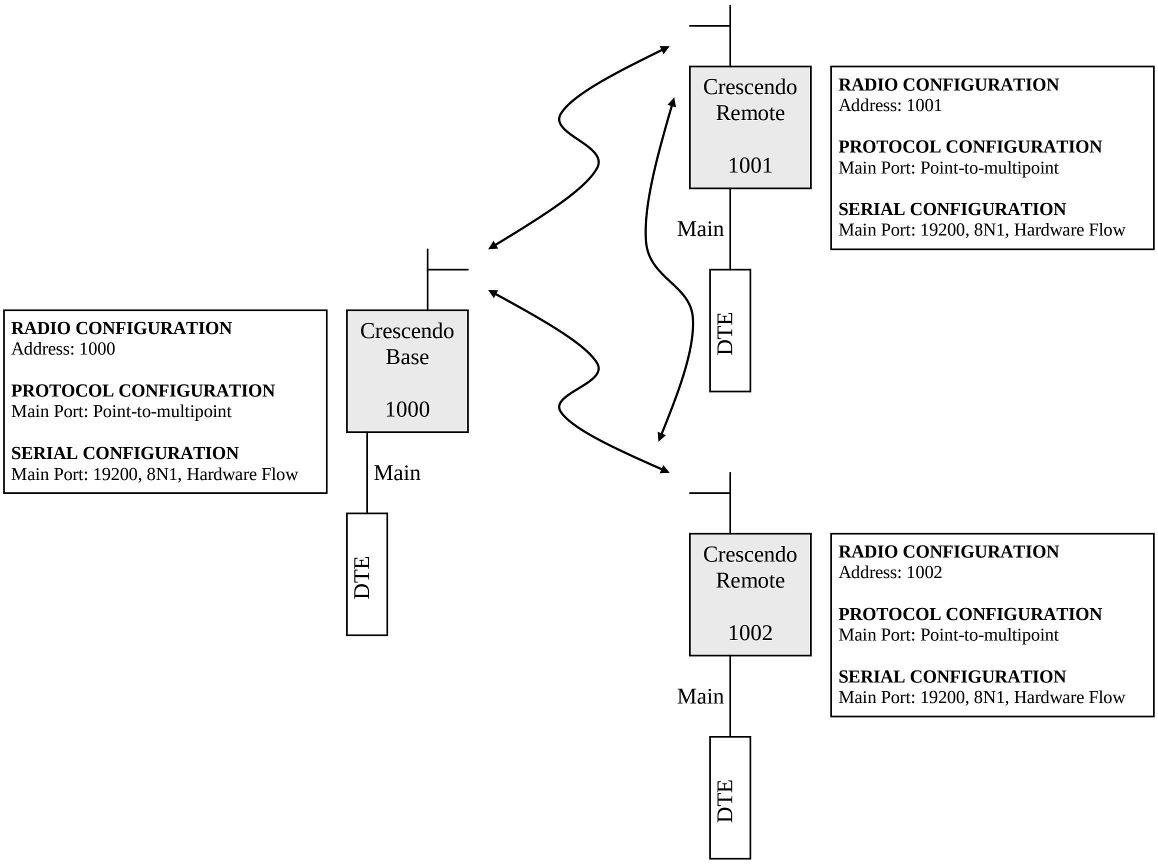

Figure 17: Basic point-to-multipoint network

In this network, data passed to the main port on any unit will be output on the main port of both other units.

Other configuration parameters which may help in fine tuning the system operation are:

- Rx packetiser timers. See page 18 for more information.
- Max packet size.
- Broadcast retransmissions. See page 24 for more information.

7.2.2 Point-to-multipoint Network with Roaming Remote

In some applications the remote unit may be mobile, and needs to 'roam' between areas of coverage. A point-to-multipoint network configured for this purpose is shown in Figure 18.

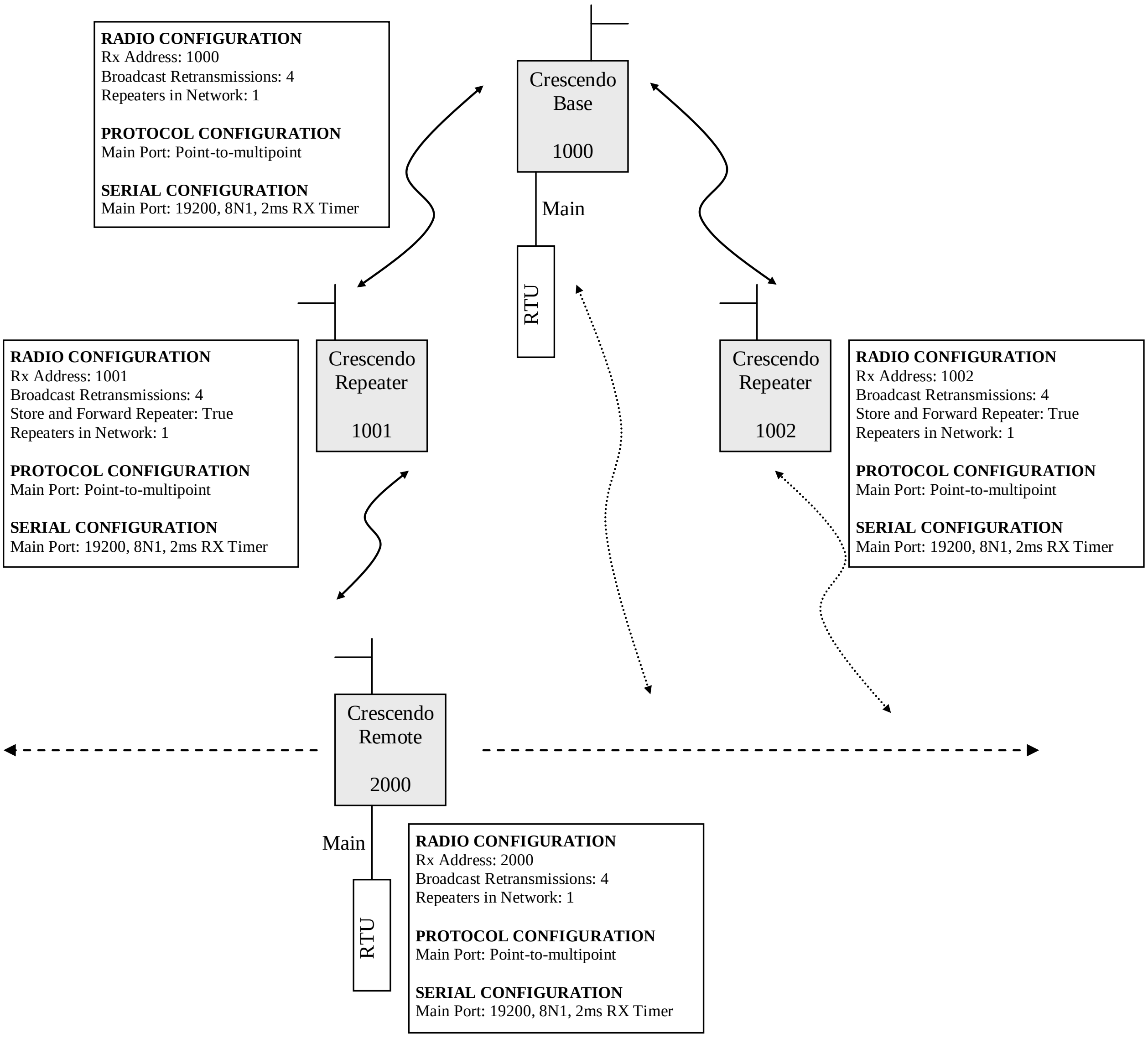

Figure 18: Point-to-multipoint network with roaming remote

As with other types of broadcast network, setting the max packet size will help fine tune the network. It is also worth nothing that while there are two store-and-forward repeaters in the network, the repeaters in network setting is set to one. Repeaters in network specifies the maximum number of repeaters a packet must go through to reach a destination.

7.3 Hayes Dial-up Networks

7.3.1 Basic Hayes Dial-up Network

A basic Hayes dial-up network is given in Figure 19.

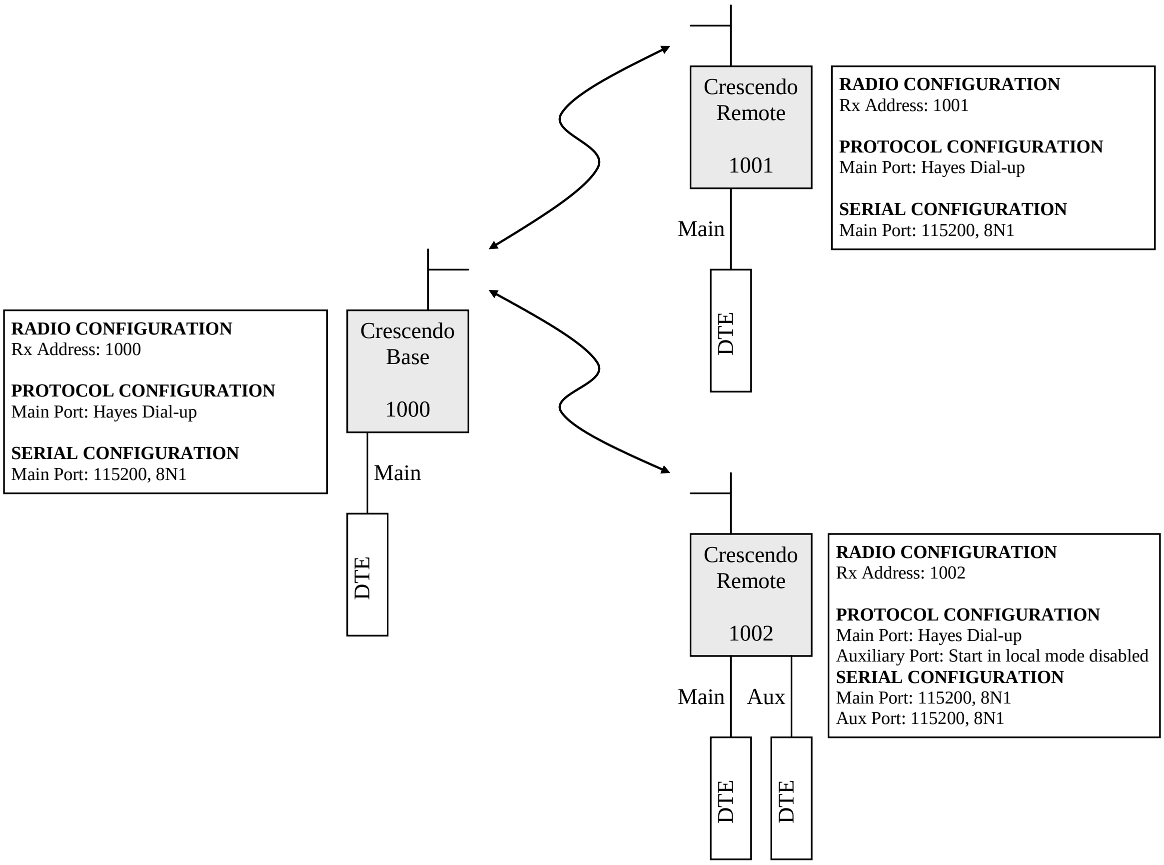

Figure 19: Basic Hayes dial-up network

In order to establish a connection from the base to the main port on remote 1001, the following dial string is used:

```
ATD100100<CR>
```

To establish a connection to the auxiliary port of remote 1002, the following dial string is used:

```
ATD100201<CR>
```

Information on hanging up a Hayes dial-up connection can be found in section 6.5.4 on page 36.

7.3.2 Hayes Dial-up Network with Repeaters

Repeaters can be used to extend the range of a Hayes dial-up network, as shown in Figure 20.

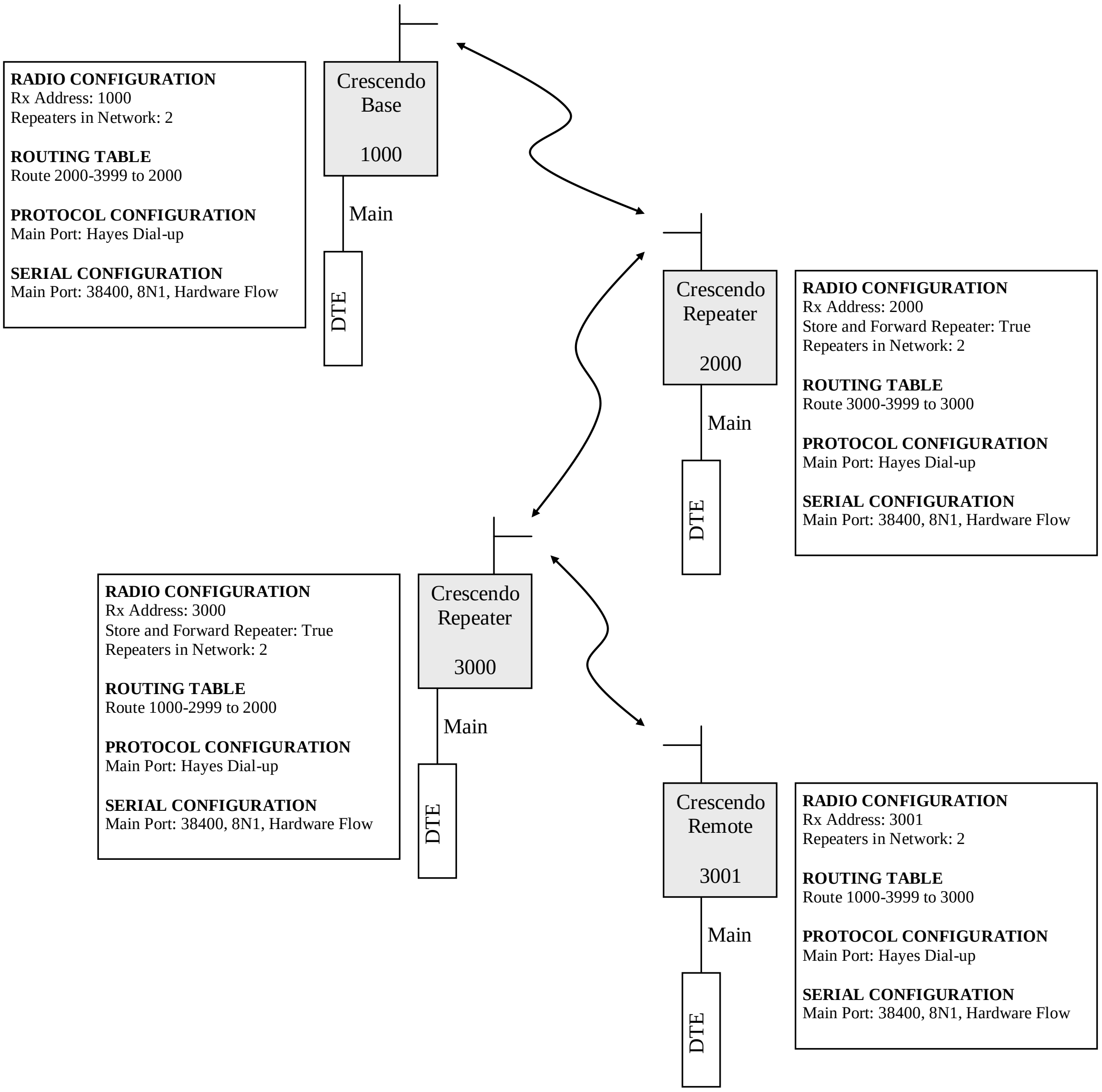

Figure 20: Hayes dial-up network with repeaters

The following dial string is used to dial the second main port on the second store-and-forward repeater:

```
ATD300000<CR>
```

To dial the main port on the remote, the following dial string is used:

```
ATD300100<CR>
```

7.4 Modbus RTU Network with Repeater

A Modbus network with repeater is shown in Figure 21.

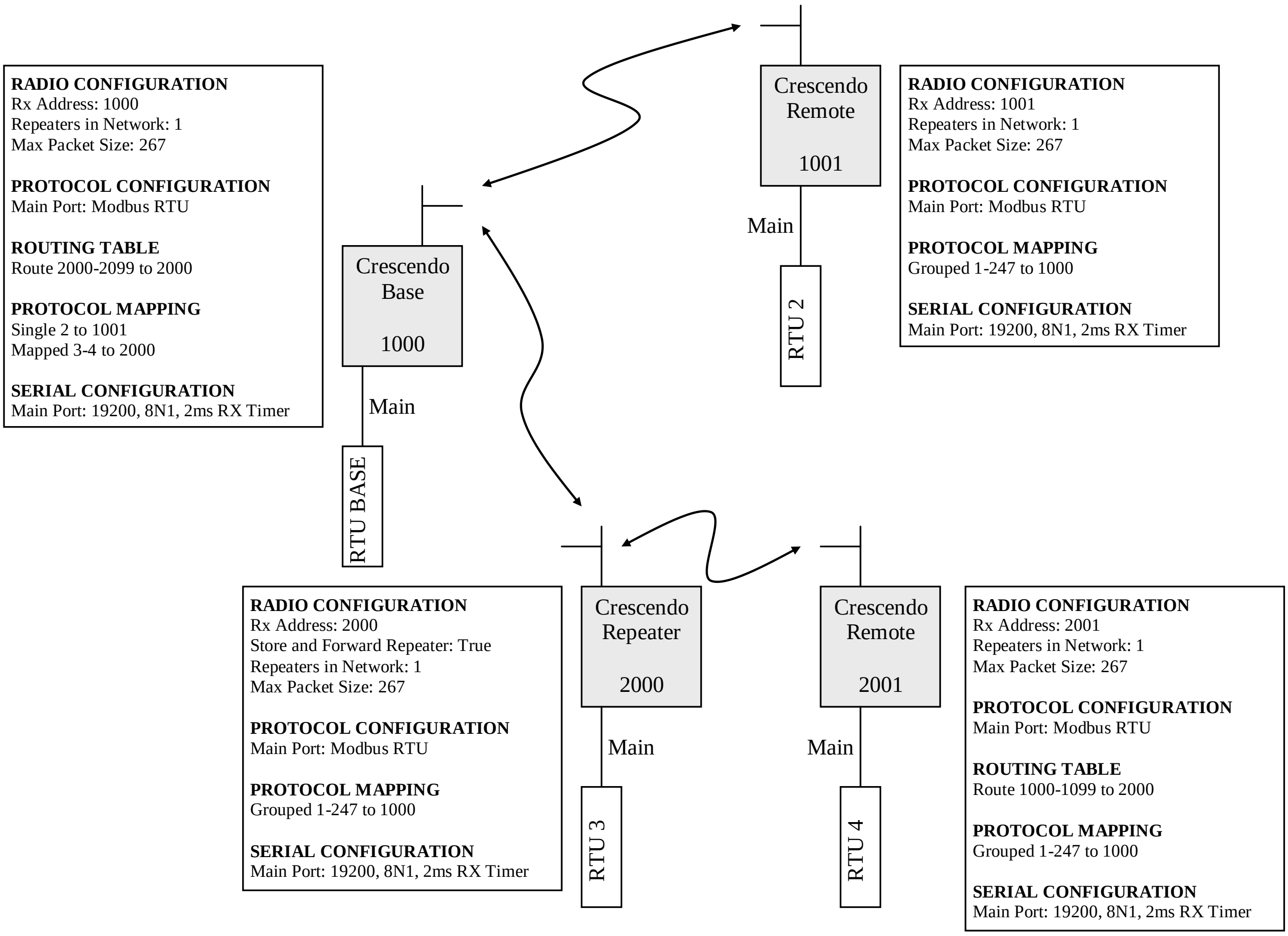

Figure 21: Modbus network with repeater

In order to support the ModBus protocol, an RX packetiser timer of 2ms has been used on the main port of each unit. See section 4.3.2 on page 18 for more information on packetiser timers.

7.5 DNP Network with Repeater

A DNP network with repeater is shown in Figure 22.

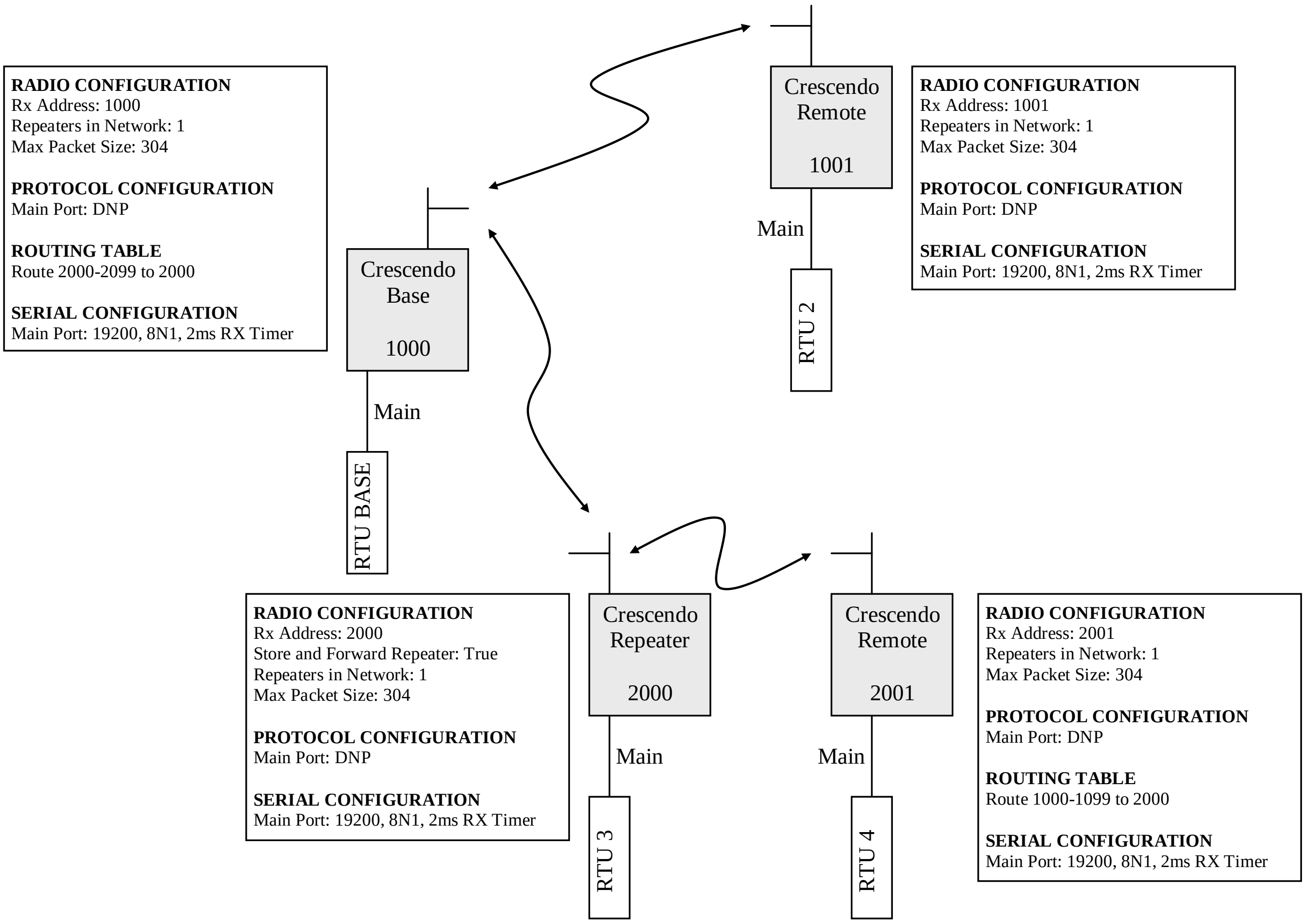

Figure 22: DNP network with repeater

Note that no protocol mapping has been utilised. It is therefore assumed that the mapping from protocol address to radio address is one-to-one, and the protocol address is the same as the radio address.

7.6 Datagram Networks

7.6.1 Basic Datagram Network

A basic datagram network is shown in Figure 23.

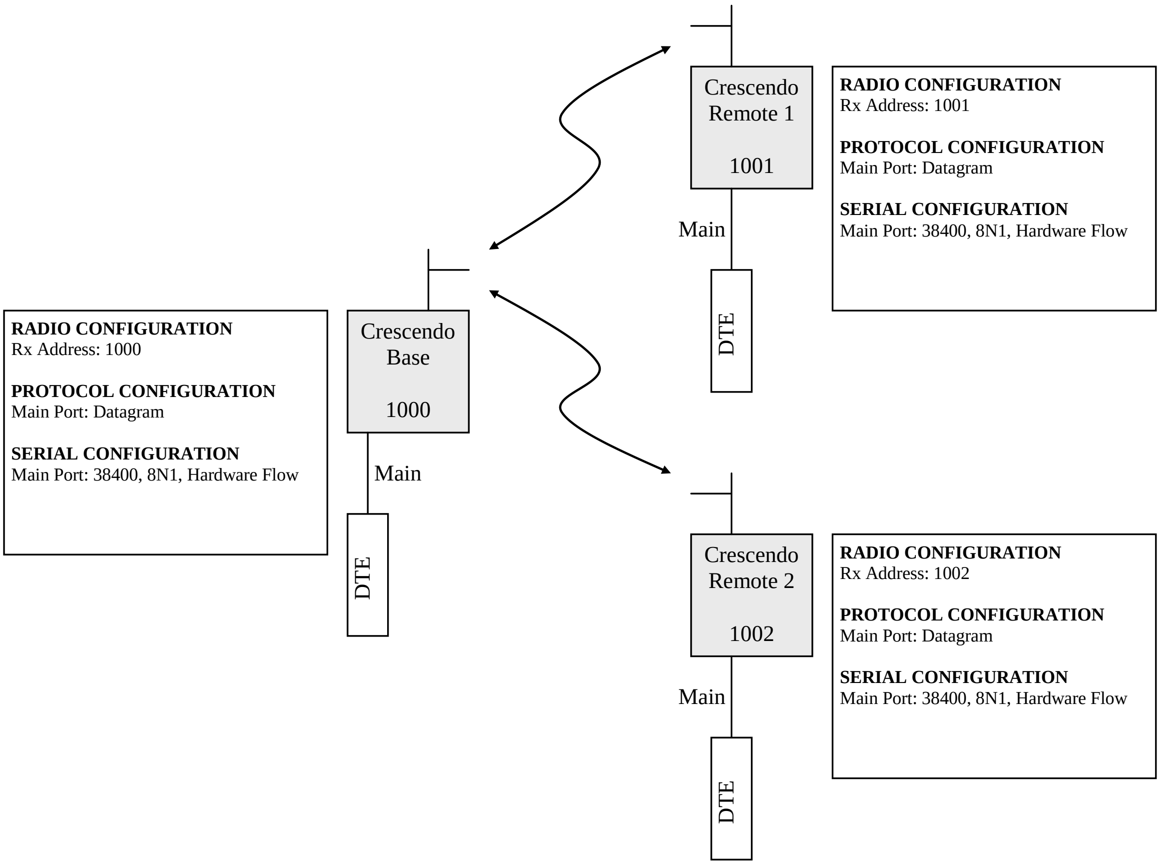

Figure 23: Basic datagram network

In this network, datagrams presented to the main port of the base with the destination address set to 1001 will be routed to remote 1, while those with destination address 1002 will be routed to remote 2.

Appendix A Technical Specifications

A.1 Type Approvals

Australia/ New Zealand	AS 4295 -1995	Australian Supplier ID: N161
FCC (planned)	CFR 47 Part 15 and Part 90	FCC ID P5MRFI150H
Industry Canada (planned)	RSS-GEN, RSS-102, RSS-119	IC: XXXXXX-RFI150H
ETSI (planned)	ETS 300 113	

Table 16: Type approvals

A.2 Radio Modem Specifications

RF Switching Bandwidth	148 – 174 MHz
RF Channel Bandwidth	Model specific: • 12.5kHz • 25kHz
RF Frequency Raster	Selectable: 25kHz, 12.5kHz, 6.25kHz
RF Output	Selectable Carrier Power (@ 13.8VDC nominal): • 0, +20, +27, +30, +36, +37dBm Continuous duty-cycle rated
Receiver Sensitivity	-104dBm at a BER of 10^{-6} (9600 bps) -102dBm at a BER of 10^{-6} (19200 bps)
Modulation	Nyquist-shaped 4-level FSK. RRC filter coefficient 0.2 Modulation deviation (max): • 4.7kHz (25kHz channel) • 2.35kHz (12.5kHz channel)
Baseband Rate	Model specific: • 19.2Kbit/s (25kHz channel) • 9.6Kbit/s (12.5kHz channel)
Serial Ports	Dual asynchronous full duplex RS-232 Data Rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200 Data Bits: 7 or 8 Parity: None, Odd, or Even Stop Bits: 1 or 2 Flow Control (Main Port only): None, Hardware (RTS/CTS)

Input Voltage	• 9V to 16VDC (negative ground)
Environmental Specifications	Temperature: -10 to +60ºC Humidity (max): 95% non-condensing at 50ºC
Connectors:	Power: Phoenix PH1776508 Main Serial Port: DB9 RS-232 Female Auxiliary Serial Port: DB9 RS-232 Female Serial Port Impedance: 3-7 kohm nominal RF: BNC Female (50 ohm nominal)

Table 17: Radio modem specifications

A.2.1 Input Current

Tx Power (dBm)	Current (mA)
Rx Only	80
0	515
20	525
27	590
30	665
36	1060
37	1190

Table 18: Nominal Input Current at 12.5V and transmit frequency of 161 MHz (Mid band.)

A.3 Connectors Pin Assignments

A.3.1 Main Serial Port

PIN	Function	Direction
1	DCD	Output
2	RxD	Output
3	TxD	Input
4	DTR	Input
5	GND	
6	N/A	
7	RTS	Input
8	CTS	Output
9	N/A	

Table 19: Main connector pin-out

A.3.2 Auxiliary Serial Port

PIN	Function	Direction
1	N/A	
2	RxD	Output
3	TxD	Input
4	N/A	
5	GND	
6	N/A	
7	N/A	
8	N/A	
9	N/A	

Table 20: Auxiliary connector pin-out

A.4 Dimensions

Length	158 mm
Width	101.6 mm
Height	43.4 mm

Table 21: Nominal dimensions without mounting plate

Length	188 mm
Width	100 mm
Height	2 mm

Table 22: Nominal dimensions of mounting plate

Unit Weight	850 g
Shipping Weight	1000 g

Table 23: Nominal weight with mounting plate

A.4.1 Mounting Plate Dimensions

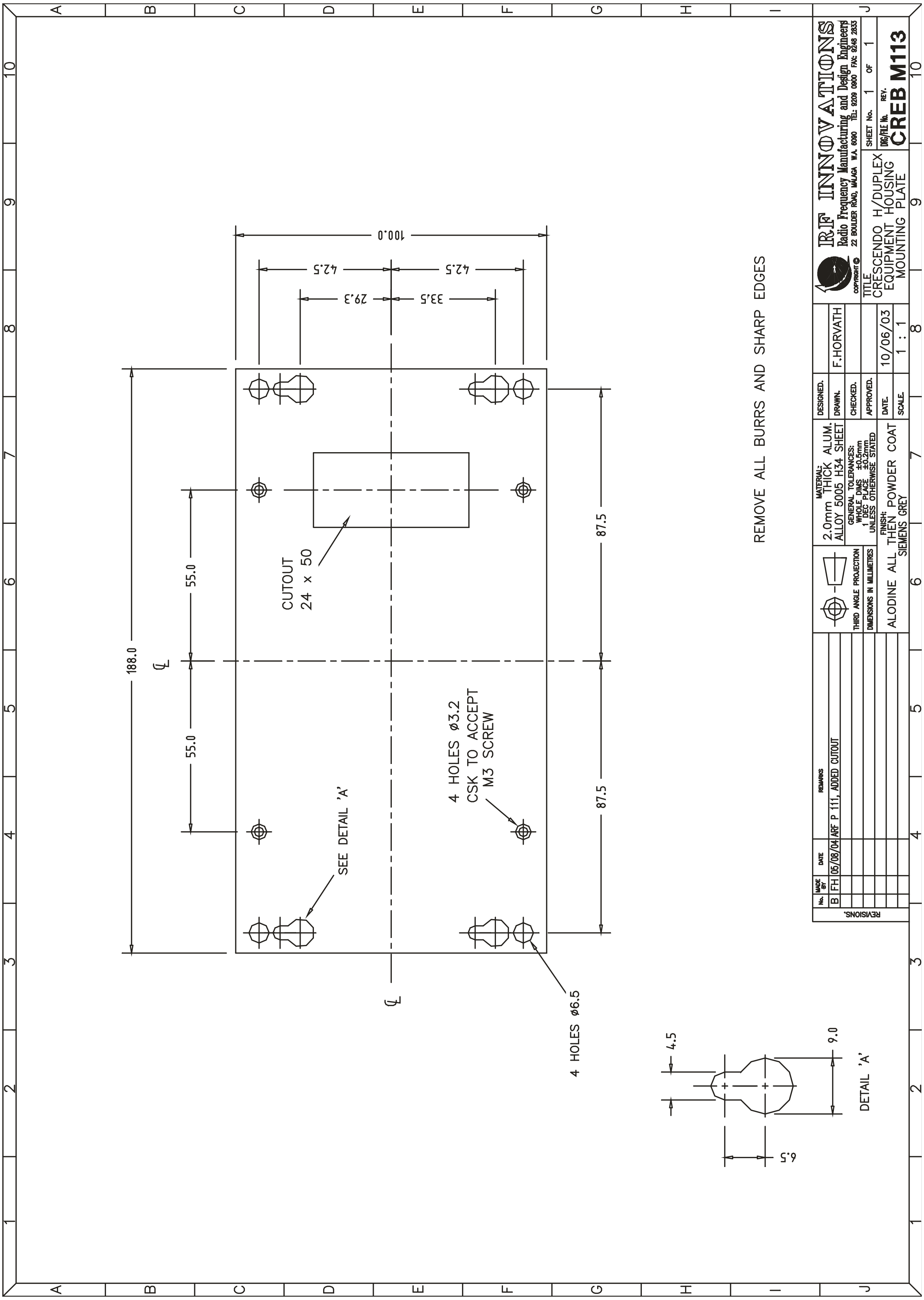

Figure 24: Mounting plate dimensions

Appendix B Management Reference

B.1 Radio Configuration

Radio		Page	AT
Address	Sets the radio local address, 0-61439	23	`S51`
Tx Power	The output power.	24	`S45`
RSSI Trip	Set the RF signal level for RF data.	24	`S53`
Network			
Network Address	The network address	27	`S50`
Store and Forward Repeater	Enables store-and-forward functionality	28	`&L`
Repeaters In Network	Sets the maximum number of repeaters for a destination for acknowledgement timing.	24	`S160`
Max Packet Size	Sets the maximum packet payload.	24	`S170`
Broadcast Retransmissions	Sets the number of times a broadcast packet is retransmitted	24	`S38`
Singlecast Retries	Sets the number of times a packet is retried before it is discarded.	24	`S41`

Routing Table	Allows routing rules to be configured	29	`S151:firstaddr`
			`S152:lastaddr`
			`S153:hopaddr`

Channel			
Tx Range	Shows the range of allowable Tx frequencies.	24	
Rx Range	Shows the range of allowable Rx frequencies.	24	
Channel Width	Shows the channel width of the radio, 12.5 or 25 kHz.	24	`I50`
Current Channel	Sets the current channel and corresponding Tx/Rx frequencies to be used.	24	`S54`

Table 24: Radio configuration

B.2 Link Control Configuration and Diagnostics

Link Control		Page	AT
Data Quality	Shows the current data quality (0-255)	30	

Lowest Data Quality	Shows lowest data quality received so far (0-255)	30	`I61`
Temperature	The temperature of the unit.		`I9`
Average Noise	The average RSSI level where no valid carrier is present on the receive channel.	30	`I11`
Average RSSI	The average RSSI level while data is being received.	30	`I12`
Last RSSI	The RSSI level for the last valid data received.	30	`I31`
Bad Trigger	The RSSI value for the last bad Trigger received.	30	

Table 25: Link control configuration and diagnostics

B.3 Serial Port Configuration and Diagnostics

Serial Port		**Page**	**AT**
Main Flow Control	The main port flow control operation.	17	`S104`
Main DCD Mode	The rule for controlling DCD.	17	`S90`
Main CTS Mode	The rule for controlling CTS.	17	`S91`
Online Timeout	The timeout used by the Follows Online CTS / DCD mode.	17, 13	`S43`
Port Settings			
Baud	The serial port baud rate.	17	`S100`
Data Bits	The serial port data bits.	17	`S102`
Parity	The serial port parity.	17	`S101`
Stop Bits	The serial port stop bits.	17	`S103`
Rx Packetiser Timer	The receive packetiser timer.	18	`S40`
Tx Packetiser Timer	The transmit packetiser timer.	18	`S39`
Statistics	The serial port statistics.	19	`I20`

Table 26: Serial port configuration and diagnostics

B.4 Protocol Mode Configuration and Diagnostics

Protocol		Page	AT
Lead-in Count	The number of lead-in bytes the radio will discard and not transmit over the air.	33	`S73`
Data timeout	The period of serial silence the radio will wait before it stops transmitting.	33	`S74`
RF Link Status	The state of the RF link for the port.	40, 34, 35	`I16`
Mode	The selected protocol mode	33	`S70`
Point-to-point Destination Address	The point-to-point partner radio address	34	`S52`
Start In Local Mode	Enables local command mode on the port when the radio powers up.	35	`S72`
Point-to-Point Mode	Connection or packet driven mode.	34	`S71`
Point-to-[multi]point Receive Mode	The receive address mode (strict or relaxed).	34	`S64`
Hayes Dial-up Protocol			
Wait for Carrier	Number of seconds to wait for a connection.	35	`S7`
Auto-Answer	Whether to auto-answer dial requests.	36	`S1`
Rings Before Answer	Number of rings to wait before auto-answering.	36	`S0`
DTR Mode	Sets the action the radio takes on DTR settings.	37	`&D`
Echo	Whether to echo bytes in local command mode.	12	`E`
Responses	Enables or disables responses.	12	`Q`
Verbal Responses	Sets responses as either strings or numbers.	12	`V`
Escape Guard Time	Time to wait for the escape sequence.	35	`S12`
Escape Character	The escape character.	35	`S2`
Allow Local Mode	Enables usage of the escape sequence while in other protocol modes (excludes data driven).	35	`S3`
Datagram Protocol			
Footer Mode	CRC-32 or fixed.	35	`S140`

Table 27: Protocol mode configuration and diagnostics

B.5 Diagnostics

Diagnostics		Page	AT
Fault	The last fault that was reported.		I15
Startup Reason	Indicates if the radio started normally or due to a watchdog reset.		
EEPROM Status	The state of the EEPROM at start-up.		R10
Build Date	The date that the firmware was built.		R9
Monitor RSSI	Puts the radio in a mode when it continuously outputs the RSSI on the current channel (can only be used in menu).		
Factory Reset	Resets all settings to factory defaults.	68	&F1
Load Configuration	Reloads all configuration from EEPROM, discarding changes made with AT commands.	62	Z
Save Configuration	Saves all configuration changes made with AT commands to EEPROM.	62	&W
Data Driven MAC	Performance statistics when using the data driven serial protocol	19	
Packet Driven MAC	Performance statistics when using a serial protocol other than the data driven protocol.	19	
Baseband Statistics	Baseband specific statistics.	19	
Reset Data Driven Statistics	Clears all Data Driven MAC statistics		
Reset Packet Driven Statistics	Clears all Packet Driven MAC statistics		
Reset Baseband Statistics	Clears all baseband statistics.		&C1
Event Log			
Level	The logging level.		S60
Clear Event Log	Clears the event log		

Table 28: Diagnostics

Appendix C Hayes References

C.1 General Commands

Command	Name	Notes
ATE	Echo	Returns 1 if Hayes echo is enabled, or 0 if echo is disabled.
ATE0		Disables Hayes echo.
ATE1		Enables Hayes echo.
ATQ	Responses	Returns 1 if Hayes responses are enabled, or 0 if responses are disabled.
ATQ0		Disables Hayes responses.
ATQ1		Enables Hayes responses.
ATV	Verbal Responses	Returns 1 if verbal responses are enabled, or 0 if verbal responses are disabled.
ATV0		Disables verbal responses. Responses will all be numeric.
ATV1		Enables verbal responses.
ATZ	Initialise	Reloads all the configuration settings.
AT&C1	Clear RF Statistics	
AT&F1	Factory Reset	Performs a complete factory reset.
AT&D	Hayes DTR Mode	0: Ignore 1: Hangup on DTR Low 2: Hangup on DTR Dropped 3: Local on DTR Low
AT&D0		Sets the unit to ignore.
AT&D1		Sets the unit to hangup on DTR low.
AT&D2		Sets the unit to hangup on DTR dropped.
AT&D3		Sets the unit to go local on DTR low.
AT&L	Store-and-forward Repeater Mode	0: Store and forward repeater disabled 1: Store and forward repeater enabled
AT&L0		Disable store-and-forward repeater.
AT&L1		Enable store-and-forward repeater.
AT&T7	Soft Reset	Causes the radio to reboot, and a fault to be logged.
AT&V	View All Registers	Outputs the value in all I and S registers.

AT&V1	View All I Registers	
AT&V2	View All S Registers	
AT&W	Save Configuration	Saves the current configuration to EEPROM.
AT?	Enable Menu	
AT%30	Enable Cruise Control	Enables the Cruise Control on the serial port. Wait for 10 seconds after executing with no further data input to return to normal Hayes mode.

Table 29: Hayes general commands

C.2 Connection Management Commands

Command	Name	Notes
ATT	Traceroute	Starts a traceroute diagnostic to a destination radio. See section 6.5.6.
ATD ATDT ATDP	Dial	
ATA	Answer	
ATH ATH0	Hangup	
ATO ATO0	Go Online	

Table 30: Hayes connection management commands

C.3 I-Registers

Command	Name	Notes
ATI5	Manufacture Date	
ATI6	Serial Number	
ATI9	Temperature	
ATI11	Average RSSI	
ATI15	Fault	
ATI16[0]	RF Link Status	Returns the RF link status for the main port.
ATI16[1]		Returns the RF link status for the auxiliary port.
ATI20[p, s]	Serial Port Statistics	

ATI25[s]	Get Baseband Statistic	
ATI26[s]	Get Data Driven MAC Statistic	
ATI27[s]	Get Packet Driven MAC Statistic	
ATI50	Channel Width	

Table 31: Hayes I-register commands

C.4 S-Registers

All serial port configuration and status commands can be executed on either the main port or auxiliary port. The parameter [p] that may be passed to each serial port AT command should be set to 0 for main, or 1 for auxiliary.

Command	Name	Notes
ATS0	Rings Before Answer	Sets or returns the current number of rings before auto-answer.
ATS1	Auto Answer	0: Disabled 1: Enabled
ATS2	Escape Character	Sets or returns the current escape character.
ATS7	Wait for Carrier	Sets or returns the number of seconds to wait for a carrier to be established.
ATS12	Escape Guard Time	Sets or returns the escape guard time in ms.
ATS38	Broadcast Retransmissions	
ATS39	Tx Packetiser Timer	
ATS40	Rx Packetiser Timer	
ATS41	Singlecast Retries	
ATS45	Transmit Power	0: 0 dBm 1: +20 dBm 2: +27 dBm 3: +30 dBm 4: +36 dBm 5: +37 dBm
ATS50	Network Address	
ATS51	Radio Address	

Command	Name	Notes
ATS52	Point-to-point Destination Address	
ATS53	RSSI Trip	
ATS54	Current Channel	
ATS60	Log Filter	0: Faults 1: Warnings 2: Status 3: Information 4: Debugging
ATS64	Point-to-[multi]point Receive Addressing	0: Strict 1: Relaxed
ATS70	Protocol Mode	0: Point-to-point 1: Point-to-multipoint 2: Hayes Dial-up 3: Datagram 4: Log
ATS71	Point-to-point Mode	0: Connectionless 1: Connection Based
ATS90	Main Port DCD Mode	This command cannot have a `[p]` port specifier. 0: Always High 1: Always Low 2: Mirrors DTR 3: Mirrors RTS 4: Follows Rx Carrier 5: Follows Tx Enable 6: Follows Online
ATS91	Main Port CTS Mode	This command cannot have a `[p]` port specifier. 0: Always High 1: Always Low 2: Mirrors DTR 3: Mirrors RTS 4: Follows Rx Carrier 5: Follows Tx Enable 6: Follows Online
ATS92	Get Main Port DTR	This command cannot have a `[p]` port specifier. 0: Line is not asserted. 1: Line is asserted.

Command	Name	Notes
ATS93	Get Main Port RTS Mode	This command cannot have a [p] port specifier. 0: Line is not asserted. 1: Line is asserted.
ATS100	Baud	0: 110 1: 300 2: 600 3: 1200 4: 2400 5: 4800 6: 9600 7: 14400 8: 19200 9: 38400
ATS101	Parity	0: None 1: Even 2: Odd
ATS102	Data Bits	0: 7 1: 8
ATS103	Stop Bits	0: 1 1: 2
ATS104	Main Port Flow Control	This command cannot have a [p] port specifier. 0: None 2: Hardware (RTS / CTS)
ATS140	Datagram Footer Mode	0: Fixed 1: CRC-32
ATS151[a]	Routing Table Entry First Address	
ATS152[a]	Routing Table Entry Last Address	
ATS153[a]	Routing Table Hop Address	
ATS160	Repeaters in Network	
ATS170	Max RF Packet Size	

Table 32: Hayes S-register commands

C.5 R-Registers

Command	Name	Notes
ATR5	Manufacture Date	
ATR6	Serial Number	
ATR9	Firmware Build Date	
ATR10	EEPROM Status	

Table 33: Hayes R-register commands

Appendix D Factory Defaults

Group	Parameter	Default Value
Radio	Address	1000
	Tx Power	30 dBm
	RSSI Trip	-110
Network	Network Address	0
	Store and Forward Repeater	Disabled
	Repeaters in Network	0
	Max Packet Size	4096 bytes
	Broadcast Retransmissions	5
	Singlecast Retries	5
	Routing Table	<empty>
Channel	Channel Width	12.5 or 25 kHz (model dependant)
	Current Channel	0
	Channels (Tx and Rx)	0-8: As set by factory (not reset with factory reset)
Serial Ports	Main Flow Control	None
	Main DCD Mode	Always High
	Main CTS Mode	Always High
	Baud	19200
	Data Bits	8
	Parity	None
	Stop Bits	1
	Rx Packetiser Timer	0 ms
	Tx Packetiser Timer	0 ms

(table continues next page)

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Protocol	Protocol Mapping	<empty>
	Mode	Main: Data Driven Aux: Hayes Dial-up
	Point-to-point Destination	20
	Start In Local Mode	Main: Disabled Aux: Enabled
	Point-to-point Mode	Connection Based
	Receive Addressing	Strict
Datagram	Footer Mode	CRC-32
Hayes Dial-up	Wait for Carrier	10 seconds
	Auto-Answer	On
	Rings Before Answer	3
	DTR Mode	Ignore
	Echo	On
	Response	On
	Verbal Responses	On
	Escape Guard Time	1000 ms
	Escape Guard Character	+
Data Driven	Lead-in Count	0
	Data Timeout	2 ms
Event Log	Level	Information

Table 34: Factory defaults

Appendix E Product Identification Table

Table 35 shows the Crescendo product identification. The green shaded items are the available configurations. This table should be used when ordering a Crescendo radio modem.

FREQUENCY BAND		RF MODE		CHANNEL BANDWIDTH		AIR RATE		OPERATING MODE		COMPLIANCE CLASSIFICATION	
150	VHF	H	Half Duplex	N	12.5 kHz	L	1200/2400	BD	Bit-Driven	0	Unlicensed
290	VHF	HS	Half Duplex (Separate Tx/Rx Ports)	W	25 kHz	M	9600	DD	Data-Driven	1	Licensed
450	UHF	D	Full Duplex	C	Custom	H	19200	PD	Packet-Driven	2	Military
						C	Custom	VF	VF Only		
								CC	Custom		

Table 35: Crescendo product identification table

The product code for a Crescendo VHF, Half Duplex, 25kHz bandwidth, 19200bps, Data Driven Radio will therefore be: RFI-150 HWHDD1

Appendix F Glossary

ACK	Acknowledgement
ARQ	Automatic Repeat Request
BNC	British Naval Connector
CRC	Cyclic Redundancy Check
CTS	Clear To Send
DCD	Data Carrier Detect
DCE	Data Communications Equipment (radio modem)
DTE	Data Terminal Equipment (computer device)
DTR	Data Terminal Ready
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
RTS	Request To Send
Rx	Receive
Tx	Transmit
VHF	Very High Frequency

Table 36: Glossary

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