RF INNOVATIONS

LEADERS IN WIRELESS DATA

RFI-9256 RADIO MODEM

USER MANUAL

RFI-9256 Radio Modem

User Manual

DISCLAIMER

RF Innovations reserves the right to make improvements on the product in this manual at any time without notice.

No part of this manual may be produced, copied, translated, or transmitted in any form or by any means without the written permission of RF Innovations.

Information provided in this manual is intended to be accurate and reliable. However, RF Innovations assumes no responsibility for its use or infringements upon the rights of third parties that may result from its use.

FCC NOTIFICATIONS

This device must be operated as supplied by RF Innovations. Any changes or modifications made to the device without the express written approval of RF Innovations may void the user's authority to operate the device.

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: 1) this device may not cause harmful interference and 2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Reference No. MAN0005
Revision 3.6
August 2004

Contents

1. Introduction

The RFI-9256 is a frequency-hopping spread spectrum (FHSS) radio modem operating in the international 900MHz ISM band. It has been type approved for operation in Australia (915-928MHz), New Zealand (921-929MHz), and countries regulated by the FCC (902-928MHz).

The RFI-9256 is suitable for many applications including point-to-point, point-to-multipoint, and SCADA protocol networks.

1.1 OEM Applications

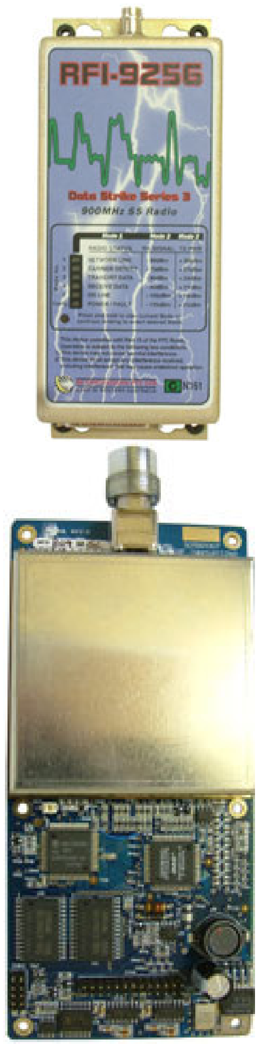
An RFI-9256 OEM module is available for OEM applications.

When used in modular applications, the device where the module is fitted will be required to display on the outside and in a clearly visible area the notice: “Contains FCC ID: P5M9256OEM”

Under FCC regulations, use of certain antennas may require a Class II permissive change from the FCC. Please contact RF Innovations for more information.

1.2 Product Overview

- CRC error detection and recovery via retries
- Up to 30km point-to-point
- Dual RS-232 serial ports
- User selectable interface speeds between 110 and 115200bps
- 1 W (30dBm) RF output power
- Programmable I/O for SCADA applications
- Front panel indicators for RSSI, TX power, and status
- Can be installed and commissioned without test equipment.
- Sensitivity <-108dBm for BER 1 part in 10-4
- Operating voltage 9 to 30VDC
- Operates at -10ºC to +60ºC with 95% non-condensing humidity
- Protocol routing modes.



2. Installation

2.1 Radio Frequency Hazard Information

The product described in this manual has been tested to comply with Maximum Permissible Exposure (MPE) limits.

When operated with the supplied antenna and at maximum transmit power [1], the antenna should not be located within 20cm of where people may come in contact.

Antennas of this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

2.2 RFI-9256 Location

There are a number of rules to observe when installing your RFI-9256.

- Placement of the RFI-9256 unit is likely to have a significant impact on its performance. The higher the placement of the antenna, the better the communication link.
- Antennas should be placed away from walls and poles as these will affect the radiated pattern and VSWR.
- Antennas in close proximity are potential sources of mutual interference. It is possible that slight adjustments in antenna placement (as little as 1 meter in either vertically or horizontally) may solve interference problems.
- The radio should be placed away from computers, telephones, answering machines and other similar equipment.
- Long RS-232 cable runs (greater than 10 meters) should be avoided in areas with frequent lightning activity or static electricity build-up. Nearby lightning strikes or elevated levels of static electricity may lead to voltage spikes on the RS-232 circuits with potential failure of the interface. RF Innovations supplies a range of external data interface converters for applications requiring long cable runs.

2.3 Antenna Installation

Use extreme caution when installing antennas and follow all instructions provided.

Any antennas placed outdoors must be properly grounded. The use of external antennas subjects the transceiver to greater exposure to direct lightning strikes.

RF Innovations recommends use of lightning surge arrestors to protect all antennas and attached equipment against lighting strike.

[1] Transmit power set to 1W (+30dBm) and antenna gain 3dBd (5.15dBi).

3. Configuration

3.1 User Interfaces

The RFI-9256 provides three user interfaces that allow the radio to be configured for a diverse range of applications.

1. **Terminal menu interface.** A menu system is available over either of the RFI-9256's serial ports. This menu interface can be accessed through a terminal emulation program, such as RFI InTerm.

2. **AT command interface.** The AT command interface is used to configure and control to the RFI-9256 through ASCII Hayes attention commands. This can be used to adjust the radio's configuration, read the radio's configuration, and read performance parameters.

3. **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, transmit power, temperature, and main serial port status.

3.2 Terminal Menu Interface

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

1. Execute the `AT?` command at the Hayes AT command interface. See section 3.3 information on executing AT commands.

2. Dial a remote radio's menu system using AT commands. See section 4.3.3 for more information on connected to remote radios via AT commands. When a menu system is accessed remotely its functionality is limited in order to prevent a configuration change that would break the connection.

3. Select mode 6 on the front panel interface. See section 3.4 for information on selecting front panel modes.

The terminal menu has the following features:

- The terminal menu can be password protected to prevent unauthorised users for reading or changing the radio configuration.

- If a terminal menu is enabled, but there is no input for a configurable period of time, then the terminal menu will disable itself. By default the terminal menu is disabled after 15 minutes.

- Only 1 terminal menu can be available at any one time. This is done to prevent multiple users from changing the configuration of a single radio at the same time.

The full terminal menu reference is provided in Appendix B.

3.3 Hayes AT Command Interface

The RFI-9256 supports many Hayes compatible commands enabling the user to fully control and operate the radio, and in most cases emulate public switch telephone network (PSTN) modems.

Hayes commands may be entered manually through a terminal or automatically through dial-up network applications and scripts. Most commands, with exception of the '%' register and connection commands, may be concatenated into a single command string. Commands or command strings must be terminated with a carriage return (ASCII 13_D, produced by the enter key).

3.3.1 The AT Commands

THE ATTENTION CODE

The attention commands are a group of commands recognised by the radio. All attention commands are prefixed by the letters AT, and are referred to as AT commands. For example, the command:

```
ATI3<CR>
```

Causes the radio to return its firmware version information:

```
Firmware: 9256 Version 1.30 Rev.D Australia

OK
```

The attention code, along with all AT commands, is case insensitive.

MULTIPLE COMMANDS

Multiple commands can be placed after an `AT` provided that the total number of characters does not exceed 255. For example, a valid command to display the radio's firmware version information and internal temperature is:

```
ATI3I9<CR>
```

This results in the output:

```
Firmware: 9256 Version 1.30 Rev.D Australia

25.5c

OK
```

S-REGISTER AND %-REGISTER COMMANDS

S-registers and %-registers are used to store complex configuration parameters. In order to set the value of an s-register or %-register the following format is used:

```
ATS<r>=<n><CR>
```

```
AT%<r>=<n><CR>
```

Where `<r>` is the register, and `<n>` is the data. The current value of an s-register or %-register can be retrieved through a command of the form:

```
ATS<r><CR>
```

```
AT%<r><CR>
```

A list of all s-registers can be found in Appendix C.2, while all %-registers are listed in Appendix C.3.

RESPONSE CODES

Whenever an AT command is executed a response code is generated. Response codes can be either strings, numbers, or be suppressed (not output to the user). The list of response codes generated by the RFI-9256 is shown in Table 1.

Response String	Response Number	Description
`OK`	0	The command executed successfully.
`CONNECT`	1	A connection has been established between this radio and another radio.
`RING`	2	Another radio is ringing this radio and attempting to establish a connection.
`NO CARRIER`	3	A connection could not be established or it has been dropped.
`ERROR`	4	A command was formatted incorrectly.
`BUSY`	7	An attempt was made to dial a remote unit and it responded with a busy signal.
`NO ANSWER`	8	An attempt was made to dial a remote unit but it could not be contacted

Table 1: AT response codes generated by the RFI-9256

3.3.2 Configuring the Radio

The radio uses s-registers to alter the configuration profile. Each s-register contains a decimal value, an ASCII character or an ASCII string. The interpretation of each value differs with each s-register.

The radio allows the contents of the s-registers to be saved to non-volatile memory using the `AT&W` command. The entire configuration profile will be retained after the radio has been powered off.

The radio also has factory default settings stored internally, allowing all communication settings and s-register values to be set to the factory default configuration. The factory defaults have been selected so most users will be able to make immediate use of their radio, with minimum changes. The default settings are listed in Appendix D.

Factory defaults can be restored using the `AT&F` command.

The `AT&V` (view) command outputs the current configuration of the radio.

The complete AT command reference is provided in Appendix C, while the use of Hayes AT commands to establish dial-up networking connections is discussed in section 4.3.3.

3.4 Front Panel Interface

The front panel interface allows for real-time monitoring of radio parameters without requiring any external equipment. The front panel can also be used to enable the menu on the RFI-9256's auxiliary port regardless of the current serial port configuration. The front panel is shown in Figure 1.

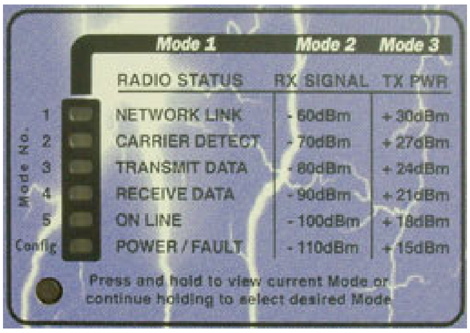


Figure 1: RFI-9256 front panel

There are six front panel modes. In order to select a front panel mode press the front panel button. This will display the current panel mode by highlighting a single LED red. In order to select another front panel mode, continue to hold the button until the LED scrolls down to the appropriate LED before releasing. The list of LED modes is shown in Table 2.

LED	Mode	Function
1 (top)	Radio Status	Section 3.4.1 describes the functionality of the LEDs when in radio status mode.
2	RSSI	Provides a bar displays of the average received single strength indication (RSSI) for this radio. Table 3 shows the level for each bar item.
3	Tx Power	Provides a bar display of the transmit power for the radio. Table 3 shows the level for each bar item.
4	Temperature	Provides a bar display of the current internal temperature. Table 3 shows the level for each bar item.
5	Main Serial Port	Shows the main serial port status. The meaning of each individual LED is shown in Table 4.
6 (bottom)	Configuration	When mode 6 is selected, the terminal menu will be enabled on the auxiliary port at 19200, 8N1, with no flow control. Once configuration mode is selected and the terminal menu enabled, the front panel displays the same settings as for radio status mode.

Table 2: Front panel modes

Front panel modes 2, 3, and 4 all display a bar graph to indicate the level of RSSI, transmit power, and temperature respectively. The top LED that is lit indicates the current value, if the LED is lit green then the value shown in Table 3 applies, while if the LED is lit red then the current value is half way between the listed value in Table 3 and the previous value.

LED	RSSI	Tx Power	Temperature
0	-60dBm	+30dBm	60ºC
1	-70dBm	+27dBm	50ºC
2	-80dBm	+24dBm	40ºC
3	-90dBm	+21dBm	30ºC
4	-100dBm	+18dBm	20ºC
5	-110dBm	+15dBm	10ºC

Table 3: RSSI, Tx Power, and Temperature displays

LED	Name	Function
0	DTR	The current state of the DTR input on the main port. Red indicates +12V, while green indicates -12V.
1	DCD	The current state of the DCD output on the main port. Red indicates +12V, while green indicates -12V.
2	TX	Flashes while RS-232 data is transmitted by the radio on the main serial port.
3	RX	Flashes while RS-232 data is being received by the radio on the main serial port.
4	RTS	The current state of the RTS input on the main port. Red indicates +12V, while green indicates -12V.
5	CTS	The current state of the CTS output on the main port.. Red indicates +12V, while green indicates -12V.

Table 4: Main serial port LED function

3.4.1 Radio Status LEDs

NETWORK LINK

When network link is green it shows that the unit can hear a remote radio that is on the same network and hopping pattern. Slave radios should show network link constantly, as master radios are constantly transmitting network synchronization messages. Master radios will only show network link when connected to a slave in point-to-point, Hayes dial-up mode, or when receiving user data.

In a radio network with a strong signal (better than -90dBm), network link should be predominately green, it may go red from time to time, but should not go off. A red network link indicator means that the radio has temporarily lost the remote unit. This should occur infrequently.

CARRIER DETECT

When carrier detect is green it shows that the unit can hear a remote radio. Slave radios in a network should always show carrier detect, as master radio radios are constantly transmitting a synchronization signal. Master radios however will only show this LED when connected to a slave in point-to-point or Hayes dial-up mode, or when receiving user data. Generally it can be assumed that if a slave can hear its master then the master can also hear its slave.

In a good radio network carrier detect should be predominately green with flashes of red. A flash of red indicated that one RF packet has been lost. It is acceptable, and expected, that some RF packets will be lost as the RFI-9256 operates in an industrial, scientific, and military band (ISM) where there is a potential for interference from other radios. A red flash of carrier detect does not mean user data has been discarded, as the RFI-9256 will retry any packet that is lost or corrupted during transmission.

TRANSMIT DATA

Transmit data indicates that data is being pushed out of the radio serial port; the colour of the LED does not matter. The LED indicates that data has been received from a remote radio and transmitted out of either the main or auxiliary serial port. If the LED is lighting up, but the end unit is not receiving data it could indicate a damaged/broken serial cable, latency issues with the protocol of the end device, or incorrect serial port configuration.

The transmit data LED will also flash when local Hayes commands are issued or the terminal menu is being used.

RECEIVE DATA

Receive data indicates that data is being pushed into the radio serial port; the colour of the LED does not matter. The LED indicates that data has been received from the end unit on either the main or auxiliary serial port and sent through to the remote radio. If the remote radio is not receiving the RF data, given there is a sufficient RF path (as indicated by the carrier detect and network link LEDs), there may be a problem with the radio addressing or protocol routing in the radio set-up.

The transmit data LED will also flash when local Hayes commands are issued or the terminal menu is being used.

ONLINE

When the online LED is green it shows that a packet has been received from a remote unit. The Online LED will remain green while two units are connected in point-to-point mode or Hayes dialup mode. It is not expected that the online LED will flash red in mode 1, a red Online LED indicates that there is something wrong with the RF link, including mismatched frame time, directional bias settings, or a poor signal path.

POWER / FAULT

The power/fault LED indicates whether there is something seriously wrong with the radio configuration. In normal operation the power/fault LED will flash green. When the Power LED flashes red there is most likely something wrong with the serial configuration between the radio and the end device. The red LED can also indicate an internal fault in the radio; the diagnostics fault log menu can provide more information. There are two possibilities for the power/fault LED flashing red.

- **The firmware image has become corrupted.** If this is the case and the diagnostics status menu can be reached, then it will display the message "Firmware CRC mismatch."

- **A framing, parity, overrun, or overflow occurs on either serial port.** In this case the error is latched for 500ms before being cleared.

4. Operation

4.1 Serial Port Operation

The RFI-9256 radio has two data communications equipment (DCE) RS-232 serial ports provided on a single DB25 connector. The DB25 pin out can be found in Appendix A.

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 main and auxiliary serial ports have internal 4096 byte buffers on both transmit and receive interfaces. This configuration is shown in Figure 2.

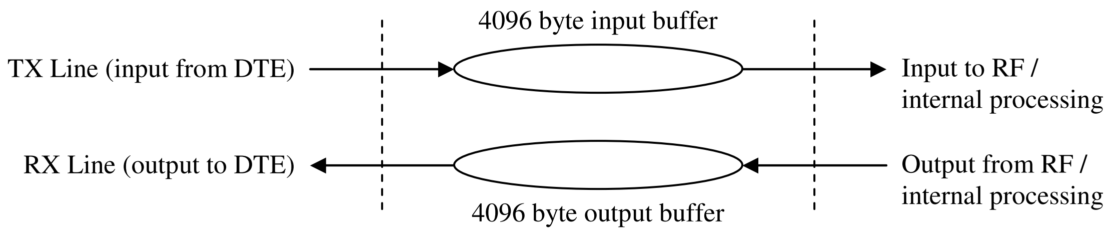


Figure 2: Buffering scheme on the RFI-9256

This serial port buffering scheme has a number of ramifications on the RFI-9256 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 RFI-9256 can buffer that data until the DTE is ready to accept the data.

4.1.1 Configuration

Both main and auxiliary serial ports support the configuration settings shown in Table 5.

Setting	Possible Values	Default
Baud	110, 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	19200
Data bits	7, 8	8
Parity	None, Odd, Even	None
Stop bits	1, 2	1

Table 5: Serial port configuration

4.1.2 Control Lines and Flow Control

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 there its input buffer is less than the high water mark (defaults to three quarters full), and drop the CTS line when its input buffer is greater than or equal to the high water mark.

The flow control high water mark can be configured by the user.

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

- **ONLINE controls CTS/DCD**: The line is active when the front panel online LED is green or red, and is off when the front panel online LED is black.
- **NEWTORK LINK controls CTS/DCD**: The line is active when the front panel network link LED is green or red, and is inactive when the front panel online LED is black.
- **CARRIER DETECT controls CTS/DCD**: The line is active when the front panel carrier detect LED is green or red, and is inactive when the front panel online LED is black.
- **Remote DTR controls CTS/DCD**: The line is active when a remote radio’s DTR input line is active in point-to-point or Hayes dial-up mode.
- **Local DTR controls CTS/DCD**: The line is active when the local radio’s DTR input line is active.
- **Remote RTS controls CTS/DCD**: The line is active when a remote radio’s RTS input line is active in point-to-point or Hayes dial-up mode.
- **Local RTS controls CTS/DCD**: The line is active when the local radio’s RTS input line is active.
- **CTS/DCD Always ON**: The line is always active.
- **CTS/DCD Always OFF**: The line is always inactive.

- **CTS/DCD disabled**: The line control has been disabled.

Note that when hardware flow control is enabled, the CTS line configuration is ignored.

4.1.3 Statistics

Each serial port has associated with it a set of statistics that can be used to debug RFI-9256 applications. The serial port statistics are described in Table 6.

Name	Description
Rx Bytes	The total number of bytes that have been received.
Rx Errors	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	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	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. This error should never occur.
Rx Framing	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.
Tx Bytes	The total number of bytes that have been transmitted.
Tx Errors	The total number of errors that have occurred while transmitting. This is equal to the Tx Overflows count.
Tx Overflows	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 6: Serial port statistics

These statistics can be used to isolate a number of potential problems in an RFI-9256 system.

- A large number of rx framing errors indicates that the radio serial port configuration (baud, data bits, parity, and stop bits) is not configured to match the serial port configuration of the DTE.

- A large number of rx overflow errors indicates that the DTE is supplying data faster than it can be transferred over the air. This can usually be corrected by enabling flow control. If flow control is already enabled on the radio then it may not be operating correctly on the DTE.

- A large number of tx overflow errors indicates that data is arriving over the air faster than the DTE can retrieve it from the radio,.

4.2 Radio Operation

4.2.1 Overview of Operation

The RFI-9256 is a time division duplex / frequency division duplex (TDD/FDD) frequency hopping spread spectrum (FHSS) radio. The RFI-9256 divides its transmission up into frames, where each frame contains communication between two radios on a fixed channel and lasts for a fixed period of time.

The RFI-9256 is a master / slave based system. In any one radio network there is a single master and multiple slaves. The master may send messages to any slave, but the slaves may only send messages to the master. It is the responsibility of the master to synchronise all the slaves, and to allocate time for slaves to transmit.

The framing arrangement is shown in Figure 3.

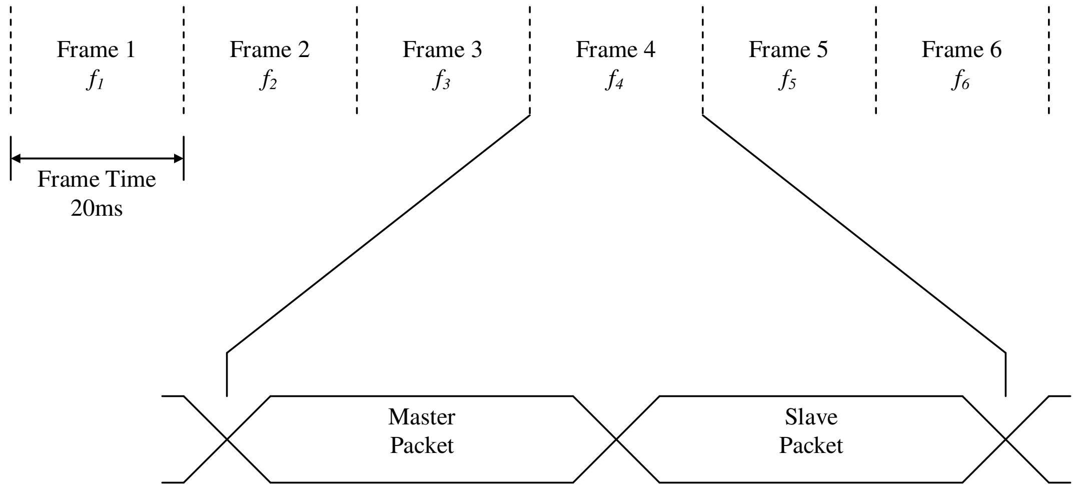


Figure 3: RFI-9256 time division duplex / frequency division duplex (TDD/FDD) operation

Each frame occurs on a different frequency and lasts for a fixed period of time, 20ms in the above diagram. This is referred to as the channel dwell time or the frame time. The RFI-9256 supports configurable frame times between 8 and 35ms. The selection of frequencies is based on a pseudo-random hopping sequence, with 32 user selectable hopping sequences.

Each frame can be used to transmit up to two packets, the master packet and the slave packet. In the master packet the master sends control data, followed by user payload that is destined for either one slave, or broadcast to all slaves. In the slave packet a slave will transmit control data followed by a user payload destined for the master.

DATA PATH

Internally, the RFI-9256 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, an overall picture of the data path in the RFI-9256 radio can be obtained. This is shown for a master unit in Figure 4.

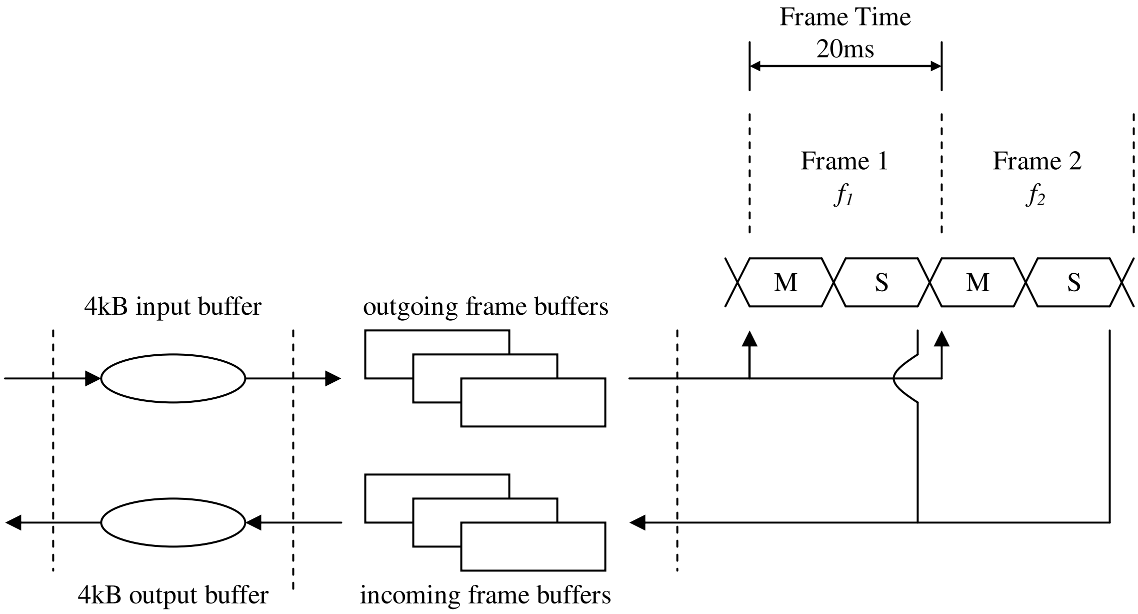


Figure 4: Overall data path in the RFI-9256 radio

Due to the framing structure over the air, and the data path shown above, the RFI-9256 cannot be regarded as a direct wire replacement. It will induce additional latency into the communications link, as well as potentially causing changes in the timing between bytes (inter-character delay).

LATENCY

The RFI-9256 will introduce latency into the system. This latency is caused by the following factors:

- **Serialisation delays.** Serialisation delays are caused by 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 for a single serial port in ms

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 9,600 baud, 8N1 the serialisation delay is around 1ms per serial port.

- **Framing delays.** Framing delays will occur depending on where data arrives relative to the start of a frame. Consider the situation in Figure 5.

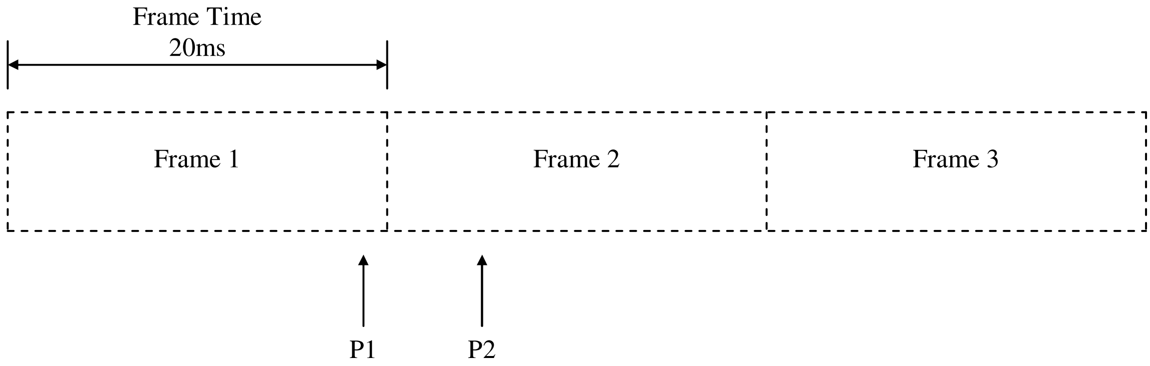


Figure 5: Data arriving at different times relative to the start of frame

The data arriving at P1 would be transmitted almost immediately in frame 2, while the data arriving at P2 will have to wait until the start of the next frame. In the worst case, the amount of latency introduced will be equal to the frame time.

- **Link quality.** The quality of a link can have a substantial impact on the latency induced by the radio. The RFI-9256 will retry frames that become corrupted due to RF interference, configurable between 0 and 50 retries. The more retries that are required to get a packet through the greater the latency induced. Each retry adds an additional frame time to the latency induced by the radio.

DATA TIMING

The RFI-9256 will change the inter-character and inter-packet timing of data that it transmits as all data received by the RFI-9256 is framed for transmission over the air. Consider the situation shown in Figure 6.

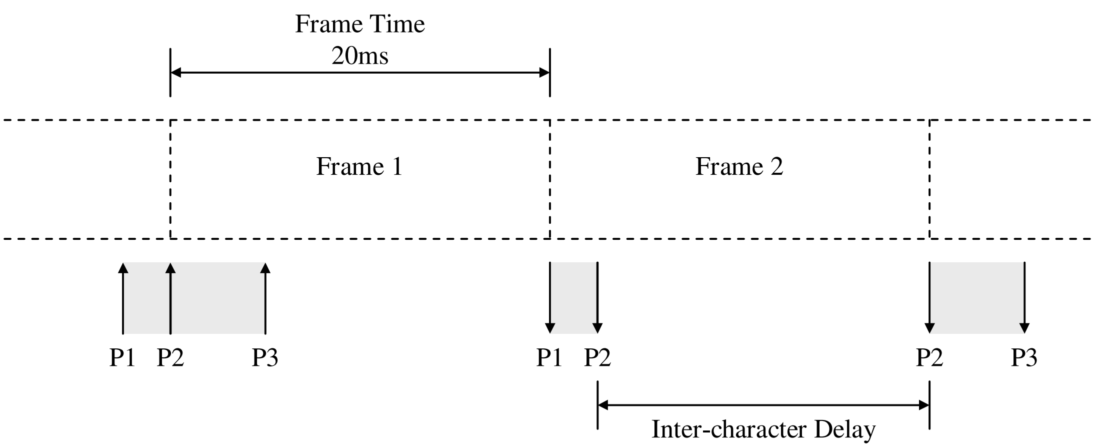


Figure 6: Data timing variation due to framing

Data between P1 and P2 arrives before the start of Frame 1. This is then transmitted over the air, and is output at the end of Frame 1. The data between P2 and P3 had to wait for frame 2 to be transmitted, so now there is an artificial gap introduced between the bytes before P2 and after P2.

This problem can be exaggerated by additional retries occurring for frame 1 or frame 2.

In order to counteract this problem, packetisation timers, described in the section Time Based Packetisation of Data on page 24.

4.2.2 Radio Parameters

ADDRESSING

Each radio in a RFI-9256 network has a local address. The local address is a decimal number between 1 and 9999.

When allocating addresses on an RFI-9256 network, the convention is to allocate the address 1000-9999 to the master and slaves, while reserving the addresses 10-99 to be allocated to any back-to-back repeaters. In general, addresses 1-9 are not used. The reason for this is explained in the section Back-to-back Repeater Operation on page 23.

NETWORK FAIL TIMER

When power is first applied to a slave, it enters the unlocked state. In the unlocked state the slave has not heard a master unit, and waits on a single channel listening for a master to hop past. When the master hops past, the slave will start hopping with the master.

If the master loses power, or becomes unreachable, then the slave will continue to hop over the channels, searching for the master. If after the network fail timer period expires the slave has failed to hear from its master it reverts to the unlocked state.

TRANSMIT POWER

The transmit power of the RFI-9256 can be configured at fixed intervals 0dBm, +10dBm, +20dBm, +25dBm, and +30dBm.

When operating in the 900MHz ISM band, the maximum allowed output power at the antenna is 1 Watt effective isotropic radiated power (EIRP). This translates to +30dBm. Noting that cables will introduce loss, and the antenna may introduce gain, the transmit power of the RFI-9256 should be adjusted so that the power at the antenna is as close to +30dBm as possible.

RSSI TRIP LEVEL

The RFI-9256 supports a configurable RSSI trip level, or squelch. The RSSI trip level sets the lowest RSSI that the RFI-9256 is to attempt to acquire data. When the radio has to operate in a very noisy environment, where the background noise has risen above its sensitivity (-108 dBm), the RSSI trip level will need to be set higher than the default to allow the radios to communicate.

When operating in a normal environment the RSSI trip level should be set below the radio's sensitivity otherwise the radio will be artificially deafened.

FRAME TIME

The frame time is the amount of time that the RFI-9256 will spend on each channel in the hopping pattern. This is also referred to as the channel dwell time. The frame time can be adjusted to suite a particular application. The set of values are shown in Table 7.

Frame Time	Bytes per Packet	Throughput (One Way)	Throughput (Total)
5ms	5	8kbps	16kbps
8ms	26	26kbps	52kbps
10ms	41	32kbps	64kbps
15ms	77	41kbps	82kbps
20ms	113	45kbps	90kbps
25ms	149	48kbps	96kbps
30ms	185	49kbps	98kbps
35ms	221	51kbps	102kbps

Table 7: Frame time configuration

Selection of frame time will trade off maximum throughput against latency. A low frame time will decrease both latency and throughput, while a high frame time will increase both latency and throughput. This is discussed in the section Latency Reduction on page 24.

DIRECTIONAL BIAS

A single frame on the RFI-9256 contains two packets, one from the master and one from the slave. In the default configuration the size of both packets is the same, so the system is unbiased. In many systems data will flow in one direction substantially more than in the other direction. When this is the case the RFI-9256 can be configured to bias its frames so that the master packet and slave packet are of different lengths.

In order to configure a link for directional bias, one radio must be set to the outgoing radio, and one to the incoming radio. The link from the outgoing radio to the incoming radio has more bandwidth, while the link from the incoming radio to the outgoing radio has its bandwidth reduced.

Table 8 shows the different settings that can be obtained through directional bias.

Frame Time	Outgoing Bytes per Packet	Incoming Bytes per Packet	Outgoing Throughput	Incoming Throughput
5ms	5	5	8kbps	8kbps
8ms	26	26	26kbps	26kbps
10ms	55	27	44kbps	22kbps
15ms	125	28	67kbps	15kbps
20ms	197	28	79kbps	11kbps

25ms	269	28	86kbps	9kbps
30ms	338	31	90kbps	8kbps
35ms	410	31	93kbps	7kbps

Table 8: Directional bias configuration for different frame times

RETRIES

The maximum number of retries per frame can be configured between 0 to 255. When a low number of retries is selected, the link may become unreliable in the presence of interference. When a high number of retries is selected the link will be reliable, however it may induce substantial latency in the presence of interference.

If an RFI-9256 is given data to transmit to a slave that is non-existent, either due to a misconfigured destination address, the slave being out of range, or the slave unit being faulty, then it will transmit each frame the maximum number of retries. This can dramatically slow down the throughput of a radio network.

The RFI-9256 also supports exponential back-off and retry. This mechanism is intended for a situation where there are multiple slaves that may have data to transmit at the same time. If these slaves are configured with exponential back-off and retry mode enabled, collisions will have a minimal impact on system performance.

SYNCHRONISATION

When two or more RFI-9256 are located in very close proximity, such as when they are in a back-to-back repeater configuration, the transmitter from one can interfere with the receiver of the other even though they are on different channels, simply due to the large amount of power that is being radiated.

In order to prevent this from happening it is desirable to synchronise the radios so that they will transmit at the same time. Only master units can be synchronised in this way, as slave units must obtain their synchronisation from the network master.

The frame synchronisation is a TTL I/O on the DB25 connector described in Appendix A.3.

Each RFI-9256 can be configured with one of the following synchronisation options:

- **No Sync Mode**: Disables synchronisation.
- **Output Sync Signal**: The radio will output a frame synchronisation signal. This is a falling edge on the TTL output every time a new frame starts.
- **Follow Sync Signal**: The master radio will follow the synchronisation signal output by another unit. This causes the master radio to adjust the start of its frame to match the falling edge detected on the synchronisation TTL input. This mode should be used when a master is following another collocated master.
- **Repeater Sync Mode**: The master radio will follow the synchronisation signal output by another unit. This causes the master radio to adjust the start of its frame to be 50% offset from the falling

edge detected on the synchronisation TTL input. This mode should be used when a master is following a collocated slave, such as when they are in back-to-back repeater configuration.

Synchronisation does not operate correctly when directional bias has been enabled on either unit.

MASTER / SLAVE CONFIGURATION

A network of RFI-9256 radio radios will consist of one master, and one or more slaves. Multiple co-located masters are supported in the RFI-9256 system through three mechanisms:

- **Hopping Pattern.** Each master unit has a unique hopping pattern. The hopping pattern determines the order that the master hops over all available channels. There are 32 available hopping patterns, and these have been selected so as to cause minimum interference between co-located masters.

- **Network Address.** The network address is a number between 0 and 63 that defines the network to which the master belongs. The network address provides a second layer of differentiation between multiple masters.

- **Security Code.** Each RFI-9256 can be programmed with a 32-bit security code. A slave will only be able to communicate with a master if both units have the same security code.

The master and all the slaves in a single network must be configured with the same values for hopping pattern, network address, and security code.

BACK-TO-BACK REPEATER OPERATION

The RFI-9256 supports network extension through the use of a back-to-back repeater. A back-to-back repeater consists of two RFI-9256 radio radios. This is shown in Figure 7.

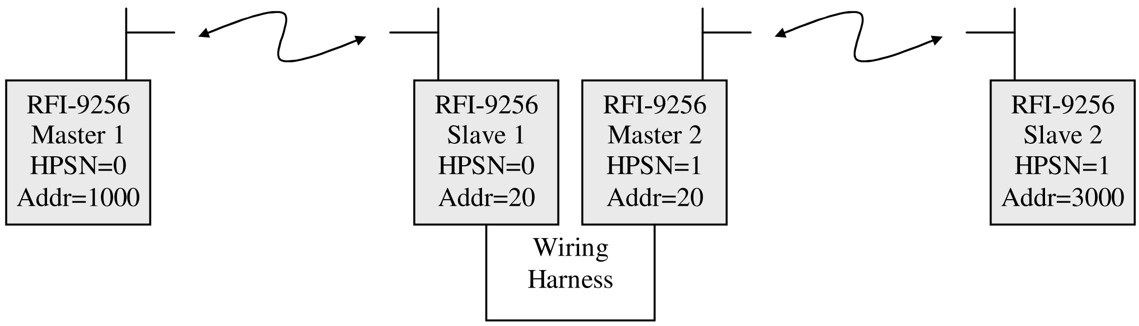


Figure 7: Back-to-back repeater configuration

A back-to-back repeater configuration is the joining two separate RFI-9256 networks via a wiring harness between a slave on one network and the master of a second network. The wiring harness can link the main port, auxiliary port, or both ports via a null-modem cable. A wiring diagram for a back-to-back repeater cable that links both main, auxiliary, and the auxiliary I/O lines is given in Appendix A.4.

When setting up back-to-back repeaters, the following rules should be followed:

- Both master and slave radio must have the same local address, and it must be in the range 10-99 (i.e., two characters).

- All other radios in the network must have local addresses in the range 1000-9999.

These rules come about due to the way Hayes dial-up works in a back-to-back repeater network. See section 4.3.3 for more information on Hayes dial-up networking.

Back-to-back repeaters should be synchronised, as discussed in the section Synchronisation on page 22, in order to prevent them from jamming each other due to collocated antennas.

- The slave must be configured to output a synchronisation signal.

- The master must be configured to follow a repeater synchronisation signal.

This guarantees that both master and slave will transmit at the same time.

4.2.3 Performance Tuning

LATENCY REDUCTION

Some systems will require a radio link that induces very low latency, usually where the RFI-9256 is being used to replace an existing wired system. There are a number of parameters that can be traded off in order to reduce latency.

- **Throughput.** The throughput of the RFI-9256 can be reduced, with a corresponding reduction in latency. This is achieved by reducing the frame time as the frame time has a direct impact on latency. A smaller frame time will give lower latency. See section Latency on page 18 for a discussion on why this is the case.

- **Reliability.** By reducing the maximum number of retries the latency performance of the RFI-9256 can be improved in harsh RF environments. Given that each retry will add an extra frame time to the latency induced by the radio, calculate the maximum acceptable latency induced by retries, and divide by the frame time to give the maximum retries that should be configured. Note that by reducing the maximum number of retries, data may be lost so the underlying system should be robust enough to handle this situation.

TIME BASED PACKETISATION OF DATA

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 TDD nature of the RFI-9256, simply passing this data into the radio can cause it to become disrupted as there is no guarantee that timing will be maintained over the air link (see section Data Timing on page 19). In order to correct this problem, two configuration items should be used.

- Set the RX packetisation timer to the number of milliseconds that will appear between each packet.

- Set the frame time to the smallest number that will provide enough bytes in a single frame for the largest protocol message.

The packetisation time is used to detect the end of each packet. Only once the end of the packet has been detected will the RFI-9256 transmit any of the packet.

The frame time must be configured to allow a full packet in a single frame, as if the frame time is too small then the packet will be split across multiple frames and inter-character delay could occur due to retries.

When packets are larger than the maximum frame time, yet must still be kept together the TX packetisation timer can be used. This timer operates in the same way as the RX packetisation timer, except that it will attempt to bunch received data frames together. When the TX packetisation timer is enabled the radio will not transmit data out of its serial port until an amount of time equal to the packetisation timer has passed with it receiving no data over the air.

4.2.4 Diagnostics

RSSI AND NOISE

The RFI-9256 can report the RSSI and noise detected on each individual channel in the 900MHz ISM band. This is accessed through the diagnostics menu (Appendix B.6).

There are two factors to be aware of when using the RSSI / Noise report of the RFI-9256.

1. The master is transmitting all the time, while slaves only transmit when they have data or a connection has been established to them. Thus, a slave will always be able to report the RSSI of the master, while the master can only report slave RSSI when communications is occurring.

2. Each individual slave can only hear the master unit, while the master can hear all the slaves. This means that when a master is communicating with multiple slaves there is no guarantee which slave the RSSI value refers two, in fact it is most likely to be an average of all slaves. In order to counteract this effect a special link margin test is provided on the master unit. The link margin test will take control of the communications link and determine the exact RSSI that the master is receiving from a particular slave. This is covered in Appendix B.6.

RF COMMUNICATIONS STATISTICS

The RFI-9256 provides a number of communications statistics that can be used to debug a RFI-9256 system. These parameters are shown in Table 9.

Statistic	Description
Frame count	The total number of frames that have passed while the radio has been operating.
Empty frames	The number of frames that have been received but contained no user data.
Good packets	The number of good packets received.

Bad packets	The number of bad packets received.
Lost packets	The number of packets that have been lost.
Retries	The number of retries this unit has used while transmitting.
Good headers	The number of good header packets received. Header packets contain synchronisation and control information.
Bad headers	The number of bad header packets received.
Lost frame lock	The number of times this unit has lost lock. A loss of lock occurs on a slave when it can no longer hear the synchronisation messages from the master.
Low RSSI	The number of times the RSSI level has been at or below the nominal sensitivity of the radio while receiving.
Data Recv	The number of user data bytes received.
Data Sent	The number of user data bytes transmitted.
Rx Overflows	The number of times received data has been discarded due to there be no free frame buffers.
Rx Overruns	The number of times data has been lost due to internal radio errors.
Tx Overflows	The number of times an attempt has been made to obtain a frame buffer for transmission, and there have been no free frame buffers.
Busy Waits	The number of times the slave radio has had data to transmit, but has been unable to do so due to communications between the master unit and another slave radio.

Table 9: RF communications statistics

4.3 Protocol Operation

The protocol mode of a serial port determines how the serial port data is interpreted and converted into packets for transmission over the air. There are four basic protocol modes:

- **Point-to-point Protocol**: Communications occurs between two radios only.
- **Broadcast Protocol**: Communications occurs between the master and any number of slaves, and any slave back to the master. Data is broadcast from the master to all slaves, while the slave only transmits data directly back to the master.
- **Hayes Dial-up Protocol**: Communications occurs between a master and any number of slaves one at a time, where Hayes dialling commands are used to create and destroy connections.
- **SCADA Protocols**: Communications occurs using SCADA communications protocols such as Modbus, Honeywell, DNP3, or TDE.

All protocol modes support back-to-back repeaters for extending network coverage.

4.3.1 Point-to-point Protocol

A point-to-point network establishes a link between two radio radios, through an optional number of repeaters. A point-to-point connection can be established on the main, auxiliary, or both serial ports.

A single master unit and a single slave unit are configured such that:

- The have the same hopping pattern, network address, and security code.
- The master and slave have different local addresses.
- Both the master and slave have the point-to-point protocol selected on their main serial port.
- The point-to-point destination address on the slave is set to the master's local address, while the point-to-point destination address on the master is set to the slave's local address.

This results in a connection being established between the two units. The online LED should turn green on both units, and data transmitted by the DTE on the master be received on the DTE on the slave, and vice versa.

4.3.2 Broadcast Protocol

In a point-to-multipoint broadcast network, data transmitted by the master unit is output by all the slaves, while data transmitted by each slave is only output by the master.

When using point-to-multipoint broadcast mode, there are no acknowledgments on the master to slave transactions. This is because multiple slaves 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, the master will transmit each message a fixed number of times equal to the maximum retries. For this reason, the number of retries used in a broadcast network should be configured to between 1 and 5 in order to maintain a reasonable throughput.

4.3.3 Hayes Dial-up Protocol

Hayes dial-up networks provide 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 broadcast networks, as it allows dedicated communication between a master and one of many slaves.

CONNECTION MANAGEMENT

DIALLING

The AT commands may be used to initiate dialling of a remote radio. The `ATD` command is use to establish a connection. The form 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 10.

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,
91	Virtual Hayes	Establishes a connection between the current serial port and the Hayes command interface running on the remote unit.
92	Remote Menu	Establishes a connection between the current serial port and the menu of the remote unit. When connection to a menu system remotely, the radio configuration menu (Appendix B.1) will not be available. This is done to prevent configuration changes that could sever the connection to the remote radio.
93	Remote Logger	Establishes a connection between the current serial port and the logs of the remote unit.
99	Loop-back	Establishes a connection that loops back all data that is transmitted to the remote unit.

Table 10: Hayes dial-up extension numbers

The <address> and <extension> sections of the ATD command can include any number of colons, dashes, or spaces as these will be stripped out of the string by the radio.

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

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

ANSWERING

The RFI-9256 provides two options for answering dial-up calls:

- **Auto-answer**. When in auto answer mode and a connection request is made the RFI-9256 will output a configurable number of `RING` responses on the destination radio and extension, and then automatically connected. When dialling an extension other then the main or auxiliary port, auto-answer is used by default.

- **Manual answer**. When in manual answer mode the RFI-9256 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 within the connect timeout the connection is not established.

Manual answering of dial-up requests only applies to the main and auxiliary ports. The internal extension numbers for the virtual Hayes, remote menu, remote logger, and loop-back services will always answer automatically.

ESCAPE SEQUENCE

When there is no communications link established to a remote radio, and AT commands are issued locally then the radio is in local command state.

When a connection is established to a remote radio, all communications occurs between the DTE's connected to the ports on the two radios. This is known as online state. Once a radio enters online state, it assumes all the data sent to it is to be sent on to the remote radio, so it ignores all AT commands.

Unlike the other commands, there is no AT prefixing the escape sequence, and no carriage return after the escape sequence. Instead, wait a full second before entering the three characters (default is '+') typed rapidly, then wait another full second. As soon as the radio returns to local command state, it will respond with the message `OK`.

This delay period before and after the escape sequence is called the escape sequence guard time. This allows the radio to distinguish the escape sequence from the normal flow of user information between radios.

The character used for the escape sequence is set in s-register 2, while the length of the escape guard time is set in s-register 12.

When entering local command state, the connection is not disrupted. In order to return back to online state, the command `ATO` is used.

HANGING UP

The `ATH` command is used to terminate a connection.

After communications has finished enter the escape sequence (+++). The radio responds with an `OK` message. Then execute the `ATH` command and the local radio will respond with `OK`. The remote radio will output `NO CARRIER` as the communications link is lost.

DTR CONTROL OF HAYES STATE

The Data Terminal Ready (DTR) input to the radio can be used to control the Hayes dial-up state.

- **Ignore DTR:** The radio does not use the DTR signal to control its connection state.
- **Hang-up on DTR Low:** The radio will hang-up whenever the DTR line is low. If this option is selected, and DTR is low when a remote radio is dialled then the connection will be terminated the moment after it is established.
- **Hang-up on DTR Dropped:** The radio will hang-up whenever DTR changes from high to low.
- **Local on DTR Low:** Whenever DTR goes low, the radio will enter local command state. This is the same as entering the escape sequence.

DIAL-UP NETWORKING WITH BACK-TO-BACK REPEATERS

A Hayes dial-up network can be extended by one or more back-to-back repeaters. In order to establish a dial-up connection through a back-to-back repeater, an extension to the dialling system is used:

ATD<repeater$_0$><repeater$_1$>...<repeater$_n$><address><extension><CR>

The address of each repeater to dial through is prefixed before the address of the destination radio and extension. Thus to dial the auxiliary port of the radio with address 2200 first through repeater 10 and then through repeater 43 the following dial string would be used:

```
ATD1043220001<CR>
```

In order to access the repeater slave's terminal menu, dial up the menu system as if it were any other slave. In order to access the repeater master's terminal menu dial up the main port of the slave (the port that has been connected through to the master unit), then use the master units AT command interface to bring up the menu system via the `AT?` command.

When using back-to-back repeaters in dial-up networks, there are a number of rules that must be observed:

- The escape character on the repeater master and repeater slave must be set to '-'.
- The escape guard time on the repeater master and repeater slave must be set to 200ms.
- The main port DTR mode on both the repeater master and repeater slave must be set to "Hang-up on DTR dropped".
- The local address of the repeater slave and repeater master must both be the same, and must both be in the range 10-99.
- The local address of all non-repeater units must be in the range 1000-9999.

The DTR line is used in the back-to-back repeater wiring harness in order to propagate Hayes hang-up requests through the network. If this line is not connected there is a possibility that the hang-up request could get lost and the repeater network lock-up, believing there to be an established connection.

For this reason it is not advised to use dial-up networking through back-to-back repeaters on the auxiliary port.

4.3.4 SCADA Protocols

The RFI-9256 supports SCADA protocol networks in two ways:

- Providing a point-to-multipoint broadcast network, where any SCADA packet that is inserted at the master will be delivered to all slaves, and a SCADA packet inserted into any slave is delivered to the master. This was covered in section 4.3.2.
- Providing a point-to-multipoint routing network, where master to slave communications is no longer broadcast. In this case the RFI-9256 will decode each SCADA protocol packet to extract the destination address and match it against a radio address.

Routing services are provided for a number of SCADA protocols, specifically:

- Modbus
- Honeywell
- DNP3

- TDE

PROTOCOL ROUTING

The protocol decoder for the packet based SCADA protocols extracts the destination remote terminal unit (RTU) address from the protocol and maps it to a radio address. This routing scheme is shown in Figure 8.

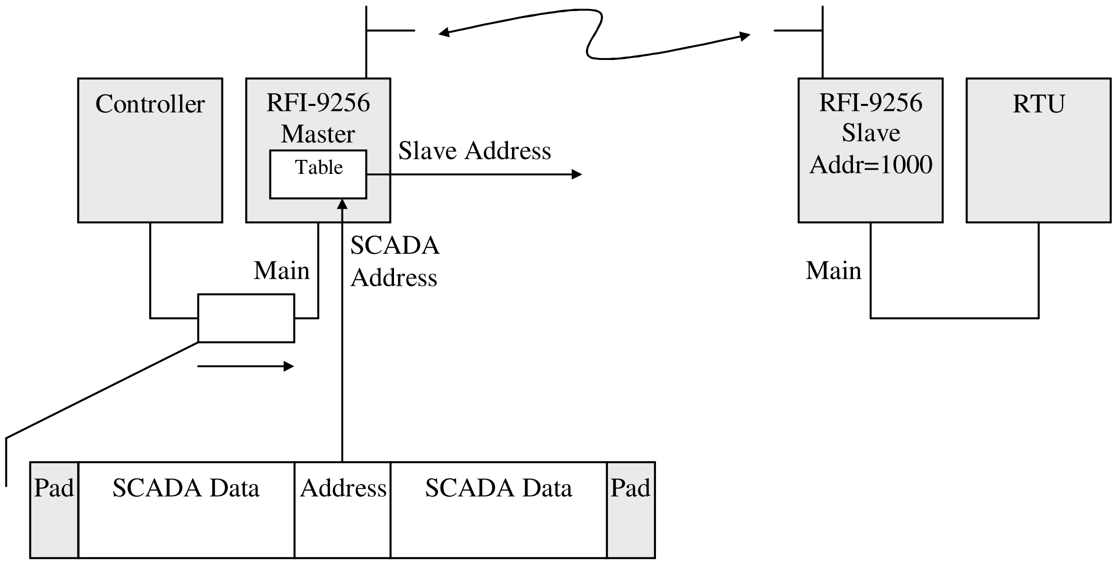


Figure 8: SCADA protocol routing

The SCADA protocol routing table on the RFI-9256 can have four types of entries.

- **Default route.** This route is mostly used by slaves and is a required entry for any slave in a protocol network. This route only requires the address of the destination radio. This route is used when no other route can be matched in the routing table. On slave units this destination address must always be the address of the master unit.

- **Single route.** This route explicitly maps a single RTU address to a radio address. If a single route exists, then it overrides any matching mapped route or range route.

- **Mapped route.** This route maps a relationship between RTU addresses and radio addresses. This is an efficient method of describing a network providing the RTUs and radios are numbered sequentially. This route configuration requires an RTU address to be assigned as the base for the route and an RTU address to define the range of addresses to be used by the route. It also requires a radio address associated with the base RTU address.

  The decoder subtracts the RTU base address from each decoded RTU address. This result is then added to the radio base address. Consider the situation shown in Figure 9.

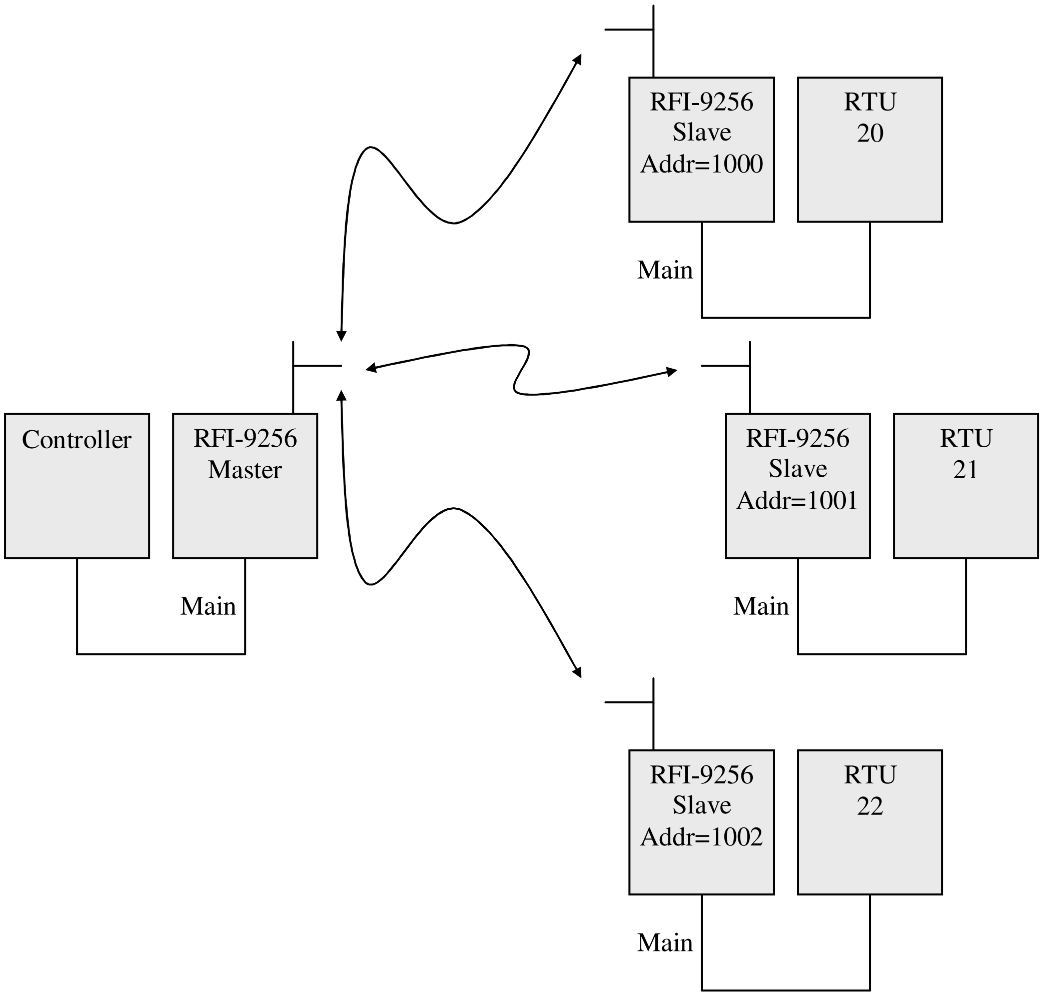


Figure 9: Range routing relationship between radio address and RTU address

The base RTU address is 20 and the range is 22. The base radio address is 1000 . When the decoder finds RTU address 21 it subtracts it from the base RTU, leaving a result of 1. This is then added to the base radio address giving a radio address of 1001 which has RTU 21 attached.

- **Range route.** This route mode routes any RTU address between a start and end RTU address to a single radio address.

4.3.5 Mixed Protocol Networks

The RFI-9256 offers dual independent serial ports that can be used for different network configurations. This allows for any combination of the following network configurations to co-exist in a single radio network.

- Point-to-point configurations.
- Point-to-multipoint broadcast configurations.
- Hayes dial-up configurations.
- SCADA protocol configurations.

The most common use for this co-existence is to allow remote monitoring of radios without disrupting the main data path through the network. This is achieved by configuring the main data path on the main port, and leaving the auxiliary port on the master unit for Hayes dial-up. Hayes commands can then be used to connect to the terminal menu of each individual radio in the network.

4.3.6 Network Link and Online Determination

There are two important indications given by the RFI-9256 as to the current network status, network link and online. These two parameters have different functionality when running in point-to-point, point-to-multipoint broadcast, Hayes dial-up, and SCADA routing modes as shown in Table 11.

Mode	Network Link on Master	Online (both Master and Slave)
Point-to-point	Comes on whenever a point-to-point connection is established with a slave, and is turned off when the point-to-point connection is closed. In turning off it waits for 3 * network link timeout ms.	While there is no point-to-point link established, the LED is off. Once the point-to-point link is established the LED is set on (green). If connection is severed, both units will flash the Online light red every time a packet is dropped due to running out of retries. This will happen once per online request poll (defaults to 3 seconds). Once the network link light is turned red, the online light will be turned off.
Point-to-multipoint Broadcast	Turns green whenever data is received. Turns off again after no data has been received for 3 * network link timeout ms.	Turns green whenever data is received. Turns off after a short period with no data.
Hayes Dial-up	Comes on whenever a dial-up connection is established with the slave, is turned off when the dial-up connection is closed. In turning off it waits for 3 * network link timeout ms.	While there is no dial-up connection, the LED is off. Once the dial-up connection is established, the LED is set on (green). If connection is severed, the dialler (source of the connection) will flash the Online light red every time a packet is dropped due to running out of retries. This will happen (in the absence of data) once per online request poll. Once the network link LED is turned red, the online light will turn black. The receiver (destination) will turn its online light off immediately upon losing the first online request from the dialler.
SCADA protocol networks	Turns green whenever data is received. Turns off again after no data has been received for 3 * network link timeout ms.	Turns green whenever data is received. Turns off after a short period with no data.

Table 11: Network link and online functionality in different protocol modes

Network link always functions the same way on the slave unit, regardless of protocol mode. On a slave network link comes on whenever the slave has successfully locked with a master radio and is hopping with it. It will be turned off after the time specified 2 * network link timeout (ms) passes without the slave receiving its master's transmission.

When a serial port output (DCD or CTS) has been configured to follow online or follow network link, the output will be high so long as online or network link is red or green. Once online or network link goes black the serial port output will go low.

4.4 Auxiliary I/O

The RFI-9256 supplies 8 auxiliary digital I/Os (+5V TTL) that can be mirrored across a radio network. Each digital I/O can be individually configured as an input or output, and digital outputs can have a default state when power is applied before a connection is established to a remote radio (see appendix B.4.2 for details).

4.4.1 Input Sampling

All digital inputs are sampled at a fixed interval that may also be configured. The smaller the sample interval the faster changes will be propagated across the radio network. However if a lot of changes occur to the digital I/Os in rapid succession this can generate a large amount of traffic that may adversely affect serial port data throughput.

4.4.2 I/O Routing

I/Os are routed transparently on point-to-point or Hayes dial-up links. When a point-to-point link is used and remote I/O is enabled, each output on a unit will be set to the current state of the input on the other unit. For this reason it is important to ensure that the outputs on one unit are matched with inputs on the other unit.

When Hayes dial-up is used, the I/Os will be mirrored so long as a connection is established. When the connection is closed the I/Os will be held at the last known value.

5. Applications

5.1 Basic Point-to-point Network

A basic point to point network is shown in Figure 10.

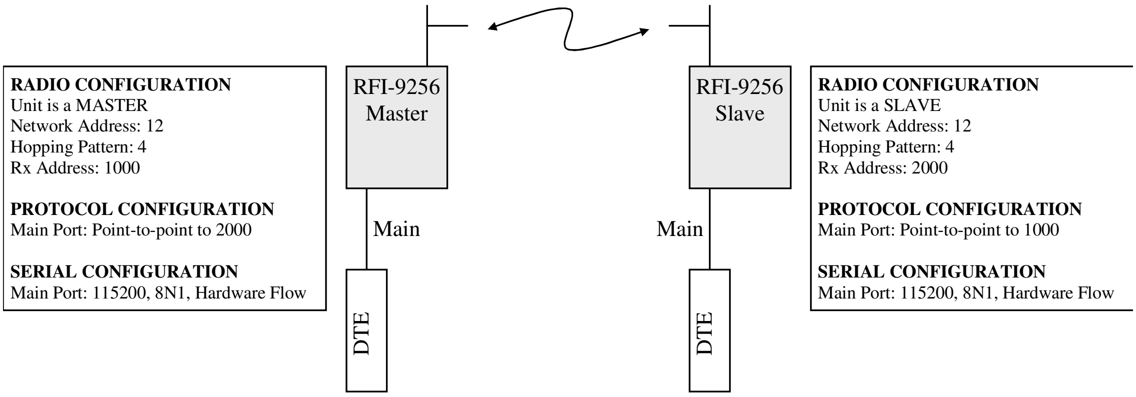


Figure 10: Basic point-to-point network

A single master unit and a single slave unit are configured such that:

- The have the same hopping pattern, network address, and security code.
- The master and slave have different local addresses.
- Both the master and slave have the point-to-point protocol selected on their main serial port.
- The point-to-point destination address on the slave is set to the master's local address, while the point-to-point destination address on the master is set to the slave's local address.

5.2 Simplex Point-to-point Network

A simplex point-to-point network is the same as a basic point-to-point network, except that user data is only going to flow in a single direction. This situation is shown in Figure 11, where user data is only flowing from the slave to the master unit.

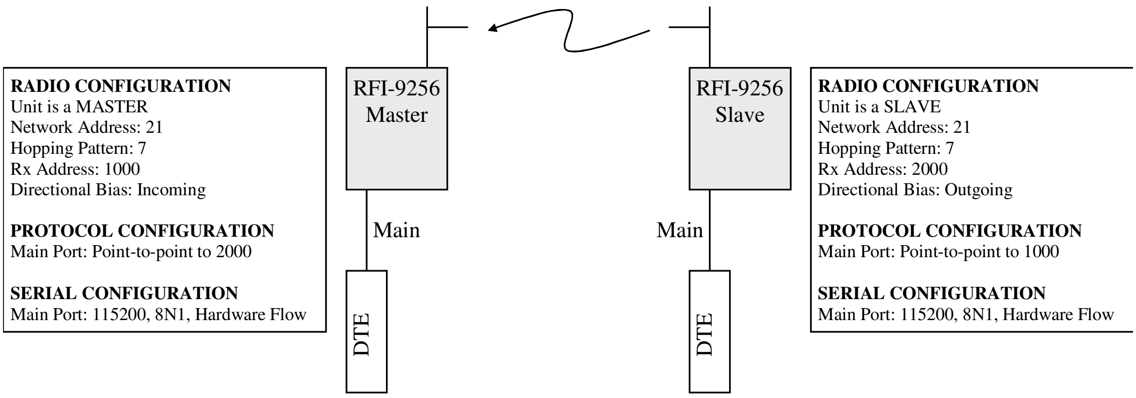


Figure 11: Simplex point-to-point network

Even though user data is only flowing in one direction, there is data being transmitted from the master to the slave in the form of acknowledgments for each packet received.

The simplex point-to-point network has the same configuration as the basic point-to-point network, except that now the slave is configured with an outgoing directional bias and the master is configured with an incoming directional bias.

5.3 Multiple Slave Point-to-point Network

The multiple slave point-to-point network can be expanded to allow two slave units to be connected to a single master using point-to-point links. This configuration is shown in Figure 12.

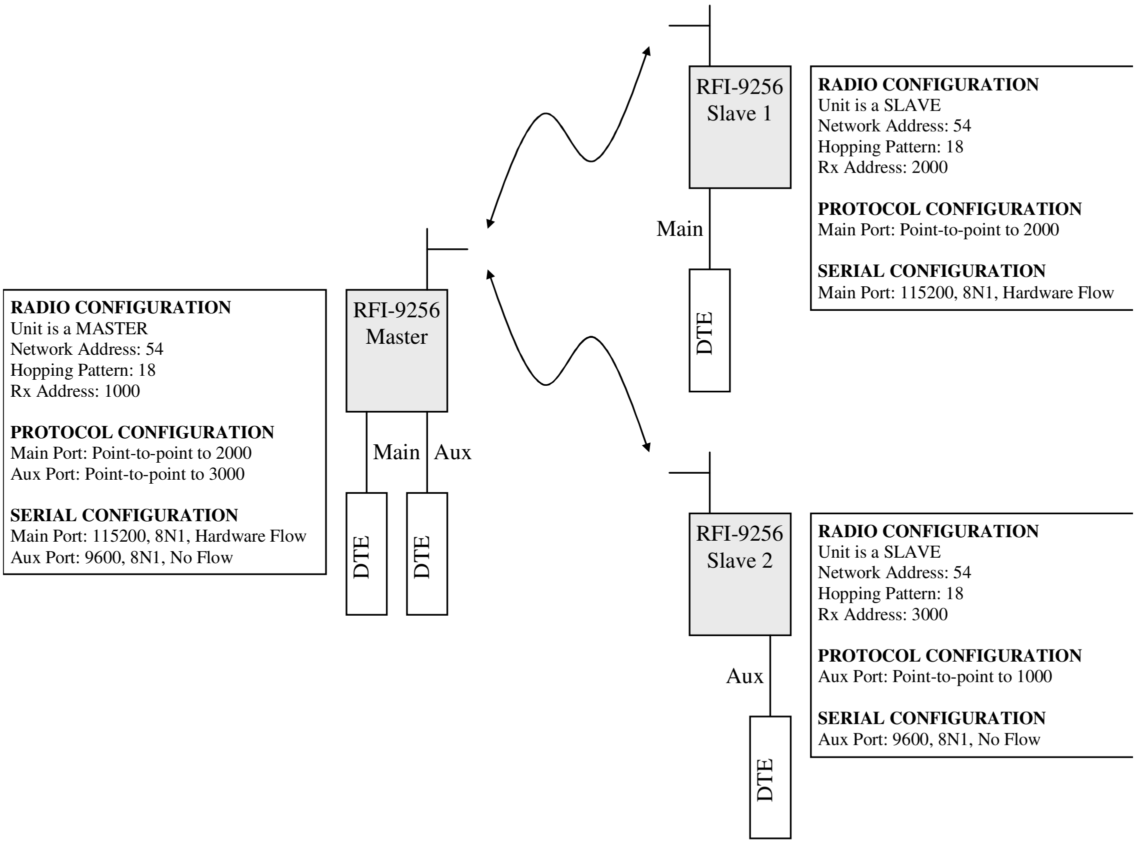


Figure 12: Multiple slave point-to-point network

In this scenario, the radios are configured in the same way as for the basic point-to-point network, however now the auxiliary port must be configured in point-to-point mode and given the destination address as the address of slave 2. This allows all data transmitted on DTE1 on the master to be received by DTE1 on slave 1, and vice versa. At the same time all data transmitted by DTE2 on the master will appear at DTE2 on slave 2 and vice versa.

5.4 Point-to-point Network with Back-to-back Repeaters

The final point-to-point configuration involves the addition of one or more back-to-back repeaters. Back-to-back repeaters can be used to extend the range of an RFI-9256 based network.

The basic network set-up for back-to-back repeaters in point-to-point links is shown in Figure 13.

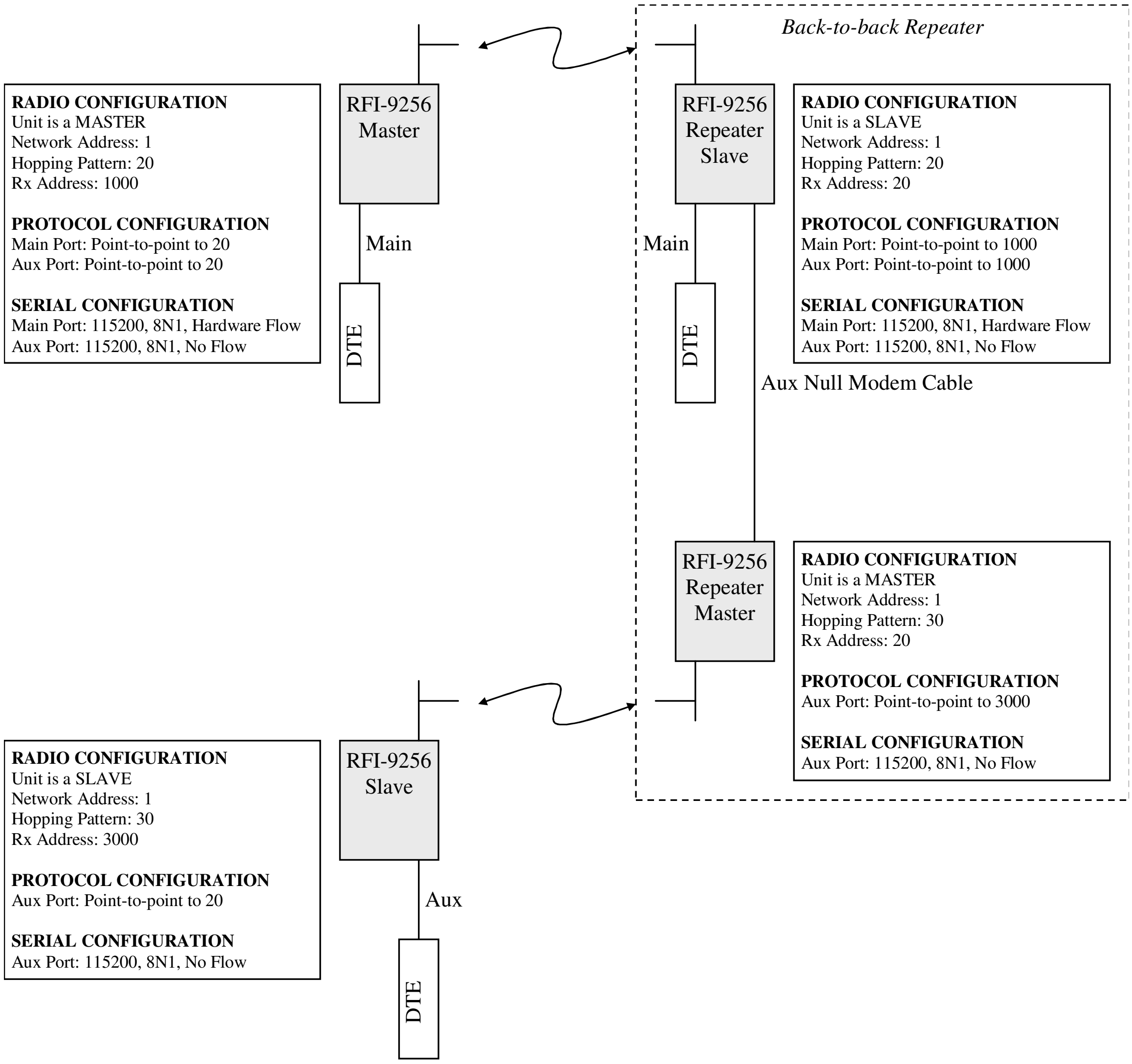


Figure 13: Point-to-point network with a back-to-back repeater

In this scenario, the master 1 and slave 1 form the first network. A point-to-point connection is established between both main and auxiliary ports of these two units. Data transmitted by DTE1 on master 1 will be received on DTE1 of slave 1. Data transmitted by DTE2 on the master will be received by slave 1, and passed to master 2 via a null modem cable linking the two auxiliary ports. This data is then re-transmitted to slave 2, which outputs the received data on its auxiliary port.

5.5 Broadcast Network

The basic configuration for point-to-multipoint broadcast networks is shown in Figure 14.

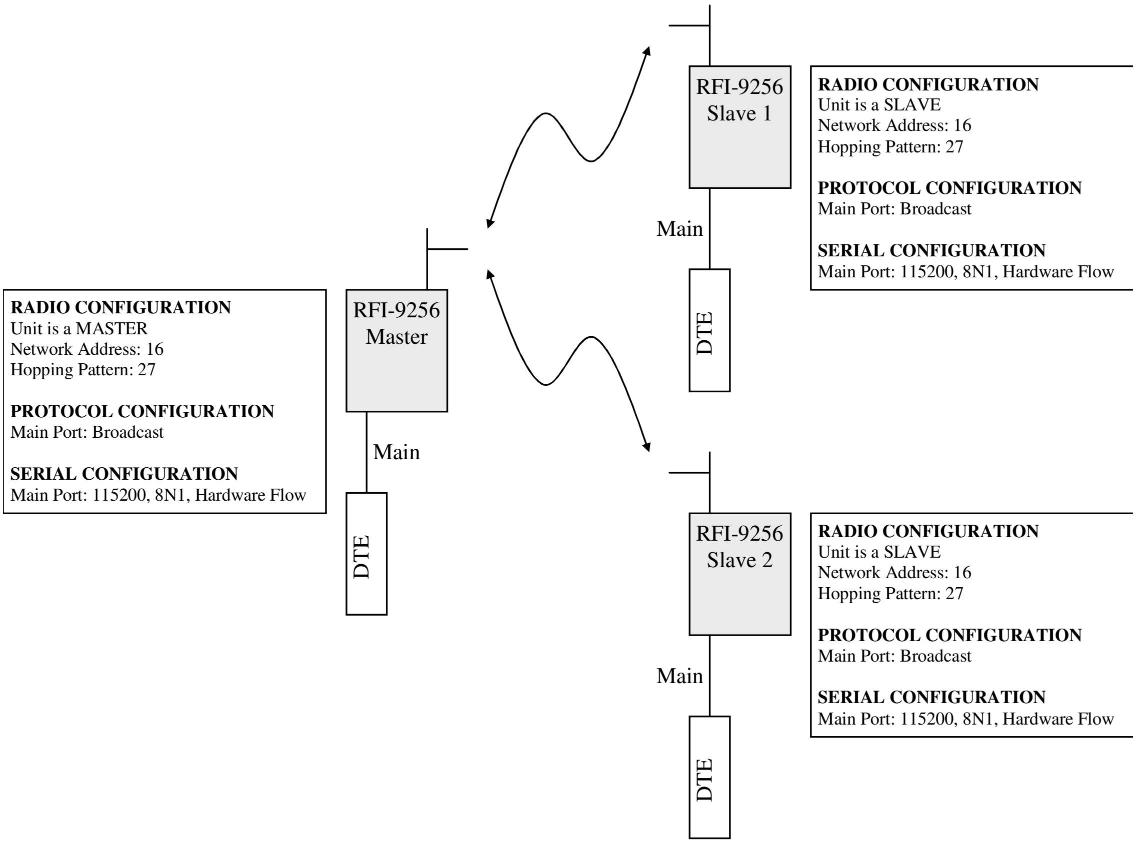


Figure 14: Broadcast network

The master and all the slaves must be configured such that:

- They have the same hopping pattern, network address, and security code.
- Both the master and slave have the broadcast protocol selected on their main serial port.

5.6 Broadcast Network with Back-to-back Repeaters

Back-to-back repeaters can be used in point-to-multipoint broadcast networks to extend the network range. This scenario is shown in Figure 15.

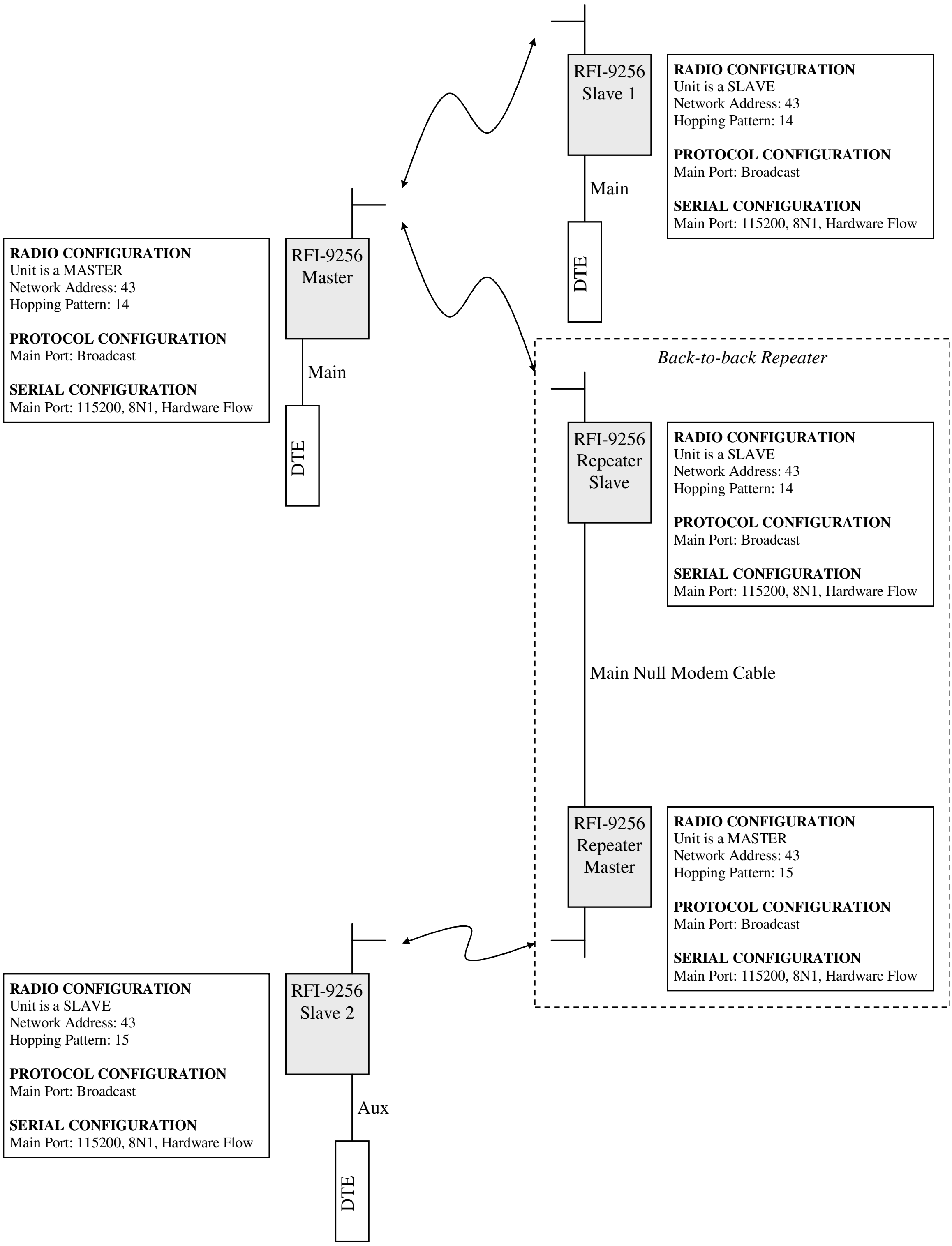


Figure 15: Point-to-multipoint broadcast network with three destinations and a back-to-back repeater

Each segment of the network consists of a master that is either connected to a DTE or to a slave that is on another segment of the network. The transmissions from master 1 will be output on the main port of slave 1, and thus be re-transmitted by master 2. In a similar fashion data received by master 2 will be output on its main port and thus retransmitted by slave 1 back to master 1.

5.7 Hayes Dial-up Networking

The simplest form of Hayes dial-up networking is shown in Figure 16.

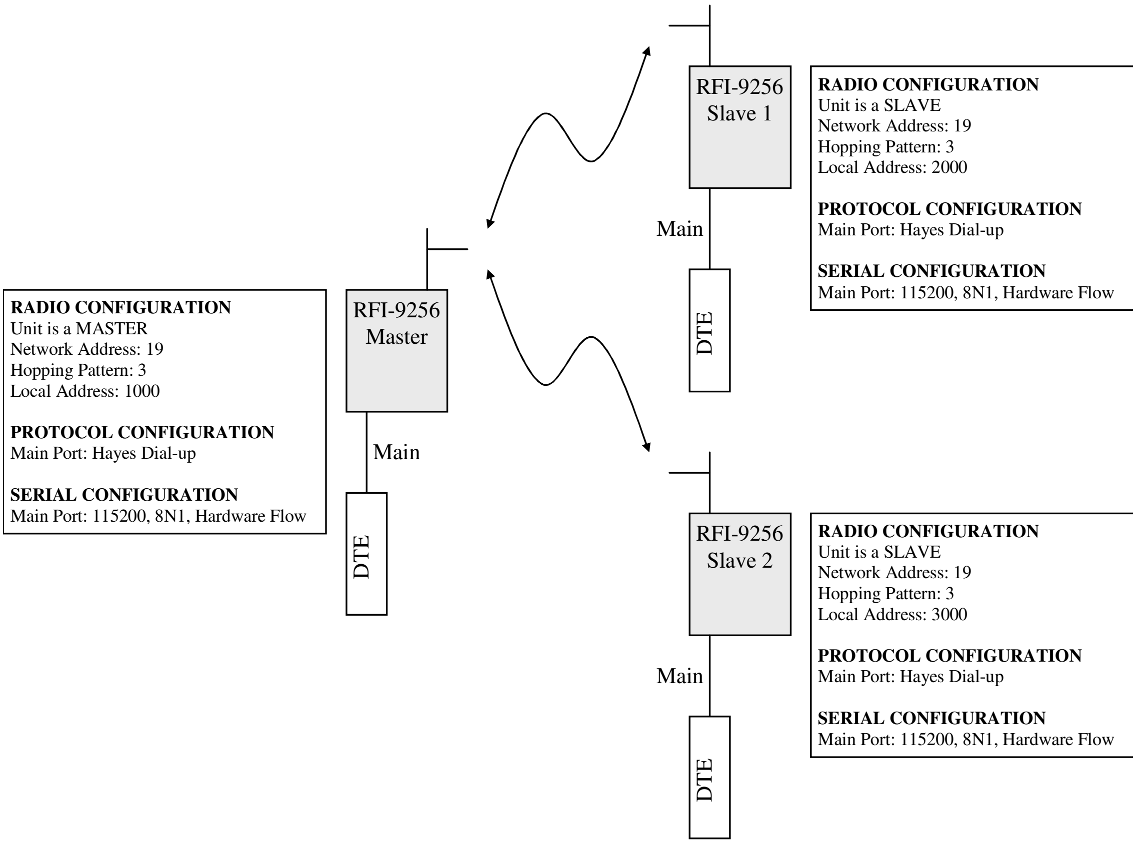


Figure 16: Hayes dial-up network

A single master unit can dial either slave 1 or slave 2. Either slave can dial the master unit.

Example dial strings from the master are:

- `ATD200001<CR>`: Dial the auxiliary port of slave 1 (address 2000, extension 01).
- `ATD300092<CR>`: Dials the internal menu system of slave 2 (address 3000, extension 92).

An example dial string from slave 1 is:

- `ATD 100000<CR>`: Dial the main port of the master (address 1000, extension 00).

5.8 Dial-up Networking with Back-to-back Repeaters

A Hayes dial-up network can be extended by one or more back-to-back repeaters. Figure 17 shows a Hayes dial-up network where a single back-to-back repeater has been used to extend coverage.

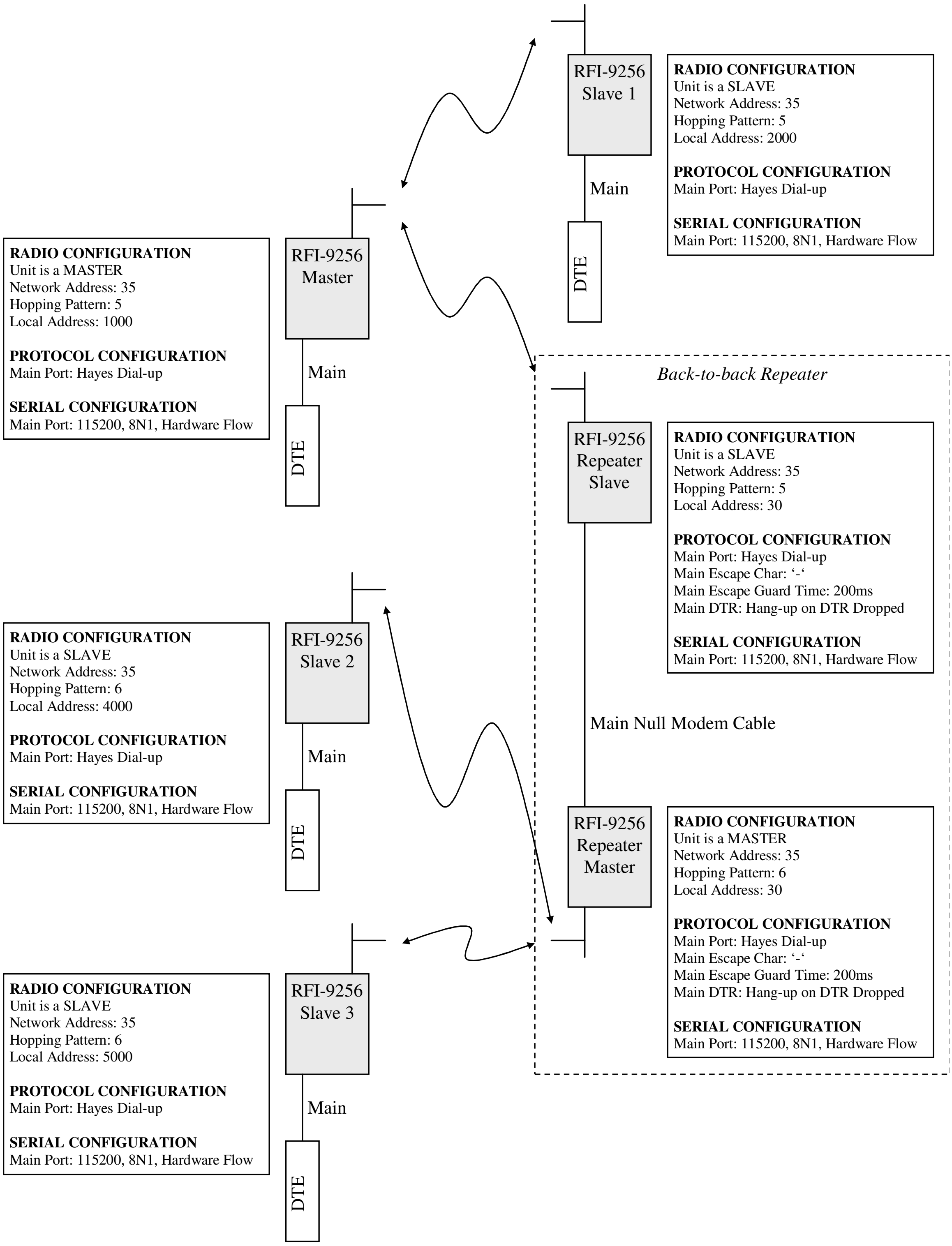


Figure 17: Hayes dial-up network with three destinations and a back-to-back repeater

In order to establish a dial-up connection through a back-to-back repeater, an extension to the dialling system is used. When dialling from the master unit in Figure 17, the following dial strings are used:

- `ATD30400000<CR>`: Establishes a dial-up connection between the master and slave with address 4000 main ports through the back-to-back repeater with address 30.
- `ATD30500091<CR>`: Establishes a dial-up connection between the master and the remote menu system on the slave with address 5000 through the back-to-back repeater 30.
- `ATD200001<CR>`: Establish a connection with the auxiliary port of slave 1. As there is no back-to-back repeater involved in the connection the format does not change.
- `ATD3091<CR>`: Establishes a dial-up connection from the master to the dial-up repeater slave unit's remote menu system.
- `ATD3000<CR>`: Establishes a dial-up connection from the master to the main port of the repeater slave unit. This will in effect put the master radio in communications with the Hayes AT command mode on the repeater master unit.

These last two dial strings illustrate how to access the terminal menu on either of the back-to-back repeater units. In order to access the repeater slave's terminal menu, dial up the menu system as if it were any other slave. In order to access the repeater master's terminal menu dial up the main port of the slave (the port that has been connected through to the master unit), then use the master units AT command interface to bring up the menu system via the `AT?` command.

5.9 SCADA Network with Routing Table

A simple SCADA network using a routing table is shown in Figure 18.

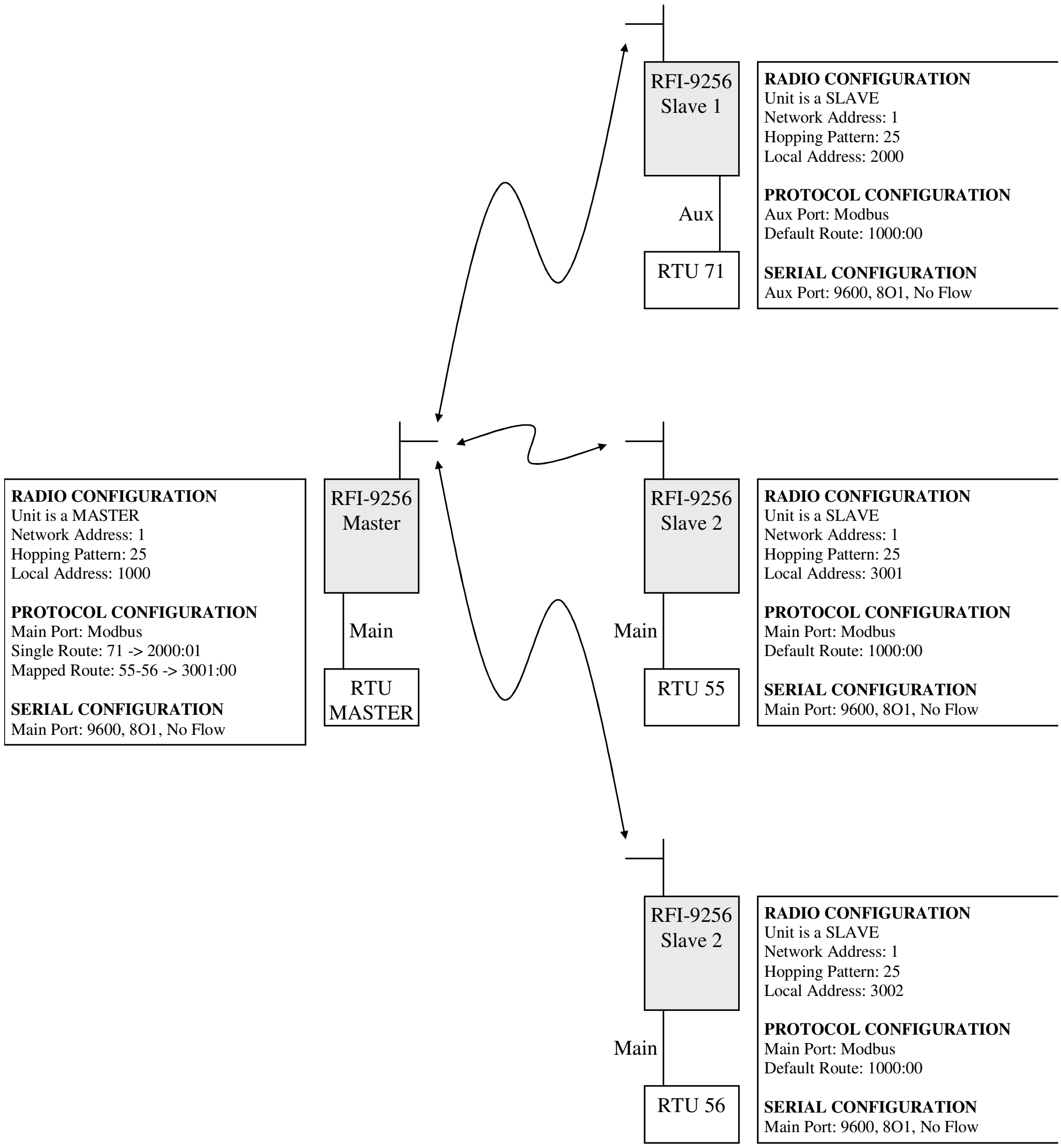


Figure 18: SCADA network with routing table

In all SCADA routing networks, data travels from the master to one of the slaves, or from one of the slaves to the master. The slaves each require a default route with the master units address.

The routing table for the master is Table 12.

Route Type	RTU Address	Radio Address
Single Route	71	2000:01
Mapped Route	55-56	3001:00

Table 12: Master SCADA routing table

There are two routes used in this network. The first route is a single route that links RTU address 71 to radio address 2000:01. All traffic with an RTU destination of 71 will be routed to the auxiliary port of the slave with address 2000 (slave 1 in the above diagram).

The second route is a mapped route that links RTU addresses 55 and 56 to radio addresses 3001:00 to 3002:00. This means that traffic destined for an RTU with an address in the range 55-56 will be routed to the main port of the slave with address 3001 + RTU Address – 55.

The slave units would all have the same routing table, shown in Table 13.

Route Type	RTU Address	Radio Address
Default Route	N/A	1000:00

Table 13: Slave SCADA routing table

5.10 SCADA Network with a Back-to-back Repeater

SCADA networks can use back-to-back repeaters in order to extend the network coverage. This scenario is shown in Figure 19.

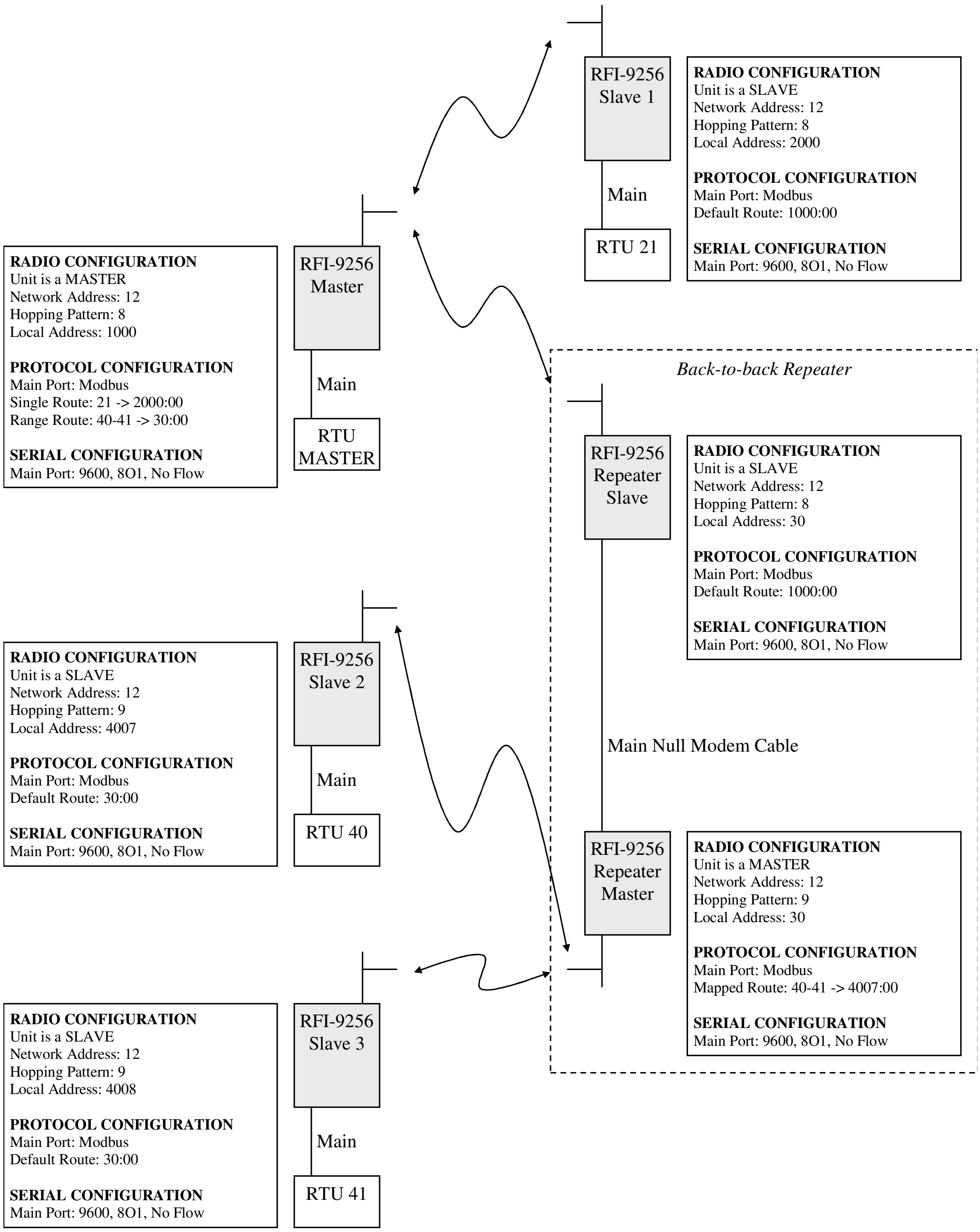


Figure 19: SCADA network with a back-to-back repeater

In this situation Master 1 must route all SCADA packets that are destined for the slaves connected to Master 2 to Slave 2, the slave component of the back-to-back repeater. This routing table is shown in Table 14

Route Type	RTU Address	Radio Address
Single Route	21	2000:00
Range Route	40-41	30:00

Table 14: Master 1 routing table

Master 2 must then correctly route all SCADA protocol packets onto the slaves in its network. This is done using the routing table in Table 15

Route Type	RTU Address	Radio Address
Mapped Route	40-41	4007:00

Table 15: Master 2 routing table

The slaves that hang off master 1 must have the following routing table shown in Table 16.

Route Type	RTU Address	Radio Address
Default Route	N/A	1000:00

Table 16: Slaves from master 1 routing table

The slaves that hang off master 2 must have the following routing table shown in Table 17.

Route Type	RTU Address	Radio Address
Default Route	N/A	30:00

Table 17: Slaves from master 2 routing table

5.11 Point-to-point Auxiliary I/O

The simplest way to route auxiliary I/Os is in a point-to-point network as shown in Figure 20.

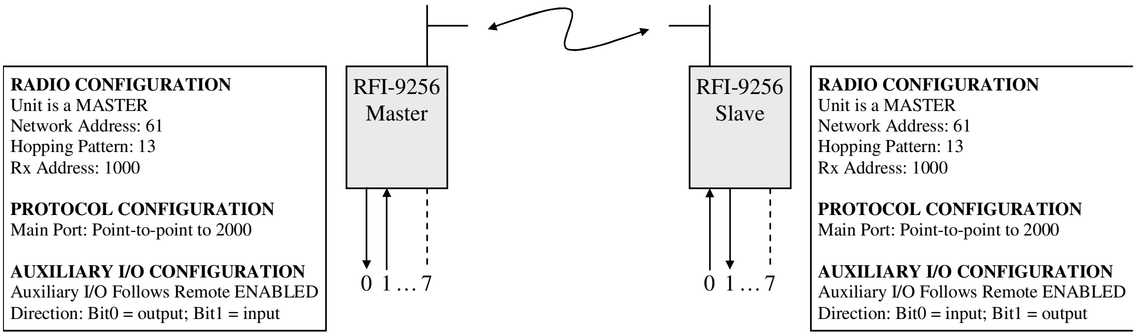


Figure 20: Point-to-point routing of auxiliary I/Os

In this scenario, the master has I/O 0 configured as an output, and I/O 1 configured as an input, while the slave has I/O 0 configured as an input and I/O 1 configured as an output. I/O2 2 through 7 are not used.

The input applied to I/O 0 on the slave will be mirrored on the master, while the input applied to I/O 1 on the master will be mirrored on the slave.

5.12 Point-to-point Auxiliary I/O with a Back-to-back Repeater

Auxiliary I/Os can also be routed through back-to-back repeaters by connecting the outputs on one radio to the inputs on the second radio. Such a configuration is shown in Figure 21.

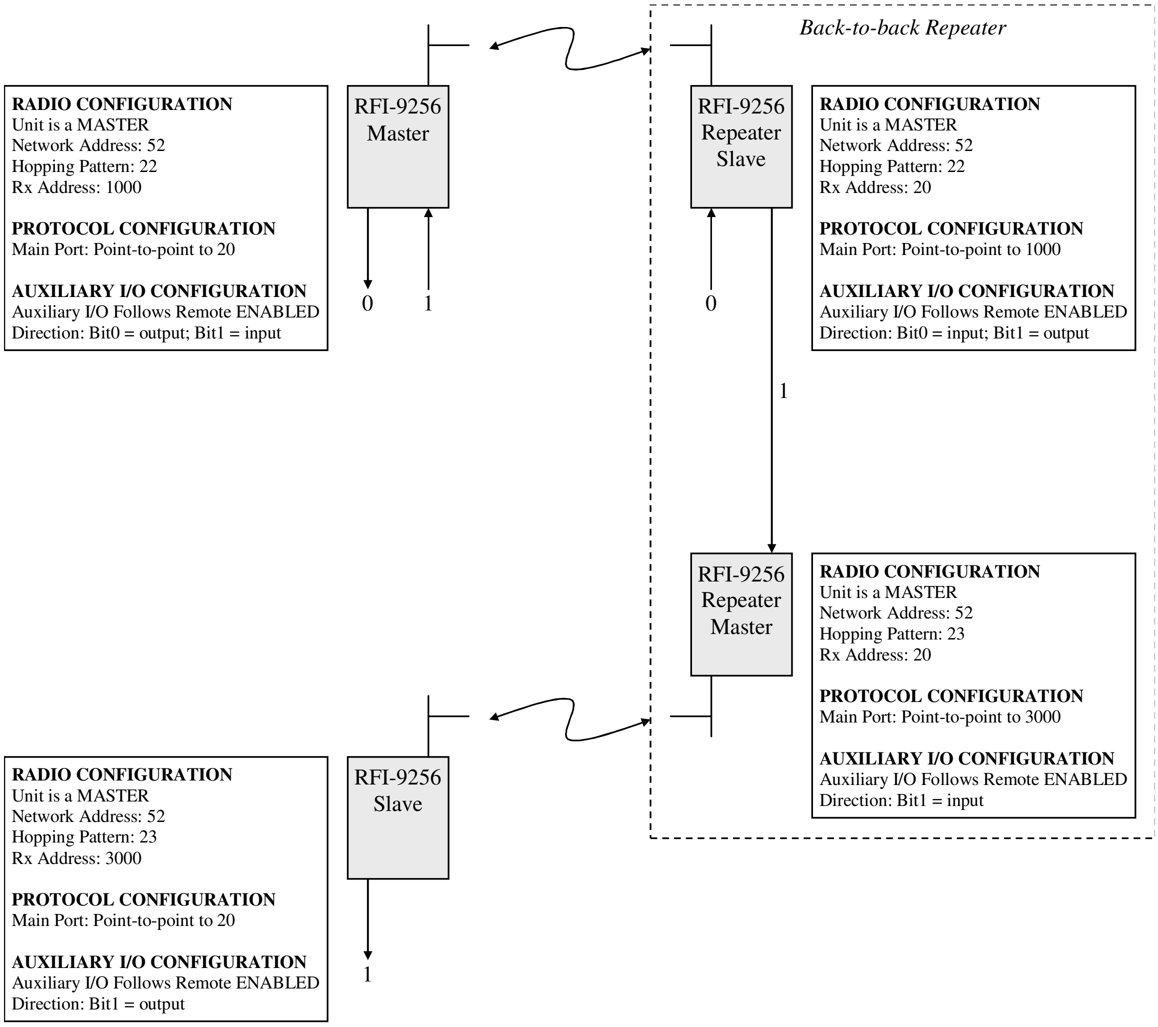


Figure 21: Point-to-point auxiliary I/O with a back-to-back repeater

In this scenario, I/O 0 has been configured as an output on master 1, and as an input on slave 1, thus output 0 on master 1 will mirror input 0 on slave 1.

Auxiliary I/O 1 on master 1 has been routed to I/O 1 on slave 2 via the back-to-back repeater. This is achieved by configuring I/O 1 as an output on the repeater slave and as an input on the repeater master. Thus, the value of I/O 1 will be mirrored on slave 1, which then feeds into master 2, and slave 2 will mirror the value of I/O 1 on master 2.

5.13 Hayes Dial-up Auxiliary I/O

Hayes dial-up connections can be used to control auxiliary I/Os. Whenever a dial-up connection is established, the I/Os will mirror each other. When the dial-up connection is terminated the I/O outputs on either end of the connection will retain their state but will no longer change. This scenario is shown in Figure 22.

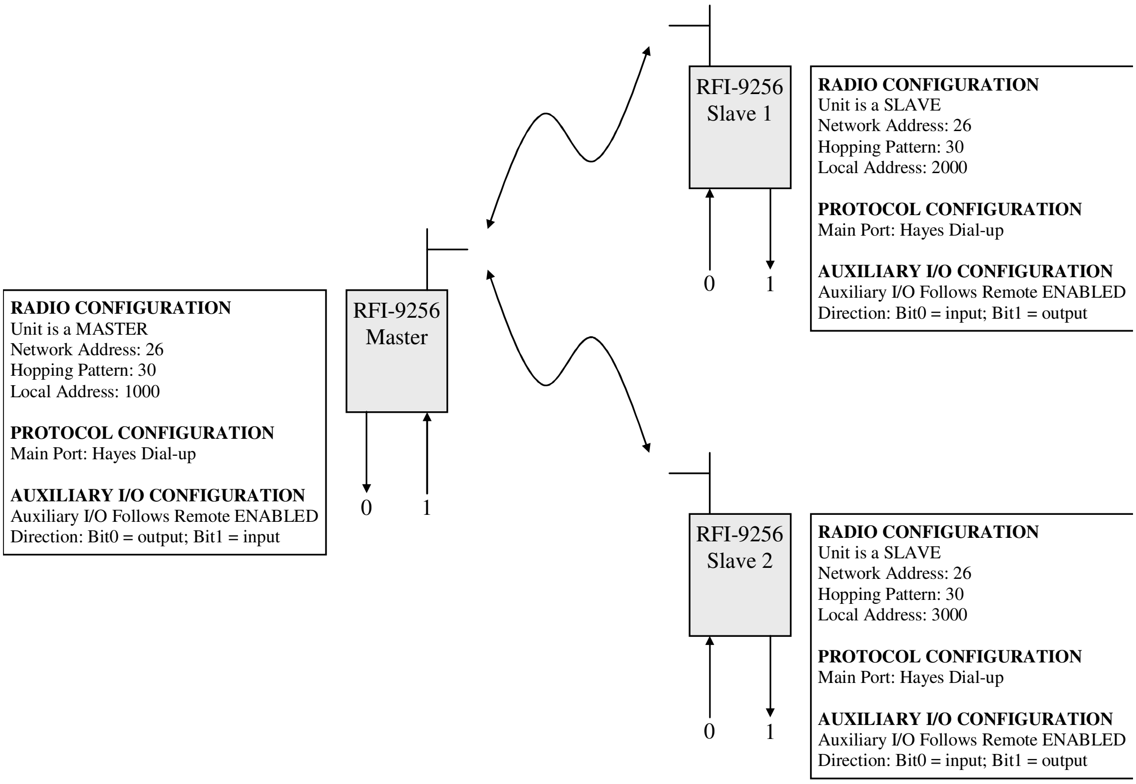


Figure 22: Hayes Dial-up auxiliary I/O

In the Hayes dial-up situation, when the master dials slave 1, the auxiliary I/O 0 on the master will mirror the value on the slave, while the input 1 on the master will be mirrored on output 1 on the slave. When the master hangs-up the connection, output 1 on slave 1 will remain at the last value of input 1 on the master.

The same situation can be repeated when the master dials slave 2.

Appendix A Technical Specifications

A.1 Type Approvals

Australia/ New Zealand	AS/NZS 4771:2000	Australian Supplier ID: N161
FCC	CFR 47 Part 15 Sub-Part C Section 15.247	FCC ID: P5M9256TRX (radio modem) P5M9256OEM (OEM module)

A.2 Radio Specifications

Range	Up to 30km point-to-point
RS-232 Data Rates	110 baud – 115,200 baud
RS-232 Interface	Asynchronous full duplex
Receiver Sensitivity	-108 dBm @ 10^{-4} raw BER -100 dBm @ 10^{-6} raw BER
Modulation Type	Gaussian-Shaped FSK (GFSK)
Spreading Code	Frequency-Hopping
Hopping Patterns	32 user selectable
Output Power	1mW – 1W (0dBm to +30 dBm)
Error Detection	32-bit CRC with packet re-transmit (ARQ)
Antenna	BNC
Power Requirements	9.0 to 16.0 VDC
Power Consumption	350mA @ 12VDC Transmit 200mA @ 12VDC Receive 150mA @ 12VDC Average (normal data loading)
Connector	DB-25 male (power and data combined)
Unit Address (Network ID)	User programmable
Operating Modes	Point-to-point Point-to-multipoint Broadcast Hayes Dial-up SCADA Protocol Router (ModBus, DNP3, TDE, Honeywell) Back-to-back Repeater
Operating Environment	-10ºC to +60ºC

Table 18: Radio Specifications

A.3 Connector Pin Assignments

Pin	Function
1	+12V input
2	Transmit data out (TXD) main port
3	Receive data in (RXD) main port
4	Transmit data out (TXD) auxiliary port
5	Receive data in (RXD) auxiliary port
6	I/O control 7
7	I/O control 5
8	I/O control 0
9	I/O control 2
10	Synchronisation I/O
11	NC
12	NC
13	GND
14	+12V input
15	CTS output (main port)
16	RTS input (main port)
17	DCD output (main port)
18	DTR input (main port)
19	I/O control 6
20	I/O control 4
21	I/O control 1
22	I/O control 3
23	NC
24	NC
25	GND

Table 19: RFI-9256 DB25 Pin Assignments

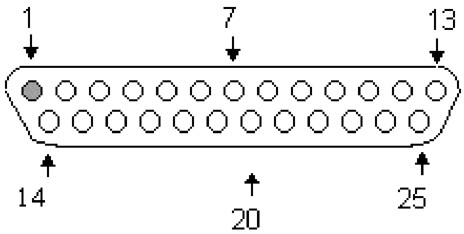


Figure 23: DB25 pin numbering

Pin	Function	DTE Function	DCE Function
1	Data Terminal Ready (DTR)	Output	Input
2	Received Data (RX)	Input	Output
3	Transmitted Data (TX)	Output	Input
4	Data Carrier Detect (DCD)	Input	Output
5	Signal Ground (SG)		
6	Data Set Ready (DSR)	Input	Output
7	Clear to Send (CTS)	Input	Output
8	Ready to Send (RTS)	Output	Input
9	Ring Indicator (RI)	Input	Output

Table 20: DB9 Pin Assignments

A.4 Back-to-back Repeater Connector

The connector used for a back-to-back repeater is shown in Table 21. Note that the main and auxiliary port have been crossed to form a null modem cable (highlighted sections). All eight auxiliary I/O lines along with synchronisation I/O are passed straight through.

Slave Pin	Function	Master Pin
1	+12V input	
2	Transmit data out (TXD) main port	3
3	Receive data in (RXD) main port	2
4	Transmit data out (TXD) auxiliary port	5
5	Receive data in (RXD) auxiliary port	4
6	I/O control 7	6
7	I/O control 5	7
8	I/O control 0	8

9	I/O control 2	9
10	Synchronisation I/O	10
11	NC	
12	NC	
13	GND	13
14	+12V input	
15	CTS output (main port)	16
16	RTS input (main port)	15
17	DCD output (main port)	18
18	DTR input (main port)	17
19	I/O control 6	19
20	I/O control 4	20
21	I/O control 1	21
22	I/O control 3	22
23	NC	
24	NC	
25	GND	

Table 21: RFI-9256 back-to-back repeater pin assignments

A.5 Power Supply Notes

Power supplies used to power the RFI-9256 should have sufficient current rating and ripple rejection. Typically <500m VRMS of power supply noise can be tolerated. The RFI-9256 contains a built in thermal fuse that will open the circuit in the event of any over current conditions, over temperature or reverse polarity. Power supplies used should be capable of at least 1A continuous current.

A.6 Version Numbering Scheme

The RFI-9256 contains a firmware version string. This version string provides some information regarding compatibility with other firmware versions, and consists of:

- **Product Name**: Identifies the radio hardware type.
- **Major and Minor Number**: The major number generally reflects the hardware compatibility of the firmware but may be incremented if the firmware has had a major overhaul. The minor number is incremented as new suites of functionality have been added or when changes have been made which render the firmware incompatible with previous versions. Combined they are the version number.

- **Revision**: The revisions reflect bug fixes or minor changes that don't render the system incompatible.

- **Country**: Firmware with versions with different country identifiers, are always incompatible with their air interface. This is due to the frequencies and hopping sequences that they use. Each country has its own spectrum allocation and laws governing radio spectrum usage.

An example version number string is shown in Figure 24.

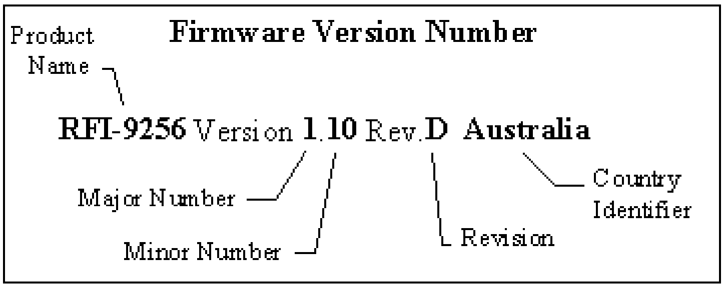


Figure 24: Example firmware version number

Firmware revisions with major version number 1 will be compatible with this hardware build, while firmware revisions with major version number 1 and minor version number 10 will be compatible over the air with this build.

A.7 Case Dimensions

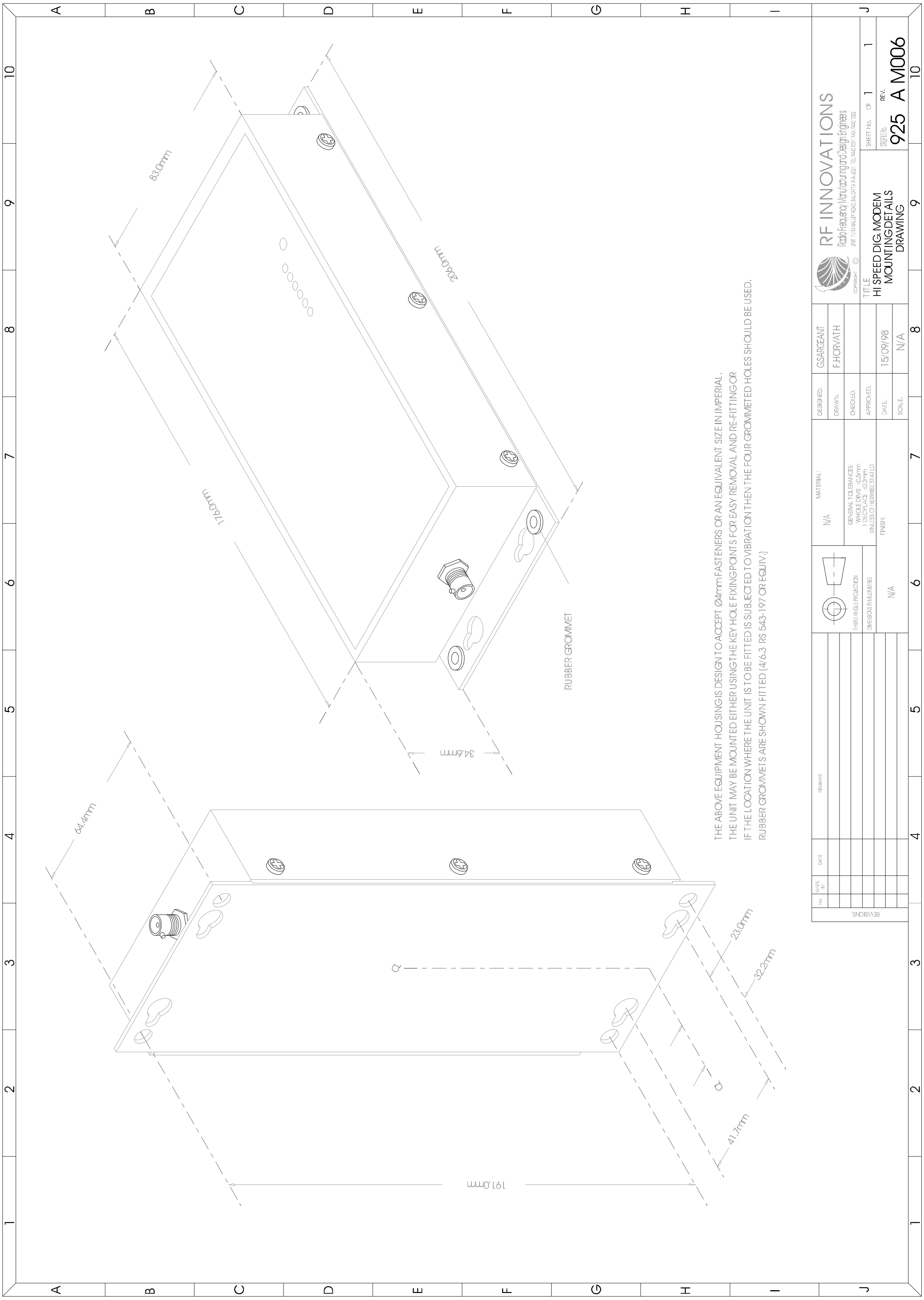


Figure 25: Case physical dimensions

Appendix B Terminal Menu Reference

```
***  MiROS MAIN MENU (Version 2.0)  ***

RFI-9256 Version 1.30 Rev.D
Unit Name: test
Unit is a: SLAVE
Serial No: 207311DF2765
Manufactured Date: 30/01/2002

(R)  Radio Configuration Menu
(L)  Protocol Port Selection
(S)  Serial Port Configuration Menu
(M)  Radio and I/O Configuration Menu
(P)  Radio Personality Menu
(D)  Diagnostics Menu
(Esc) To Exit Menu

Enter Choice:
```

Figure 26: Main menu

- **Status Information:** The main menu displays the RFI-9256 model and firmware revision (1.30 Rev D in Figure 26), along with the unit name, current mode, serial number and manufacture date.

B.1 (R) Radio Configuration Menu

```
***  Radio Configuration Menu  ***

Unit is a: SLAVE
Network Address =  32
Rx Address    =  20
Hopping Pattern =   0
Point to Multipoint Dialup Connection

(M)  Set unit as Master
(S)  Set unit as Slave
(N)  Set Network address
(L)  Set Local Rx address
(P)  Set ports as Point to Point Direct
(D)  Set ports as Point to Multipoint Dialup
(R)  Set ports as Dialup Repeater
(1)  Special Controls Menu
(2)  Link Control Menu
(3)  Radio Characteristics Menu
(F)  Restore Factory defaults
(Esc) Previous Menu

Enter Choice:
```

Figure 27: Radio configuration menu

- **Set unit as Master:** In any communications link, at least one radio must be configured as a master. The master synchronises communications with the slaves, and a may communicate with any slave. A master may not communicate with another master unit.
- **Set unit as Slave:** In any communication link one unit must be set as a master and the rest as slaves. Slaves can initiate communication but follow the synchronisation of the master. A slave can only communicate with the master.
- **Set Network address:** The network address is the network identification number, and every radio on a single network must have the same network address. Slaves will only synchronise with a master that has the same network address. Radios ignore data originating from a radio with another network address. A maximum of 64 network addresses are available, in the range 0 to 63.
- **Set Local Rx Address**: The local address is used to identify individual radios within a network. Each radio must have a unique address, otherwise destructive collisions will occur. It is advised that individual radios be given an address in the range 1000-9999, while radios configured as repeaters (see section Back-to-back Repeater Operation on page 23) must be given the same local address in the range 10-99.
- Radios in different networks can have the same local address.

- **Set ports as Point to Point Direct**: This is a shorthand way of configuring a point-to-point connection on both main and auxiliary ports. For more information see section 4.3.1.

- **Set ports as Point to Multipoint Dialup**: This is a shorthand way of configuring a point-to-multipoint dial-up connection on both main and auxiliary ports. For more information see section 4.3.3.

- **Set ports as Dialup Repeater**: A repeater extends the range of a RFI-9256 radio network. Repeaters consist of a pair of radios, one master and one slave wired together in a back-to-back configuration. This is covered in the section Back-to-back Repeater Operation on page 23. This function will configure the current RFI-9256 for dial-up repeater operation, with the settings for Hayes dialup described in the section Dial-up Networking with Back-to-back Repeaters on page 27.

- **Special Controls Menu**: When the antennas from more than one radio are placed within close proximity, the units may be synchronised to prevent interference. One radio must be configured to output a synchronisation signal while the other radio follow the synchronisation signal. Slave units cannot be configured to follow an external synchronisation signal as the slave must synchronise from the master of its network. In order for synchronisation to operate correctly both radios must be configured with the same frame length and bias setting. For more information see the section Synchronisation on page 22. The following synchronisation options are available:

  (a) **Follow Sync Signal**: The radio will follow a synchronisation signal provided by another. Only the master radio can have this option configured.

  (b) **Output Sync Signal**: The radio will output the frame synchronisation signal.

  (c) **Repeater Sync Mode**: The radio will follow a synchronisation signal provided by another. In this case the radio will synchronise to a 50% offset.

  (d) **No Sync Mode**: Disables synchronisation.

- **Restore Factory defaults**: Restores the default settings of the RFI-9256. The factory defaults settings are given in Appendix D.

B.1.1 (2) Link Control Menu

```
***  Link Control Menu  ***

Main Port: ARQ Retries = 50
Aux Port: ARQ Retries = 50
Network Fail Timer = 5000ms
Online Request Timer = 1000ms
Backoff Retry is Disabled

(A)  Number of Retries for ARQ
(F)  Network Fail Timer
(O)  Online Request Timer
(B)  Backoff Retries Enable/Disable
(Esc) Previous Menu

Enter Choice:
```

Figure 28: Link control menu

- **Number of Retries for ARQ**: The ARQ (automatic repeat request) controls the number of times the radio will resend a packet of lost information before discarding the packet. This can be set as high as 255 retries. Each serial port can be configured independently allowing for modes like broadcast (where a low retry count is desirable) to co-exist with point-to-point or Hayes dial-up modes on the same radio. This is done through the protocol link control menu outlined in Appendix B.2.2.3.

- **Network Fail Timer**: The network fail timeout controls the time a slave waits when a signal is lost before attempting to re-synchronise. The network link LED on the front panel also indicates this loss.

- **Online Request Timer**: This timer controls the length of time between integrity checks between radios running in point-to-point or Hayes dial-up modes.

- **Backoff Retries Enable / Disable**: When several slaves are to be connected simultaneously to a single master, they should be configured with back-off retries. This allow for collisions between the slaves to be resolved using exponential back off and retry.

B.1.2 (3) Radio Characteristics Menu

```
***  Radio Characteristics Menu  ***

Hopping Pattern =   0
Tx Power Level = 20 dBm
RSSI trigger level = -110
Frame Time = 20 milliseconds
Max Tx bytes per frame = 113
Directional Bias is Disabled

(H)  Hopping Pattern
(P)  Tx Power Menu
(R)  RSSI trigger level
(F)  Frame Time Menu
(B)  Directional Bias Menu
(Esc) Previous Menu

Enter Choice:
```

Figure 29: Radio characteristics menu

- **Hopping Pattern:** There are 32 (0-31) hopping patterns available. The hopping pattern determines how the radio hops through the frequency spectrum. Co-located master units should all use different hopping patterns to minimise interference, and all units on the same network must have the same hopping pattern.

- It is advised that the default hopping pattern not be used in order to minimise the change of interference with other RFI-9256 in the area.

- **Tx Power Menu:** The transmit power menu allows the user to select the output power of the RFI-9256. The options are:

  (a) OFF

  (b) 0 dBm

  (c) +10 dBm

  (d) +20 dBm

  (e) +25 dBm

  (f) +30 dBm

  The total output power from the antenna must not exceed 1W EIRP (30dBm) noting that antennas will usually provide gain, and cables and connectors produce a loss.

- **RSSI trigger level:** The RFI-9256 will only attempt to acquire data if the power on the channel exceeds the RSSI trigger level. This can be configured between -120dBm and -50dBm, however setting this to greater than the radio sensitivity (-108dBm) will cause an artificial loss in sensitivity and should only be done in noisy environments.

- **Frame Time Menu:** This function changes the maximum length (in time) of each packet frame. The size in bytes of each frame, and the available frame times is covered in the section RSSI Trip Level on page 20.

- **Directional Bias Menu:** The directional bias menu allows the master/slave biasing of frames to be adjusted. This is often used in simplex systems. The effect of biasing frames is covered in the section Directional Bias on page 21.

B.2 (L) Protocol Port Selection Menu

```
***  Protocol Port Selection  ***

Main Port: Protocol Type: Hayes Dialup
Aux Port: Protocol Type: Hayes Dialup

(M)  Main Port
(A)  Aux Port
(Esc) Previous Menu

Enter Choice:
```

Figure 30: Protocol Port Selection Menu

- **Main Port:** Select to change the protocol on the Main Port and bring up the menu shown in Figure 31

- **Aux Port:** Select to change the protocol on the Auxiliary Port.

```
***  Link/Port Protocol Menu  ***

Main Port: Protocol Type: Hayes Dialup

(P)  Protocol Selection Menu
(C)  Configure Protocol Menu
(Esc) Previous Menu

Enter Choice:
```

Figure 31: Link/Port protocol menu for the main port

B.2.1 (P) Protocol Selection Menu

```
***  Protocol Selection Menu  ***

Main Port: Protocol Type: Hayes Dialup

(P)  Point to Point
(B)  Broadcast
(D)  Hayes Dialup
(M)  Modbus
(H)  Honeywell
(3)  DNP3
(T)  TDE
(X)  Disabled
(Esc) Previous Menu

Enter Choice:
```

Figure 32: Protocol selection menu

- **Point to Point:** Configures the serial port for point-to-point operation. See section 4.3.1 for more information on point-to-point network operation.
- **Broadcast:** Configures the serial port for point-to-multipoint broadcast operation. See section 4.3.2 for more information on point-to-multipoint broadcast network operation.
- **Hayes Dialup:** Configures the serial port for Hayes dial-up operation. See section 4.3.3 for more information on Hayes dial-up network operation.
- **Modbus:** Configures the serial port for the Modbus SCADA protocol. See section 4.3.4 for more information on SCADA protocol network operation.
- **Honeywell:** Configures the serial port for the Honeywell SCADA protocol.
- **DNP3:** Configures the serial port for the DNP3 SCADA protocol using the FT3 frame formal (LPDU).
- **TDE:** Configures the serial port for the Introl systems TDE protocol.
- **Disabled:** Disables any transmission of data though the selected serial port.

B.2.2 (C) Configure Protocol Menu

```
***  Configure Protocol Menu  ***

Main Port: Protocol Type: Hayes Dialup

(M)  Hayes Command Control Menu
(R)  Route Manager Menu
(L)  Link Control Menu
(Esc) Previous Menu

Enter Choice:
```

Figure 33: Configure protocol menu

B.2.2.1 (M) Hayes Command Control Menu

```
***  Hayes Command Control Menu  ***

Main Port: Hang-up on DTR Dropped, Echo is ON, Response is ON, Auto-answer is
ON
Escape character = + Escape guard time = 1000ms
Connect Timeout  = 9985ms
Ring Count     = 1

(C)  Connect Timeout
(X)  Escape character (ie +)
(G)  Escape guard time
(H)  Hang-up on DTR (low)
(Z)  Hang-up on DTR Dropped
(L)  Local on DTR (low)
(I)  Ignore DTR
(E)  Echo (ON/OFF)
(R)  Response codes (ON/OFF)
(A)  Auto-answer (ON/OFF)
(N)  Set Max Rings
(D)  Set to Defaults
(Esc) Previous Menu

Enter Choice:
```

Figure 34: Hayes command control menu

- **Connect Timeout:** The maximum amount of time that the radio will wait for a connection response, configurable between 100 and 30000ms.

- **Escape character (i.e., +):** Sets the escape character. This is the character that is used in the escape sequence to return from online state to local command state. The escape sequence consists of the escape character being typed three times, with set communication-free periods of time before and after the sequence. Back-to-back repeaters used in Hayes dial-up mode should have the escape character set to '-'. See the section Back-to-back Repeater Operation on page 23.

- **Escape guard time:** The time before and after the escape sequence has been entered that there needs to be no activity for the radio to enter local command state.

- **Hang-up on DTR (low):** DTR is an RS-232 signal used to indicate to the radio whether the local terminal is ready to communicate. Hang-up on DTR (low) causes a connection to be broken whenever the DTR line is low.

- **Hang-up on DTR Dropped:** Hang-up on DTR dropped is used to disconnect whenever DTR changes from a high to a low.

- **Local on DTR (low):** When DTR is low the radio goes into local command state. This is equivalent to typing the escape sequence. Once the unit is in local command state, it will only return to online state if the `ATO` command is issued. DTR should be high at this time to prevent the radio immediately returning to local command state.

- **Ignore DTR:** The radio does not use the DTR signal to control its connection state.

- **Echo (ON/OFF):** Toggles the echo setting between on and off. When on characters typed at the terminal will be echoed back to the screen while in local command state.

- **Response codes (ON/OFF):** This toggles whether the radio returns response codes. If the response codes are on, all codes such as `OK`, `CONNECT`, and `NO CARRIER` will be returned to the terminal.

- **Auto-answer (ON/OFF):** When auto-answer is on, the radio will automatically answer any incoming call after the maximum number of rings has passed. When auto-answer is off the `ATA` command must be used to answer an incoming call.

- **Set Max Rings:** Sets the number of `RING` messages to output before automatically answering.

- **Set to Defaults:** Restores the Hayes settings to their factory defaults for the selected port. The factory defaults are given in Appendix D.

B.2.2.2 (R) Route Manager Menu

```
***  Route Manager Menu  ***

Main Port: Protocol Type: Modbus
Used Space  :  0
Free Space  : 3935

Total Routes :  0
Single Routes :  0
Mapped Routes :  0
Range Routes :  0
No Default Route

(A)  Add Route
(D)  Delete Route
(X)  Delete All Routes
(L)  List All Routes
(T)  List Routes by Type
(Esc) Previous Menu

Enter Choice:
```

Figure 35: Route manager menu

- **Add Route:** Adds a new route to the routing table.
- **Delete Route:** Deletes an existing route from the routing table.
- **Delete All Routes:** Deletes all routes in the routing table for the selected port.
- **List All Routes:** Lists all the configured routes for this RFI-9256. Slave radios only have a default route configured, while masters may have an extensive routing table. The following items are displayed for each route:
  - (a) **IDX** is the individual route identifier.
  - (b) **Route Type** is the type of route (single, mapped or range).
  - (c) **Route Source** is the destination address that is found in the protocol packet.
  - (d) **Destination Radio** is the radio that the packet is sent to.
- **List Routes by Type:** Provides a list of all routes sorted by the route type.

B.2.2.3 (L) Link Control Menu

```
***  Link Control Menu  ***

Main Port: ARQ Retries = 50
Network Fail Timer = 5000ms
Online Request Timer = 1000ms

(A)   Number of Retries for ARQ
(F)   Network Fail Timer
(O)   Online Request Timer
(Esc) Previous Menu

Enter Choice:
```

Figure 36: Link control menu

- **Number of Retries for ARQ:** Sets the number of ARQ retries to be used on the selected port. See section B.1.1 for more information.
- **Network Fail Timer:** Sets the network fail timer for the selected port. See section B.1.1 for more information.
- **Online Request Timer:** Sets the online request timer for the selected port. See section B.1.1 for more information.

B.3 (S) Serial Port Configuration Menu

```
***  Port Selection Menu  ***

Main Port: 19200 Baud, No Parity, 8 Data, 1 Stop, No Flow
Main Port: Packet Timers: Output = Disabled, Input = Disabled
Aux Port: 19200 Baud, No Parity, 8 Data, 1 Stop, No Flow
Aux Port: Packet Timers: Output = Disabled, Input = Disabled

(M)   Main Port
(A)   Aux Port
(Esc) Previous Menu

Enter Choice:
```

Figure 37: Serial port selection menu

- **Main Port:** Allows the serial port settings for the main port to be configured as shown in Figure 38.

- **Aux Port:** Allows the serial port settings for the auxiliary port to be configured.

```
***  Serial Port Configuration Menu  ***

Main Port: 19200 Baud, No Parity, 8 Data, 1 Stop, No Flow
Main Port: Packet Timers: Output = Disabled, Input = Disabled
Main Port: Rx Buffer Limit = 3072

(B)   Baud Rate Menu
(F)   Flow Control Menu
(N)   No Parity
(E)   Even Parity
(O)   Odd Parity
(1)   One Stop Bit
(2)   Two Stop Bits
(7)   Seven Bit Data
(8)   Eight Bit Data
(A)   Advanced Functions Menu
(D)   Set to Defaults
(Esc) Previous Menu

Enter Choice:
```

Figure 38: Main serial port configuration menu

- **Baud Rate Menu:** Selects the serial port baud rate for this port.
- **Flow Control Menu:** Selects the flow control method used for this port. The main port supports both hardware and software flow control, while the auxiliary port only supports software flow control
- **No Parity / Even Parity / Odd Parity:** Selects the parity to use on the serial port.
- **One Stop Bit / Two Stop Bits:** Selects the number of stop bits to use on the serial port.
- **Seven Bit Data / Eight Bit Data:** Selects the number of data bits to use on the serial port.
- **Set to Defaults:** Restores the factory default settings for the serial port. The factory defaults are given in Appendix D.

B.3.1 (A) Advanced Functions Menu

```
***  Advanced Functions Menu  ***

Main Port: Packet Timers: Output = Disabled, Input = Disabled
Main Port: Rx Buffer Limit = 3072

(T)  Tx (Out) Packetiser Timer
(R)  Rx (In) Packetiser Timer
(L)  Rx Buffer Limit
(Esc) Previous Menu

Enter Choice:
```

Figure 39: Advanced functions menu

- **Tx (Out) Packetiser Timer:** The tx (out) packetiser timer is used to packetise data incoming from the RF. When the packetising time has passed with no further data being received, all data will be output on the serial port.
- **Rx (In) Packetiser Timer:** The rx (in) packetiser timer is used to packetise data that comes into the serial port. When the packetising time has passed with no data received on the serial port, all available data is transmitted over the air.
- **Rx Buffer Limit:** The rx buffer limit allows control over how full the internal buffer should get before flow control is triggered.

B.4 (M) Radio and I/O Configuration Menu

```
***  Radio and I/O Configuration Menu  ***

(H)  Hayes Command Control Menu
(D)  DCD Output Control Menu
(R)  CTS Output Control Menu
(A)  Auxiliary I/O Config Menu
(Esc) Previous Menu

Enter Choice:
```

Figure 40: Radio and I/O configuration menu

- **DCD Output Control Menu:** DCD (Data Carrier Detect) is an output from the RFI-9256 that can be set to one of the options given in section 4.1.2.
- **CTS Output Control Menu:** The CTS (clear to send) output is used in flow control. When it is not being used for hardware flow control it can be set to one of the options given in section 4.1.2.

B.4.1 (H) Hayes Command Control Menu

```
***  Port Selection Menu  ***

Main Port: Hang-up on DTR Dropped, Echo is ON, Response is ON, Auto-answer is
ON
Escape character = + Escape guard time = 1000ms
Connect Timeout  = 9985ms
Ring Count    = 1
Aux Port: Echo is ON, Response is ON, Auto-answer is ON
Escape character = + Escape guard time = 1000ms
Connect Timeout  = 9985ms
Ring Count    = 1

(M)  Main Port
(A)  Aux Port
(Esc) Previous Menu

Enter Choice:
```

Figure 41: Hayes command control menu

- **Main Port:** Select to change the Hayes Command settings on the Main Port. This is the same menu as described in B.2.2.1.
- **Aux Port:** Select to change the Hayes Command settings on the Auxiliary Port. This is the same menu as described in B.2.2.1.

B.4.2 (A) Auxiliary I/O Port

```
***  Auxiliary I/O Config Menu  ***

Sample Time = 500 (ms)
Aux I/O Follows remote = Disabled

(D)  Aux I/O Direction Menu
(P)  Powerup defaults Menu
(S)  Sample Rate
(F)  Aux I/O Follows remote
(E)  Enable/Disable Aux I/O
(Esc) Previous Menu

Enter Choice:
```

Figure 42: Auxiliary I/O menu

- **Aux I/O Direction Menu:** Allows individual configuration of each I/O line as either an input or an output.
- **Powerup defaults Menu:** Sets the default state of each output line when power is applied to the RFI-9256.
- **Sample Rate:** The number of milliseconds between each sample of the digital inputs. The smaller the sample time the faster changes will be propagated across the radio network. The sampling time can be set between 8ms and 5000ms.
- **Aux I/O Follows remote:** Toggles auxiliary I/O control via a remote radio.
- **Enable/Disable Aux I/O:** Enables or disables the auxiliary I/O port.

B.5 (P) Radio Personality Menu

```
***  Radio Personality Menu  ***

Unit Name:
Time: 00:18:27
Menu Password is Disabled
Security Code is Disabled
Menu Timeout is 15 minutes

(U)   Set Unit Name
(P)   Set Menu Password
(R)   Remove Menu Password
(S)   Set Security Code
(D)   Delete Security Code
(T)   Set Current Time
(M)   Set Menu Timeout
(Esc) Previous Menu

Enter Choice:
```

Figure 43: Radio personality menu

- **Set Unit Name:** Sets the name of the unit. This can help identify each unit on the network by name, location, number or function.
- **Set Menu Password:** Sets the menu password to prevent an unauthorised person from entering the menu system and changing the radio’s settings.
- **Remove Menu Password:** Removes the password used to access the radio's menu, disabling password protection.

- **Set Security Code:** Sets the security code. The security code protects the radio network from interference from other networks using RFI-9256 radio radios. The code is a 32-bit (9 digit) number, which allows 0 to 4294967295 combinations.
- **Delete Security Code:** Clears the security code
- **Set Current Time:** Sets the internal real-time clock. The real-time clock on the RFI-9256 does not use non-volatile storage, and thus will be reset whenever power is removed.
- **Set Menu Timeout :** Sets the amount time a menu remains idle before it is closed.

B.6 (D) Diagnostics Menu

```
***  Diagnostics Menu  ***

(S)  Display Status
(E)  Event Log Menu
(T)  Test Indicator LEDs
(D)  Test Digital Outputs
(N)  Show channel signal/noise
(L)  Show Stats/Logging
(M)  Test Link Margin
(1)  Statistics Menu
(2)  Display Tasks
(3)  Display Links
(Esc) Previous Menu

Enter Choice:
```

Figure 44: Diagnostics menu

- **Display Status:** This function gives a summary of the information regarding the configuration of the radio.
- **Test Indicator LEDs:** Selecting this function starts a test of the front panel LEDs. This is a visual test and the LEDs must be observed while this test is in progress. It simply turns the LEDs on and off operating using all the colours in a predefined sequence.
- **Test Digital Outputs:** This will cause all the auxiliary I/Os to be set as outputs, and then each I/O turned on then off in turn. This is used to test the functionality of the I/O port.
- **Show channel signal/noise:** When this function is selected, a table showing the signal and noise levels for each channel is displayed. If a '??' is displayed as the signal value then there wasn't a recent sample for that channel.
- **Show Stats/Logging:** Shows the statistics relating to the quality of the data throughput and information regarding the performance of both serial ports.

- **Test Link Margin:** Displays the average signal and average noise the radio is measuring. If the unit is configured as a master then it will require an address of the slave.

- **Display Links:** Displays all the links that the radio current has established. This is a table with the following items:

  (a) **Idx**: the index number used internally.

  (b) **LocSrc**: the local port number that is the source/destination for the data.

  (c) **LocExt**: the extension that has been dialled if a remote has dialled this unit

  (d) **DestSrc**: the remote port that is the source/destination for the data

  (e) **DestExt**: the extension that this unit has dialled.

  (f) **DestAddr**: the remote unit address.

  (g) **State**: the internal state of the link.

  (h) **Link Name**: is the name assigned to the link. It reflects the mode of operation for that link.

  The source/destination ports are one of three ports, the main, auxiliary or the virtual port. The virtual port is an internal port used by the radio to communicate through the menus.

B.6.1 (E) Event Log Menu

```
***  Event Log Menu  ***

Log Level = General Information

(V)   View Log
(L)   Logging Level Menu
(C)   Clear Log
(Esc) Previous Menu

Enter Choice:
```

Figure 45: Event log menu

- **View Log:** Used to view the debugging information supplied by the radio.

- **Logging Level Menu:** Selected to change the type of information logged by the radio for display when viewing the log. There are five available levels.

  (a) **Errors**: Only displays severe errors.

  (b) **Warnings**: Displays both errors and warnings.

  (c) **State**: Displays state changes, along with errors and warnings.

  (d) **Info**: Displays all available information, along with stats, errors, and warnings.

  (e) **Debug**: Displays internal debugging information along with info, states, warnings, and errors.

- **Clear Log:** Clears the log.

B.6.2 (1) Statistics Menu

```
***  Statistics Menu  ***

(N)  Show channel signal/noise
(L)  Show Stats/Logging
(P)  Reset Physical Layer Logging
(S)  Reset Serial Logging
(Esc) Previous Menu

Enter Choice:
```

Figure 46: Event log menu

- **Show channel signal / noise:** This function is exactly the same as in the diagnostics menu in section B.6.
- **Show Stats/Logging:** This function is exactly the same as in the diagnostics menu in section B.6.
- **Reset Physical Layer Logging:** Clears the RF logging information.
- **Reset Serial Logging:** Clears the serial port logging information.

Appendix C Hayes AT Command Reference

C.1 Radio Commands

C.1.1 "AT?" Menu Mode

This command enables the menu system on the current Hayes port. When the menu is exited the radio will return to AT command mode.

C.1.2 "ATD" Dial

This command dials a remote unit. The basic dialling command is:

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

Where `<address>` is the address of the remote unit, and `<extension>` is the extension number to dial. For a list of extension numbers see section 4.3.3.

Hyphens, spaces, and colons can be used to make the command more readable, however these will be ignored by the radio. For example, the command `ATD30200001` is equivalent to `ATD 30-2000:01`.

Dial commands cannot be concatenated with other AT commands. More information can be found in the section Connection Management on page 27.

C.1.3 "ATE" Echo

The echo command enables or disables the echoing of input characters in local command state.

Command	Description
`ATE0`	Disable local command echo.
`ATE1`	Enable local command echo.

Table 22: ATE Echo commands

C.1.4 "ATH" Hang Up

The hang-up command forces the radio to terminate the current dial-up connection.

C.1.5 "ATI" Information

The information commands can be used to return various information about the radio. The list of commands are shown in Table 23.

Command	Description
`ATI`	Displays the firmware identifier.

ATI0	Displays the numeric identify code (UNIRADIO PnP).
ATI1	Displays the CRC-32 firmware checksum.
ATI2	Returns OK if the firmware checksum is correct, or ERROR if the firmware checksum is invalid.
ATI3	Displays the firmware revision level.
ATI4	Displays the firmware revision / build date.
ATI5	Displays the radio manufacture date.
ATI6	Displays the radio serial number.
ATI7	Displays the mode identification string.
ATI8	Displays the connection type.
ATI9	Displays the internal temperature of the radio in degrees C.
ATI10	Displays the offline time in milliseconds.
ATI11	Displays the radios average RSSI in dBm.
ATI12	Displays the radios average NOISE in dBm.
ATI13	Displays the current port identifier (0 for main, 1 for aux, or 2 for a virtual Hayes dial-up port).
ATI14	Displays the radio link status.

Table 23: ATI information commands

C.1.6 "ATO" Return to Online State

The return to online state command returns the radio to online state from local command state.

When a radio is online (connected to a remote computer), anything transmitted over the serial port is sent to the remote unit. In order to send AT commands to the radio, it must be returned to local command state. This is done by sending an escape sequence (see section Escape Sequence on page 27). In order to go back online state from the local command state, the `ATO` command is executed.

C.1.7 "ATQ" Quiet (Suppress Response Codes)

The response codes that are generated by the radio can be suppressed, so that commands do not return `OK`, `CONNECT`, or `NO CARRIER`. The options for generating response codes are shown in Table 24.

Command	Description
ATQ0	Response codes are always generated.
ATQ1	Response codes are not generated.

Table 24: ATQ Quiet commands

C.1.8 "ATV" Verbal Response Codes

Response codes can be either verbal (English words), or numeric. The options for selecting response codes is shown in Table 25.

Command	Description
`ATV0`	Numeric response codes are generated.
`ATV1`	Verbal (string based) response codes are generated.

Table 25: ATV Verbal response codes commands

See the section S-Register and %-Register Commands on page 8 for a full list of response codes.

C.1.9 "ATW" Delayed Response

The RFI-9256 can often establish connections much faster than a conventional public switched telephone network (PSTN) modem. In order to be compatible with PSTN modems the `ATW` command can be used to delay the `CONNECT` response to link establishment by 1 second. The options are shown in Table 26.

Command	Description
`ATW0`	Respond as soon as a connection is established.
`ATW1`	Allow for at least 1 second of delay before responding.

Table 26: ATW delayed response codes commands

C.1.10 "AT&C" Data Carrier Detect Control

Data Carrier Detect (DCD) is an RS-232 signal used to indicate to the DTE that a connection is established to a remote radio. The `AT&C` command is used to tell the radio how it will control the DCD output as shown in Table 27.

Command	Description
`AT&C0`	DCD is always asserted.
`AT&C1`	DCD follows the online status of the radio. Online status is discussed in section 4.3.6.
`AT&C2`	DCD follows the DTR input of the remote radio when a connection is established, and is low when there is no connection established.

Table 27: AT&C data carrier detect control commands

C.1.11 "AT&D" Data Terminal Ready Activity

Data Terminal Ready (DTR) is an RS-232 signal used to indicate to the radio whether the DTE is ready to communicate. The `AT&D` command is used to tell the radio how it will react when the DTR signal changes. The options are shown in Table 28.

Command	Description
`AT&D0`	The radio ignores the DTR signal.
`AT&D1`	The radio enters local command mode whenever DTR is low.
`AT&D2`	The radio hangs up the current connection whenever DTR goes from high to low.
`AT&D3`	The radio hangs up and returns to the local command mode whenever DTR is low. The radio with this configuration must be DTR asserted before dialling or answering otherwise an immediate hang-up will occur.

Table 28: AT&D data terminal ready activity commands

C.1.12 "AT&F" Restore Factory Defaults

All configuration values in the RFI-9256 have factory default settings, outlined in Appendix D. The `AT&F` command can be used to reset some or all of these settings to the factory default state.

Command	Description
`AT&F0`	Restores the Hayes radio interface to the factory default settings.
`AT&F1`	Restores all radio settings to their factory default state.

Table 29: AT&F restore factory defaults commands

C.1.13 "AT&G" Exclusive Port Control

There are times when a DTE may require exclusive control of a radio. Since the RFI-9256 is a dual port radio, this involves preventing any dial attempts from the other serial port. There are three options for exclusive port control

Command	Description
`AT&G0`	Multi-port operation.
`AT&G1`	Exclusive port control. The other serial port will always return `BUSY` whenever an attempt is made to dial out.
`AT&G2`	Priority port control. If the other serial port already has a connection established then it will be immediately disconnected when the priority port (this port) issues a dial command, and the other serial port will always return `BUSY` whenever an attempt is made to dial out.

Table 30: AT&G exclusive port control commands

The radio should be restored to multi-port operation after hanging up from the remote radio or at the end of session.

C.1.14 "AT&K" Flow Control

The flow control mode for the current serial port is selected using the `AT&K` command. The selection options are shown in Table 31.

Command	Description
`AT&K0`	Flow control is disabled.
`AT&K3`	RTS/CTS hardware flow control is selected. This option is only available for the main serial port.
`AT&K4`	Xon/Xoff software flow control is selected. This option is available on both the main and auxiliary ports.

Table 31: AT&K flow control commands

C.1.15 "AT&V" View Active Profile

The current configuration of the radio can be viewed using the `AT&V` command. The items that can be viewed are shown in Table 32.

Command	Description
`AT&V`	Displays all registers except for I registers.
`AT&V1`	Displays all I registers.
`AT&V2`	Displays all S registers.
`AT&V8`	Displays the current communications links.
`AT&V9`	Displays the fault / diagnostics log.

Table 32: AT&V view profile commands

C.1.16 "AT&W" Store Active Profile

The `AT&W` command is used to store the current profile in non-volatile memory.

The two options when storing the active profile are shown in Table 33.

Command	Description
`AT&W`	Saves all radio configuration data to non-volatile memory.
`AT&W1`	Submits the serial port configuration. Serial port configuration changes are not made active until this command is executed.

Table 33: AT&V view profile commands

C.2 S-Register Commands

C.2.1 "ATS0" Rings Before Answer

Sets the number of rings that are output before the RFI-9256 automatically answers a call.

- `ATS0=3<CR>`: Causes 3 RING messages to be output before answering.

C.2.2 "ATS2" Escape Character

S-register 2 contains the ASCII values of the character that forms the escape sequence. The default value for this register is the '+' character, with an ASCII value of 43. The radio will recognise three + characters (+++) as the escape sequence with the escape guard time delay before and after the sequence.

- `ATS2=36<CR>`: Recognises three dollar characters "$$$" as the escape sequence.
- `ATS2=45<CR>`: Recognises three minus characters "---" as the escape sequence.

C.2.3 "ATS7" Wait for Carrier

S-register 7 contains a value, in seconds, equivalent to the length of time the radio will wait for a carrier signal after dialling. If a carrier is not detected within the time specified in this register, the radio will hang up and return a `NO CARRIER` message.

- `ATS7=20<CR>`: Wait for up to 20 seconds for a connection to be established before returning `NO CARRIER`.

C.2.4 "ATS12" Escape Sequence Guard Time

The escape sequence guard time is the time delay required immediately before and after entering an escape sequence.

For the radio to distinguish the escape sequence from ordinary data, there must be a period of silence both before and after the escape sequence is entered. If the escape sequence guard time is one second and the escape sequence character has been defined as '+', for the radio to recognise an escape sequence the line must be silent for one second, then "+++" is transmitted in rapid succession, and then another one second silence.

S-register 12 is also used to time the period between the escape sequence characters as they are typed. If the period between the first and second escape characters or second and third escape characters being entered is greater than the value in s-register 12, the radio will not recognise the escape sequence.

The guard time is in units of milliseconds (or 1/1000 of a second).

- `ATS12=990<CR>`: Maintain silence on the line for 990ms (0.99 seconds) before and after entering the escape sequence.

C.2.5 "ATS21" Set Security Code

S-register 21 sets the network security code for this radio. The range of values is from 0 to 4294967295. All radios on a single network must have the same security code in order to maintain communications.

- `ATS21=5839238<CR>`: Sets the security code to 5839238.

C.2.6 "ATS39" RX Packet Timer

S-register 39 contains the RX (in) packetiser timer. Packet timers are in the range 0 to 1000ms. When a value of 0 is set for s-register 39 packetising is disabled.

- `ATS39=30<CR>`: Sets a 30ms RX packetisation timer.
- `ATS39=0<CR>`: Disables the RX packetisation timer.

C.2.7 "ATS40" TX Packet Timer

S-register 40 contains the TX (out) packetiser. Packet timers are in the range 0 to 1000ms. When a value of 0 is set for s-register 40 packetising is disabled.

- `ATS40=870<CR>`: Sets an 870ms TX packetisation timer.
- `ATS40=0<CR>`: Disables the TX packetisation timer.

C.2.8 "ATS41" Number of Retries

S-register 41 contains the number of retries used by the radio, and is within the range 0 to 255 where a value of 0 will disable retries.

- `ATS41=25<CR>`: Sets 25 retries.
- `ATS41=0<CR>`: Disables retries.

C.2.9 "ATS42" Network fail timeout

S-register 42 sets the network fail timeout. The network fail timeout is the amount of time that must pass with no data being received on a slave for it to give up trying to communicate with its master and return to hunting for a connection. The network fail timer is configurable between 100 and 30000ms.

- `ATS42=15000<CR>`: Sets the network fail timeout to occur after 15 seconds without contact between the slave and the master.

C.2.10 "ATS43" Online requests timer

S-register 43 sets the online request timer. The online request timer is the time between automatic background polling between point-to-point and Hayes dial-up units to ensure that connections still exist. It can be configured to between 100ms and 30000ms, and must be less than the network fail timer. For more information about online requests see section 4.3.6.

- `ATS43=400<CR>`: Sets the radio to check for online status every 400ms.

C.2.11 "ATS44" Hopping Pattern Sequence

S-register 44 sets the hopping pattern sequence number used by the radio. All radios on a single network must have the same hopping pattern sequence number in order to communicate. Valid values are between 0 and 31.

- `ATS44=27<CR>`: Sets the hopping pattern sequence number to 27.

C.2.12 "ATS45" Max TX Power

S-register 45 sets the maximum transmit power of the radio. The only valid formats for setting the maximum transmit power are:

- `ATS45=0<CR>`: Sets the maximum transmit power to 0dBm.
- `ATS45=10<CR>`: Sets the maximum transmit power to 10dBm.
- `ATS45=20<CR>`: Sets the maximum transmit power to 20dBm.
- `ATS45=25<CR>`: Sets the maximum transmit power to 25dBm.
- `ATS45=30<CR>`: Sets the maximum transmit power to 30dBm.

C.2.13 "ATS47" Frame Time

S-register 47 sets the frame time in milliseconds. The only valid frame time values are:

- `ATS47=5<CR>`: Sets the frame time to 5ms.
- `ATS47=8<CR>`: Sets the frame time to 8ms.
- `ATS47=10<CR>`: Sets the frame time to 10ms.
- `ATS47=15<CR>`: Sets the frame time to 15ms.
- `ATS47=20<CR>`: Sets the frame time to 20ms.
- `ATS47=25<CR>`: Sets the frame time to 25ms.
- `ATS47=30<CR>`: Sets the frame time to 30ms.
- `ATS47=35<CR>`: Sets the frame time to 35ms.

C.2.14 "ATS48" Frame Bias

S-register 48 sets the frame bias of the radio. The only valid frame bias values are:

- ATS48=0<CR>: Disables frame bias (sets the bias to 50/50).
- ATS48=1<CR>: Sets the frame bias to outgoing/upload. This means that more data can flow out from this unit over the air.
- ATS48=2<CR>: Sets the frame bias to incoming/download. This means that more data can flow into this unit from the air.

C.2.15 "ATS50" Network Address

S-register 40 sets the network address of the radio. All radios on a single network must have the same network in order to communicate. Valid values are between 0 and 63.

- ATS50=54<CR>: Sets the network address to 54.

C.2.16 "ATS51" Unit Rx address

S-register 51 sets the units local address. Local addresses are in the range 0 to 9999.

- ATS51=1001<CR>: Sets the units address to 1001.

C.2.17 "ATS52" Unit Tx address

S-register 52 sets the destination address for point-to-point traffic from this unit. Destination addresses are in the range 0 to 9999.

- ATS52=2027<CR>: Sets the point-to-point destination address to 2027.

C.2.18 "ATS60" Set Logging Level

S-register 60 sets the current radio log level. The only valid values are:

- ATS60=0<CR>: Only errors are logged.
- ATS60=1<CR>: Warnings and errors are logged.
- ATS60=2<CR>: Status information, warnings, and errors are logged.
- ATS60=3<CR>: General information, status information, warnings, and errors are logged.
- ATS60=4<CR>: All information is logged.

C.2.19 "ATS61" Set UNIX Date/Time

S-register 61 sets the real-time of the radio in seconds since 1970.

- ATS61=1<CR>: Sets the time to one second past midnight on the 1st of January 1970.

C.2.20 "ATS62" Set System/Log Timer

S-register 62 sets the log timer. The log timer is the millisecond value displayed next to each output log.

- `ATS62=100<CR>`: Sets the log timer to 100ms.

C.2.21 "ATS70" Set Port Protocol Type

S-register 70 sets the protocol mode for the serial port. The only valid values are:

- `ATS70=0<CR>`: Disables the serial port.
- `ATS70=1<CR>`: Sets the serial port into point-to-point mode. See section 4.3.1 for information on point-to-point networks.
- `ATS70=2<CR>`: Sets the serial port into point-to-multipoint broadcast mode. See section 4.3.2 for information on point-to-multipoint broadcast networks.
- `ATS70=3<CR>`: Sets the serial port into Hayes dial-up mode. See section 4.3.3 for information on Hayes dial-up networks.

C.2.22 "ATS80" Local Auxiliary I/O Hex data

S-register 80 contains the current value being read from the auxiliary I/O input as an 8-bit number, where a bit is set to 1 for a logic high and 0 for logic low. It can also be used to set the local outputs.

- `ATS80=F0<CR>`: Sets the Auxiliary I/O bits 0…3 to output 1 and bits 4…7 to output 0.

C.2.23 "ATS81" Get Remote Auxiliary I/O Hex data

S-register 81 is a read-only register that contains the current value being read from the remote auxiliary I/O input as an 8-bit number, where a bit is set to 1 for a logic high and 0 for logic low.

C.2.24 "ATS82" Auxiliary I/O Direction Mask

S-register 82 contains the direction mask for the auxiliary I/O on the local radio. A bit set to 1 sets the I/O as an output, and 0 sets the I/O as an input.

- `ATS82=00<CR>`: This would set all eight I/Os as inputs.
- `ATS82=F0<CR>`: This would set I/Os 0…3 to be inputs and I/Os 4…7 to be outputs.

C.2.25 "ATS83" Set Auxiliary I/O Power-up Default

S-register 83 contains the power-up default value for the auxiliary I/O port. A bit set to 1 sets the I/O as logic high, and 0 sets the I/O as logic low.

- `ATS83=FF<CR>`: This would set all eight I/Os to logic high on power-up.

- ATS82=80<CR>: This would set I/O 7 to logic high, and all other I/Os to logic low on power-up.

C.2.26 "ATS84" Set Auxiliary I/O Sample Timer

S-register 84 sets the sample period for the input I/Os.

- ATS84=100<CR>: This would cause the I/Os to be sampled once every 100ms.

C.2.27 "ATS90" Set DCD control

S-register 90 sets how the data carrier detect (DCD) output is controlled. The options for controlling DCD are shown in Table 30.

Value	Description
0	Online controls DCD.
1	Network link controls DCD.
2	Carrier detect controls DCD.
3	Remote DTR controls DCD.
4	Local DTR controls DCD.
5	Remote RTS controls DCD.
6	Local RTS controls DCD.
7	DCD always off.
8	DCD always on.
9	DCD disabled.

Table 34: DCD output control options

- ATS90=2<CR>: Sets carrier detect to control DCD.
- ATS90=7<CR>: Sets DCD to always be on.

C.2.28 "ATS91" Set CTS control

S-register 90 sets how the clear to send (CTS) output is controlled. The options for controlling CTS are shown in Table 31.

Value	Description
0	Online controls CTS.
1	Network link controls CTS.
2	Carrier detect controls CTS.

3	Remote DTR controls CTS.
4	Local DTR controls CTS.
5	Remote RTS controls CTS.
6	Local RTS controls CTS.
7	CTS always off.
8	CTS always on.
9	CTS disabled.

Table 35: CTS output control options

- `ATS91=3<CR>`: Sets CTS to follow the remote value of DTR.
- `ATS91=6<CR>`: Sets CTS to follow the local value of RTS.

Note that when RTS/CTS flow control is selected, CTS is set according to the flow control and the setting in s-register 91 is ignored.

C.2.29 "ATS100" Set Port Baud Rate

S-register 100 sets the baud rate of the connected serial port. The values for S-register 100 are limited to {110, 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200}.

- `ATS100=300<CR>`: Sets the baud rate to 300.
- `ATS100=115200<CR>`: Sets the baud rate to 115200.

The value store in s-register 100 will not be applied immediately. It will only become active once the `AT&W1` command is executed.

C.2.30 "ATS101" Set Port Parity

S-register 101 sets the parity of connected serial port. There are three options for the parity:

- `ATS101=0<CR>`: Disable parity.
- `ATS101=1<CR>`: Odd parity.
- `ATS101=2<CR>`: Even parity.

The value store in s-register 101 will not be applied immediately. It will only become active once the `AT&W1` command is executed.

C.2.31 "ATS102" Set Port Data Bits

S-register 102 sets the number of data bits used by the connected serial port. There are two options for the number of data bits:

- `ATS102=7<CR>`: Seven data bits.
- `ATS102=8<CR>`: Eight data bits.

The value store in s-register 102 will not be applied immediately. It will only become active once the `AT&W1` command is executed.

C.2.32 "ATS103" Set Port Stop Bits

S-register 103 sets the number of stop bits used by the connected serial port. There are two options for the number of stop bits:

- `ATS103=1<CR>`: One stop bit.
- `ATS103=2<CR>`: Two stop bits.

The value store in s-register 103 will not be applied immediately. It will only become active once the `AT&W1` command is executed.

C.2.33 "ATS104" Set Port Flow Control

S-register 104 sets the flow control mode of connected serial port. There are three options for the flow control mode:

- `ATS104=0<CR>`: Flow control disabled.
- `ATS104=1<CR>`: Software (XON/XOFF) flow control.
- `ATS104=2<CR>`: Hardware (RTS/CTS) flow control.

The value store in s-register 104 will not be applied immediately. It will only become active once the `AT&W1` command is executed.

C.3 '%' Register Commands

C.3.1 "AT%20" Set Unit Name

The `AT%20` command sets the unit's name. A unit name can be between 0 and 16 alphanumeric characters.

- `AT%20=South<CR>`: Sets the units name to "South".
- `AT%20=<CR>`: Clears the unit's name (sets it to an empty string).

C.3.2 "AT%22" Set Menu Password

The RFI-9256 menu system can be password protected in order to prevent unauthorized access. A password can be between 1 and 12 alphanumeric characters. If the password is already set, then this command will not change it.

- `AT%22=password<CR>`: Sets the menu access password to "password".

C.3.3 "AT%62" Set RTC Date/Time

The real-time clock time can be set via the `AT%62` command. This sets the time of day in seconds since midnight, in the range 0 to 86400.

- `AT%62=120<CR>`: Sets real-time clock to 2 minutes since midnight.

C.4 Other Commands

The RFI-9256 supports many other AT commands. Most of these commands are common to many PSTN modems, however do not provide any function on the RFI-9256. They are only supplied for compatibility with existing systems. The list of commands supplied for compatibility only are given in the summary of commands in the next section.

C.5 Summary of Commands

The following section provides a summary of all AT commands supported by the RFI-9256. Each of these tables has the following headings:

- **Command**: The actual AT command.
- **Description**: A brief description of the command functionality.
- **Last on Line**: A cross, ×, indicates that the command must be the last on the line for it to be executed.
- **&W**: A cross, ×, indicates that the change will not become active until the `AT&W` command is executed.
- **&W1**: A cross, ×, indicates that the change will not be saved in non-volatile memory until the `AT&W` or `AT&W1` command is executed.
- **Compat**: A cross, ×, indicates that the command is supplied for compatibility only and does not perform any actual function.

Command	Description	Last on Line	&W	&W1	Compat
`A`	Answer a call.	×			
`D` `DT`	Dial a number.	×			

DP					
H H0	Hang-up the radio.	×			
O O0	Go online.	×			

Table 36: Dialling Commands

Command	Description	Last on Line	&W	&W1	Compat
?	Enables the menu on the current port.	×			
E0	Echo OFF.		×		
E1	Echo ON.		×		
L0	Lowest speaker volume.				×
L1	Low speaker volume.				×
L2	Medium speaker volume.				×
L3	Highest speaker volume.				×
M0	Speaker off.				×
M1	Speaker on when connecting.				×
M2	Speaker on.				×
Q0	Responses ON.		×		
Q1	Responses OFF.		×		
V0	Numeric response codes.		×		
V1	Verbal response codes.		×		
X0	Set to basic response codes.		×		
W0	Fast connection response.				
W1	Delayed connection response.				
X4	Set to extended response codes.		×		
Z	Initialise radio (power on reset).				
&A0	Auxiliary I/O Disable				
&A1	Auxiliary I/O Enable				
&A2	Auxiliary I/O Follow Remote				
&C0	DCD always on.				

&C1	DCD follow online.				
&C2	DCD follows remote DTR.				
&D0	Ignore DTR.		×		
&D1	Go local on DTR low.		×		
&D2	Hang-up on DTR high to low transition (dropped).		×		
&D3	Hang-up if DTR low.		×		
&F	Set all Hayes values to their defaults.				
&F1	Set all values to their defaults.				
&G0	Multi-radio ports.				
&G1	Exclusive use by this port.				
&G2	Priority use of this port.				
&K0	No flow control.				
&K3	Hardware RTS/CTS flow control.				
&K4	Software XON/XOFF flow control.				
&L0	Set radio to slave mode.				
&L1	Set radio to master mode.				
&M0	Set ports to point-to-point.		×		
&M1	Set ports to multipoint dial-up.		×		
&M2	Set ports to back-to-back repeater.		×		
&S0	Synchronisation mode off.				
&S1	Synchronisation mode – input (follow).				
&S2	Synchronisation mode – output.				
&S3	Synchronisation mode – repeater.				
&T8	Warm start –reset.	×			
&T9	Cold start – reset.	×			
&V	View current profile.	×			
&V0	View all basic Hayes register information (not I-registers).	×			
&V1	View all I-register profile information.	×			
&V2	View all s-register profile information.	×			
&V8	View current links.	×			

&V9	View logging.	×			
&W	Write all configuration.	×			
&W1	Submit serial port configuration.	×			

Table 37: General Commands

Command	Description	Last on Line	&W	&W1	Compat
S0	Rings before answer		×		
S2	Escape character.		×		
S6	Wait for dial tone timeout.				×
S7	Wait for carrier timeout.		×		
S12	Escape guard time.		×		
S30	Inactivity timeout.				×
S39	Rx (in) packetiser timer				
S40	Tx (out) packetiser timer				
S41	Number of retries.				
S42	Network fail timeout.				
S43	Online request timer.				
S44	Hopping pattern sequence number.				
S45	Maximum transmit power.				
S47	Frame time in milliseconds.				
S48	Frame bias.				
S50	Network address.				
S51	Unit local address.				
S52	Point-to-point destination address.				
S60	Logging level.				
S61	UNIT Date/Time in seconds since 1970.				
S62	System long timer in milliseconds.				
S70	Port protocol type.				
S80	Local auxiliary I/O.				
S81	Remote auxiliary I/O.				
S82	Auxiliary I/O direction mask.				

`S83`	Auxiliary I/O power-up default.				
`S84`	Auxiliary I/O sample timer.				
`S90`	DCD control.				
`S91`	CTS control.				
`S100`	Port baud rate.		×	×	
`S101`	Port parity.		×	×	
`S102`	Port data bits.		×	×	
`S103`	Port stop bits.		×	×	
`S104`	Port flow control.		×	×	

Table 38: S-register Commands

Command	Description	Last on Line	&W	&W1	Compat
`%20`	Unit name.	×	×	×	
`%22`	Set menu password.	×	×	×	
`%62`	Set RTC date/time.	×	×	×	

Table 39: %-register Commands

Appendix D Factory Defaults

Value	Default
Mode	Slave
Network Address	32
Rx Address	20
Hopping Pattern	0
Sync Mode	No Sync Mode
Main Port ARQ Retries	50
Aux Port ARQ Retries	50
Network Fail Timer	5000ms
Online Request Timer	1000ms
Backoff Retry	Disabled
Tx Power Level	20 dBm
RSSI trigger level	-110 dBm
Frame Time	20ms
Directional Bias	Disabled

Table 40: Radio configuration default settings

Value	Default
Main Port Protocol	Hayes Dialup
Auxiliary Port Protocol	Hayes Dialup
Hayes Connect Timeout	9985ms
Escape Character	+
Escape Guard Time	1000ms
DTR Mode	Hang-up on DTR Dropped
Echo	ON
Responses	ON
Auto-answer	ON
Ring count	1
Routing Table	Empty

Table 41: Protocol default settings

Value	Default
Baud	19200
Parity	None
Data Bits	8
Stop Bits	1
Flow Control	Disabled
Tx Packetiser Timer	Disabled
Tx Packetiser Timer	Disabled
Rx Buffer Limit	3072

Table 42: Serial port default settings

Value	Default
DCD Mode	ONLINE controls DCD
CTS Mode	CTS disabled
Auxiliary I/O Sample Time	500ms
Auxiliary I/O follows Remote	Disabled
Auxiliary I/O	Enabled
Auxiliary I/O Direction	All inputs
Auxiliary I/O Powerup Defaults	All high
Event Log Level	General Information
Unit Name	None
Security Code	None
Menu Password	None
Menu Timeout	15 Minutes

Table 43: Other default settings

Appendix E Glossary

Table 44 contains the terms, acronyms, and abbreviations used in this document.

Term	Description
BER	Bit Error Rate
CRC	Cyclic Redundancy Check
DCE	Data Communications Equipment
DTE	Data Terminal Equipment
EIRP	Effective Isotropic Radiated Power
FDD	Frequency Division Duplex
FHSS	Frequency Hopping Spread Spectrum
ISM	Industrial Scientific Military
PSTN	Public Switched Telephone Network
RSSI	Receive Signal Strength Indication
SCADA	Supervisory Control and Data Acquisition
TDD	Time Division Duplex

Table 44: Terms, acronyms, and abbreviations

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